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SUNDARBAN MANGROVE FOREST OF THE LOWLAND OF SOUTHWESTERN BANGLADESH AND ITS HYDROGEO-ENVIRONMENTAL ASPECTS

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ABSTRACT: The paper presents the Sundarban Mangrove Forest and its hydro-enivronmental aspects in particular. The Sundarban Forest is covered by numerous distributaries of the Ganges delta along the coastal belt of the Bay of Bengal of southwest lowland area. The lithological distribution of the surface area is of Geological Quaternary Age. These are clay, mud, silt, medium to fine sand and small patches of shell fragments in the beach area. Brief investigation of channel/ stream / river waters which indicated that the pH values varied from 7.5 to 8.4 and the recorded electrical conductivity (EC) ranges from 7,920 to 19,400 µs/cm, and others ionic concentrations are also found in higher condition. The Sundarban Mangrove Forest frequently become of severe cyclones, tidal flooding and storm surges. The present study can help in the future planning and development of the lowland area of the Sundarban Mangrove Forest.

Key Words: Sundarban, mangrove forest, hydrogeo-environment, electrical conductivity, tidal inundation, monsoon and royal bengal tiger.

INTRODUCTION

Natural forests in the coastal belt can be grown in different sedimentary deposits or land forms with favourable geological and environmental conditions. In Bangladesh, natural forests are found in the southwestern coastal belt, known as the Sundarban mangrove forest. The term "Sundarban" is derived from Bengali word, *sundar* comes from sundari tree (*Herifira fomes*) which is the prominent species in the area and 'ban' means forest. The Sundarban mangrove forest covers an area of about 5,770 km^2 of which about 60% lies in Bangladesh and the rest belongs to the Indian state of West Bengal (Fig. 1). In the global context it is about 4% of the total mangrove forests (Table 1).

Near about one third of the total Sundarban, rivers, channels, canals and tidal creeks varying in width from few meters to 5 km cover forest area. The land areas are subject to tidal inundation even during spring tides. The climatic conditions prevailing in the region are mainly tropical maritime climate, with an annual rainfall of about 1,650-1,800 mm in the central and the northern areas, and as much as 2,790 mm along the outer coast. On an average 80% of rain falls during the monsoon (from June to October). During this season, the humidity becomes high (over

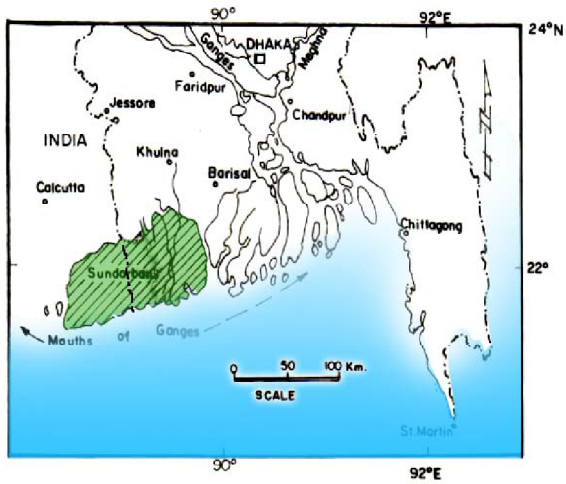

Fig. 1 Location of the Sundarban Mangrove forest between Bangladesh and India.

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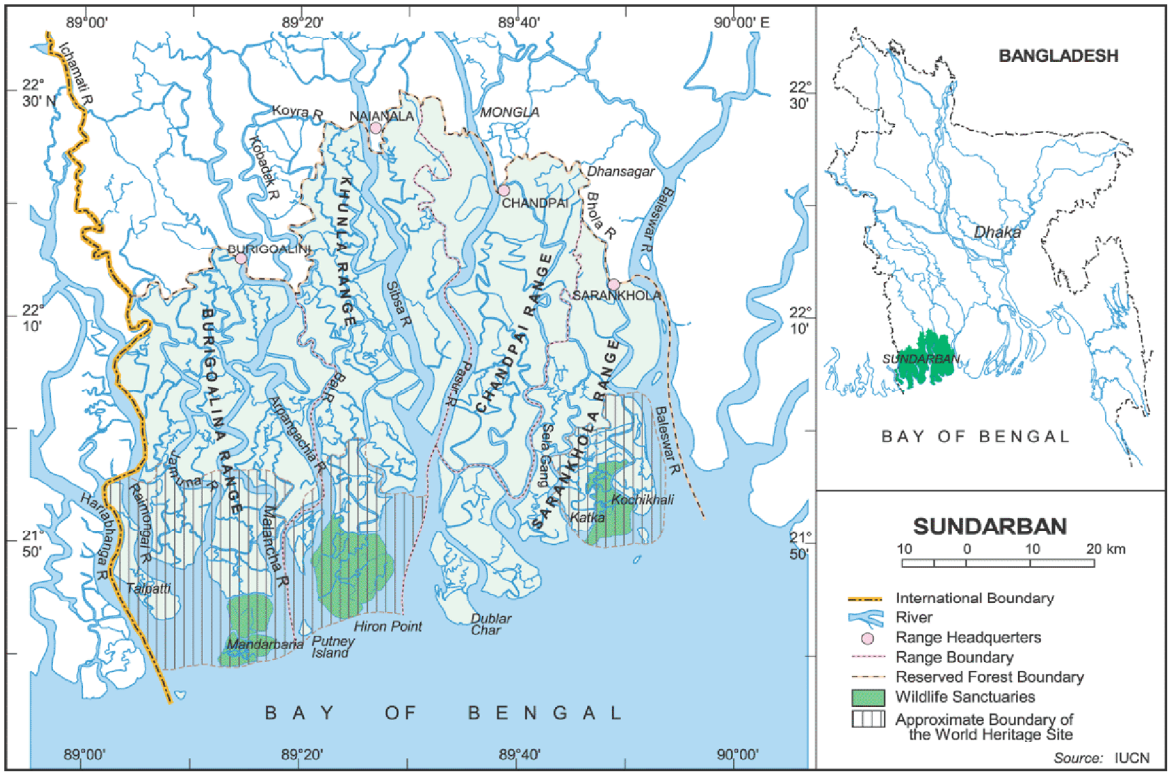


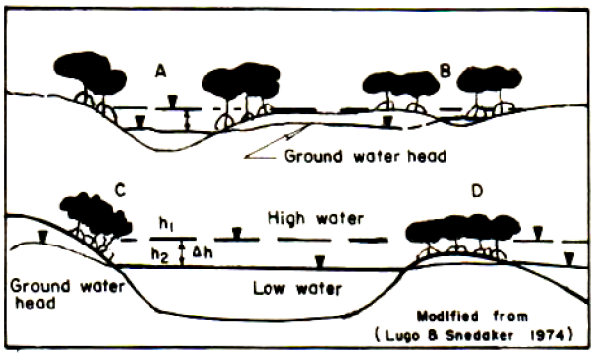
Fig.2 Location Map of the Sundarban in Bangladesh (Siddiqi 2003)

80%), the sky remains overcast for a long period, and the maximum temperature seldom exceeds 32^{0}C. The winter is mild and dry, with an average maximum temperature in January of around 24^{0}C. During the pre-monsoon in March and April, the temperature rises up to 43^{0}C.

The term "mangrove forest" is used to refer to a large variety of coastal geo-environmental systems which vary in productivity and in their make up and which have differing hydrological and ecological features depending upon the coastal morphology, water quality, and types of vegetation of the region. Presently, five types of mangroves can be found in the forests of the world (Fig. 2), e.g. riverine, basin, fringe, over-wash, and scrub mangrove forests (Lugo and Sendaker 1974). In this respect the Sundarban mangrove forest is an example, where all the above five types of forests prevail. Mangrove forest growth and development are better in areas, where sufficient freshwater runoff and periodic changes of tidal water occur. Once these flow patterns are disturbed a progressive increase of soil salinity and the die out of mangrove vegetation are almost certain to occur.

Table 1 Estimated mangrove coverage areas of the 15 countries with the largest mangrove areas (after Mahmood 1986; Hamilton et al. 1989 and Mastaller 1993)

Country	Mangrove (1000 ha)	Global (%)
Indonesia	4,250	30
Brazil	1,376	10
Australia	1,150	8
Nigeria	970	7
Malaysia	644	5
Bangladesh	611	4
Myanmar	570	4
Vietnam	540	4
Cuba	530	4
Mexico	525	4
Senegal	440	3
India	360	3
Colombia	358	3
Cameroon	350	2
Madagascar	327	2



$h_1 - h_2 = \Delta h$ Fluctuation of hydraulic head.

A=Riverine Forest
B=Basin Forest
C=Fringe Forest
D=Overwash Forest

Fig.3 Nature of distribution of Mangrove Forest in the Coastal belt (Modified from Lugo and Sredaker 1974)

The Sundarban forest is covered by numerous distributaries of the River Ganges along the coastal belt of the Bay of Bengal. The surface is covered with mud of Recent age except on the seaward side of islands in the coastal limits, where sandy beaches occur (Fig. 3). The soil developed in the area is of fine loam with alternating layers of clay, silt and sand.

The paper deals with the preliminary observation on the hydro-chemical situation of the Sundarban mangrove forest area.

MATERIALS AND METHOD

The field observations and sample collections for the present study were made during February 24 to March 1 1997 in the Supoti forest, Kachikhali, Tiger point, Kotka forest, Tambulbunia and Monghla Port areas of the Sundarban mangrove forest (Fig. 4). The expedition was conducted by a group of scientists sponsored jointly by the Alumni Association of German Universities in Bangladesh and the Goethe-Institute Dhaka with the tourist boat M.V. Chhuti (Fig. 5). The investigation was done by i) field observations on geology and geomorphology of the area and ii) collection of river water samples for hydrochemical studies in the laboratory. The analyses of the samples were carried out in the laboratories of the Department of Geology and the Department of Soil, Water & Environment of the University of Dhaka, using the standard method.

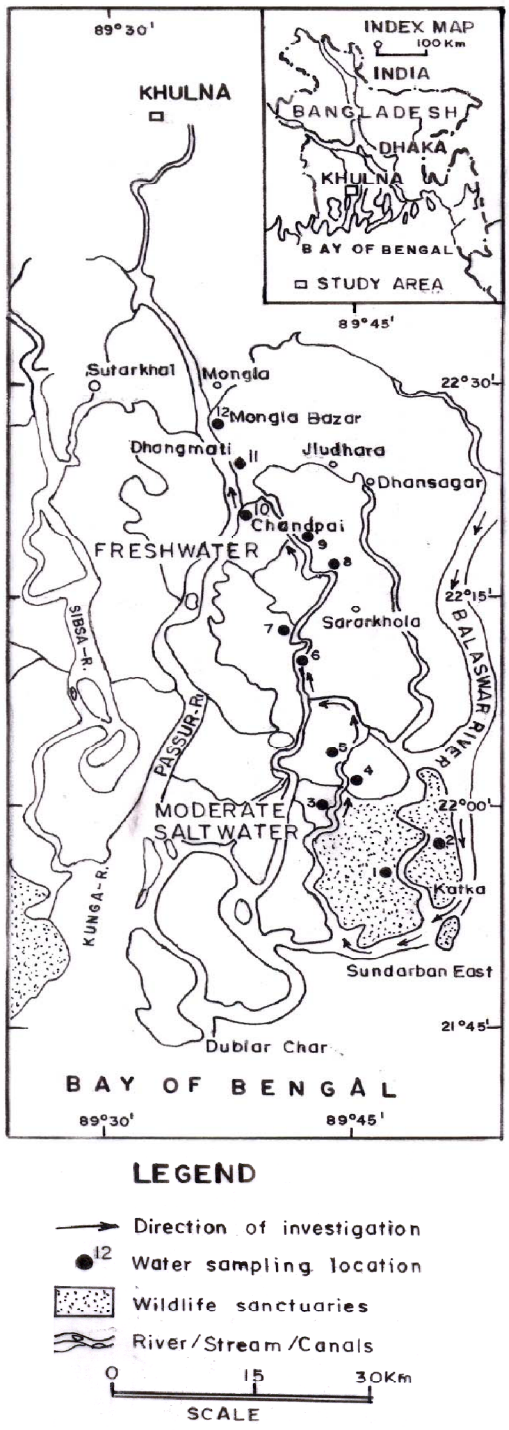


Fig.4 Location map of the study area showing the direction of journey by arrow marking from Dhaka to Monghla Port, Khulna and also water sampling point with numbers

Fig. 5 Photo showing the study ship MV-CHHUTI

Fig. 6 Inner part of the forest near Kotka with watching tower (x-sign) and authors

Fig. 7 Inside the forest near Kotka location showing the wildlife fields for dears and tigers. At that time the field was full of dears (brown colour)

Fig. 8 Inside the forest with full study group of Bangladeshi and German of different fields

RESULTS AND DISCUSSIONS

The lowlands of southwestern Bangladesh experience tidal propagation system from the Bay of Bengal twice a day. This system brings seawater through the streams, channels and rivers, and over floods the adjacent land areas, which results erosion and deposition on the riverbanks, and saltwater intrusion and salt deposition in low-lying areas. During the monsoon when the hydraulic head is higher, the saline front recedes towards the sea, and from November it moves towards the land reaching its maximum in the months of April and May. During this period the hydraulic heads of the rivers of the low-lying areas are found in the lowest condition. The inner part of the Sundarban mangrove forest near Kotka can be seen in Photos 2, 3 and 4. The Mangrove forest and its hydrogeo-environmental aspects are discussed as follows.

Mangrove Ecosystem and its Resources

The ancient mangrove forest of the Sundarban extended along the entire coastal and river dominated estuarine plains. The mangrove ecosystem is linked upstream with the land and downstream with the sea. The organic complex detrital-based food web represents a major source of food for a variety of marine and brackish organisms. The Sundarban forest is home for many different species of birds, mammals, insects, reptiles and fishes. Over 120 species of fish are commonly known by the commercial fishermen. Over 270 species of birds have been recorded in the Sundarban, including about 95 species of water birds. The area is considered to be one of the most productive zones of fisheries of the world. More than 475 species of fish belonging to 133 families, about 10 species of marine shrimps are of commercial importance, about 108 species of shellfish, mollusks, crabs and 2 species of lobsters are recorded in the Bay of Bengal (Anwar 1993). Some 42 species of mammals still occur in this forest. The Sundarban, including the Indian part, comprise the largest remaining tract of habitat for Royal Bengal Tiger (*Panthera tigris)* and provide the last refuge in the region for a variety of mammals. Recent estimate suggests a total population of about 350 tigers, 40,000 to 70,000 rhesus macaques, 50,000 to 80,000 spotted deers, 20,000 wild boars and 20,000 smooth coated

otters. The Ganges river dolphin (*Platanista gangeticus*) is common in the river and melon headed dolphins (*Peponocephala electre*) and several other small cetaceans occur in the adjacent water of the Bay of Bengal.

The unique vegetation of the Sundarban is classified under three zones: freshwater forest (northeastern part), moderately saltwater forest (eastern part) and saline forest (western part). The forest has become poorer and more open as one proceeds towards the sea or towards the west.

The Sundarban provide a livelihood for 500,000 to 600,000 people working as wood -cutters, fishermen, honey-wax collectors, and golpatta, thatching grass and other forest produces collectors. Besides, it is a source of timber and raw materials for the hard board factory, Khulna Newsprint Mill, match factories of Dhaka and Khulna, Rural Electricity Board, construction firms, cottage industries and fuel wood (Katebi and Habib 1988).

Annual Flooding and Sedimentation

Annual flooding (seasonal and tidal) is the most serious problem in lowlands of Bangladesh. Flooding is a regular occurrence, and about 18% of the country becomes inundated every year. However, several floods with catastrophic impacts have occurred between the years 1954 and 1998. (Table 2).

The region in and around the Sundarban facing the Bay of Bengal is very low and flat; inundation of the area by floods is negligible. This is because that the region is facing the sea, and dense small rivers criss-cross the entire region. Therefore, the floodwater is drained easily and rapidly. The region is, however, extremely weak against the storm tides caused by cyclones. The height of the tide sometimes exceeds 4 m above msl, but the tide ebbs rapidly (Umitsu 1985).

Landform and sediments are closely related to the characteristics of river floods and storm surges in lowlands of Bangladesh. Various types of micro-land forms, such as natural levees, point bars, crevasses, sprays, former river channels and beach ridges are common.

Table 2 Flood-affected areas above 30,000-80,000 km^2 with respective years between 1954 and 1998 in Bangladesh (modified from Chowdhury et al. 1997)

Affected Area (km^2)	Year (data range 1954-1998)
Above 80,000	1988, 1998
Above 50,000	1955, 1974, 1987
Above 40,000	1963, 1969, 1970
Above 30,000	1954, 1956, 1962, 1964, 1966, 1968, 1971 and 1980.

Soils of the Sundarban mangrove forest area differ from other inland soils. Because of the area is subjected to the effects of salinity and water logging, which naturally affect the vegetation. Soils are semi-solid and poorly consolidated. The pH value of soil ranges from 5.3 to 8.0. Soil is in general medium textured, sandy loam, silt loam / clay loam (Siddiqi 2003).

Land-subsidence and Sea Level Rise

Land-subsidence: The lowland of southeastern Bangladesh, including the Sundarban, is located in the active Faridpur geotectonic troughs of the Bengal Basin. Observation on long-term geotectonic activities on the Basin shows that the trough has been subsiding gradually. The rate of subsidence obtained from ^{14}C dates and well-log data show considerable variations. The rate of subsidence estimated from the Hizla-Muladi well suggests that the area has been subsiding at a rate of 2 cm/year. On the other hand the ^{14}C dates indicate a rate of subsidence around 2-4 mm/year (Alam 1997).

Sea-level rise: One of the major consequences of increased surface air temperature and intense floods is the rise of sea level. Coastlines in some parts of the world are unstable due to tectonic activities and isostatic adjustments. Changes in sea level should, therefore, be considered relative to such shifts in coastal topography as a result of continuing geologic activity. The sea level usually rises due to, a) thermal expansion of near-surface ocean water and b) melting of snowfields, ice-sheets and glaciers. During the last 100 years, the mean sea level has risen by about 10-15 cm (Gornitz et al. 1982).

Table 3 Physico-chemical properties of river waters of the Sundarban lowland of Bangladesh

Sample No.	EC µs cm^{-1}	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-
1	19,190	8.4	4,489	146	165	627	8,690	176	285	9.8
2	19,300	8.2	4,678	130	225	615	8,179	205	320	10.2
3	19,400	8.1	5,010	154	160	636	8,776	117	356	10.5
4	18,390	7.9	3,263	130	150	612	8,094	146	251	8.3
5	1,7650	8.4	3,100	138	165	567	7,998	132	242	8.2
6	11,950	8.4	2,112	114	120	480	5,197	130	235	8.0
7	9,620	8.4	1,715	89	95	339	4,090	132	220	8.4
8	7,920	7.7	1,669	90	105	315	3,978	131	210	7.8
9	9,880	7.9	1,767	106	90	324	4,175	132	230	8.8
10	10,890	7.5	1,865	98	105	354	4,516	146	225	8.2
11	9,670	7.8	1,767	81	95	348	4,175	148	223	8.0
12	10,050	7.9	1,870	73	45	327	4,170	145	212	8.1
Average	**13,659**	**8.05**	**2,775**	**112**	**127**	**462**	**6,003**	**145**	**251**	**8.7**

Note: cations and anions are in mg/l. Sampling locations are shown in Fig. 4.

Hydrochemistry of Surface Water

Investigation of surface water indicates that the pH value varies from 7.5 to 8.4 and the recorded electrical conductivity (EC) ranges from 7,920 to 19,400 µs/cm depending upon the locations. Table 3 shows the physico-chemical properties of surface waters of the Sundarban area.

Physical Properties of Water

Electrical Conductivity (EC): The EC is a function of ion concentration and can be used for quick checking of dissolved ionic species in waters. The importance of EC is its measure of salinity, which greatly affects the taste and thus has significant impact on the user acceptance of water as potable.

Table 4 Chemical composition of some of the earth's river water

River and locations	EC µs cm^{-1}	pH	Na+	K+	Ca++	Mg++	Cl^-	HCO_3^-	SO_4^{2-}	NO^{3-}
Colorado (USA)	-	-	[102.7]		105.8	9.5	159.5	108.4	199	-
Missouri (USA)	-	-	[38.0]		52.6	18.2	13.5	180.3	117.2	-
Rhein (Germany)	-	-	[85.9]		81.2	10.2	149.1	150.2	79.3	10.5
Nile (Egypt)	-	-	[11.8]		15.8	8.8	3.4	84.6	46.7	-
SW Bangladesh rivers*	13659.1	8.05	2775.41	112.41	126.6	462.08	6003.16	145.0	250.75	8.69

Note: cation and anion are in mg/l, (–) means no data and Total of [Na^+ & K^+]. * indicates dry period.

The EC of the water of the study area ranges from 7920 to 19,400 µs cm^{-1} with a mean value of 13659 µs cm^{-1}.

Hydrogen Ion Concentration (pH): The pH of the river water varies from 7.7 to 8.4, which is indicating that the waters are alkaline in nature. The pH of seawater is apparently determined by the system $CaCO_3$ - CO_2 - H_2O and lies close to 8 (Matthess 1982).

Fig. 9 Inside the forest with full study group of Bangladeshi and German of different fields

The average dissolved solids contents of global river waters can locally and periodically show wide deviations depending upon the local climatic as well as supply of sediment conditions, as shown in Table 4. This table also shows that the study area of southwest Bangladesh river water contents more dissolved solid then cited rivers of the world.

Chemical Constituents of Water

Sodium (Na^+) and Potassium (K^+): Sodium is generally present in fresh water as Na^+ ions in concentrated solutions in form of complex ions and sodium ion pairs. Such as $NaCO^{3-}$, $NaHCO^{3-}$ (aq.) and $NaSO^{4-}$ are present (Hem 1970). Sodium (Na^+) in the river water of the study area ranges from 1,669 to 5,010 mg/l with a mean of 2,775.4 mg/l. In general, water contains a high amount of sodium than potassium (Ka^+) because the potassium bearing minerals weather much slowly than those containing sodium. In addition, it is strongly adsorbed by clay minerals like illitic in soil. Potassium in the river water ranges from 89 to 154 mg/l with a mean of 112.41 mg/l.

Calcium (Ca^{++}) and Magnesium (Mg^{++}): Calcium together with magnesium causes hardness in water. The recorded calcium in the river water ranges from 45 to 225 mg/l with a mean of 126.6 mg/l. The presence of these materials in the river in excess of about 100 mg/l, degreases the cleaning and lather properties of soap (Hem 1980). The recorded Magnesium in the river water ranges from 324 to 636mg/l with a mean of 462 mg/l.

Chloride (Cl^-): The bulk of the chloride in the ocean should, however, originate from degassing of the Earth's crust by volcanic emanations, which early in Earth's history gave rise to the chloride in the primeval atmosphere and oceans (Goldschmidt 1937; Behne 1953; Correns 1956). In general, it is an indication of salinity in water and is one of the major important constituents of natural water. The recorded chloride (Cl^-) concentration of the river water ranges from 3,978 to 8,776 mg/l with a mean of 6,003 mg/l.

Hydrogen Carbonate (HCO_3^-): Along with hydroxide, hydrogen carbonates are responsible for the alkalinity of water. Solubility of carbonate minerals in pore water is very low but they get dissolved and from bicarbonate (HCO_3^-) compounds in water containing carbon dioxide. In the study area the recorded bicarbonate in river water ranges from 130 to 205 mg/l with a mean of 145 mg/l.

Sulphate (SO_4^{2-}): The sulphate concentration in the river water of the study area ranges from 210 to 356 mg/l with a mean of 250.75 mg/l. Sulphate concentration in drinking water should not exceed 250 mg/l, because the water will have a bitter taste and can produce laxative affects at higher levels (Bower 1978).

Nitrate (NO_3^-): The occurrence of nitrogenous compounds indicates the presence of organic matter. The nitrate content of unpolluted water rarely exceeds 10 mg/l (Rainwater and Thatcher 1960). High concentration of nitrate more than 20 mg/l could be a concern, especially when used for drinking or irrigation. The nitrate content in water ranges from 8 to 10.5 mg/l with a mean of 8.69 mg/l.

CONCLUSIONS

Anthropogenic interference of various natures is responsible for the degradation of mangrove wetland. The history of the Sundarban has been characterised by continuous land reclamation since the beginning of the British colonial time during 1775. In the largest delta region of the world, is extending between

Bangladesh and India, some 150,000 ha. mangrove forest disappeared during the past 100 years, reclaimed for agriculture, settlement sites and road networks for an ever-increasing coastal population (Mostaller 1996). The Sundarban frequently become victims of severe cyclones, tidal flooding and storm surges (Fig. 9).

The environment of the mangrove forests in the lowlands of the Sundarban can be saved taking the following measures:

a) by preserving the wildlife,
b) by preventing erosion,
c) by maintaining ecological balance
d) by developing land-form in lowlands
e) by controlling the supply of leaves and woods for industry.

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REFERENCES

Alam, M. (1997). Subsidence in the lower deltaic areas of Bangladesh. Marine Geodesy, Taylore & Francis. 20 (1): 105-120.

Anwar, J. (1993). Bangladesh: The state of the environment. CARDMA, Dhaka.: 188.

Chowdhury, A.M. et al. (1997). Consequences of global warming and sea level rise in Bangladesh. Marine Geodesy, Taylore Francis. 20 (1): 13-32.

Coleman J.M. (1969). Brahmaputra river: Channel processes and sedimentation. Sed. Geol. 3: 129-239.

Gornitz, V.S., Llebedet and Hansen (1982). Global sea level trend in the past century. Science. 21: 1612.

Hamilton, L.S., Dixon, J.A. and Miller, G.O. (1989). Mangrove forests: An under estimated resources of the land and of the sea. Ocean Year Book No.8., Chicago, London.: 254-288.

Katebi M. N. A. and Habib, G. (1988). Sundarban and forestry. CARDMA, Dhaka.

Lugo, A.E. and S.C. Snedaker (1974). The ecology of mangroves. In. Ann. Rev. Ecol. Syst. 5: 39 - 64.

Mahmood, N. (1986). Effects of shrimp farming and other impacts on mangroves of Bangladesh. FAO-Fish Report No. 370, Bangkok.: 46-66.

Mastaller, M. (1996). Destruction of mangrove wetland - causes and consequences. Nat. Res. and Develop. vol. 43/44, Tuebingen.: 37-57.

Mastaller, M. (1993). Importance of mangrove resources for stock recruitment of aquatic organisms. Abstracts, Bremen.

Siddiqi, N.A. (2003). BANGLAPEDIA, National Encyclopedia of Bangladesh, Edited by Sirajul Islam. 9: 470-471.

Umitsu, M. (1985). Natural levees and landform evolution in the Bengal lowland. Geogrphical Review of Japan. 58(B,2): 149-164.

Umitsu, M. (1997). Landform and floods in the Ganges delta and coastal lowland of Bangladesh. Marine Geodesy. Taylore & Francis. 20(1): 77-104.