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# COASTAL EROSION ON THE ISLAND OF BHOLA, BANGLADESH

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**GÖTEBORG 1999**

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# ABSTRACT

This Minor Field Study was carried out in Bangladesh, March to May 1998. The area of concern is situated on the northern part of the island of Bhola in the south of Bangladesh.

***The purpose of this project and thesis was to study how coastal transformations had influenced the people on the island of Bhola and vice versa.***

This has lead to a couple of questions and the most important one is; How has the coastline at the northern part of the island of Bhola changed during the last 10 years? Another important question is how the people living in this area have affected the coast and vice versa.

Three different methods have been used, field observations/mapping, use of GIS-applications and interviews. In the field, measurements and interviews have been made.

The magnitude of the total erosion was **7.5** to **10.4** centimetres during the fieldstudy over 24-days. The variation in magnitude depends on the different grade of vegetationcover, beachslopegradient, soil compaction and the grade of influence by human beings. The result shows that precipitation increases the magnitude of erosion.

The results show that the erosion has been big**, 68.4 meters/year** or **4.3 km$^2$** over 5 years. The accretion has been **20.9 km$^2$** during the same period. The erosion occurs on the East Side of the Island of Bhola, and the accretion on the West Side and up in the north. This phenomenon depends on the current conditions around the island of Bhola.

People living by the embankment have had to move between 2 to 4 times during a period of 20 to 30 years due to the erosion. Many of these people have been landless, and are now living illegal by the embankment in serfdom.

There are not any solutions to stop this erosion from the government's side. There are some NGO:s working with solutions but none of these seem, according to my opinion, to be enough.

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# FOREWORD

In the morning of March 11th 1998, I saw the island of Bhola for the first time. I woke up at dawn and had a really nice journey the hours before we arrived to the island of Bhola, see figure 1 on page 3. I was amazed at how beautiful a place could be with all those ricepaddies and all those villages. At the ferrystation, Kayanghat, there were a lot of people, very crowded as usual in Bangladesh. There were also many of those colourful rickshaws and babytaxis at the ferrystation, and this made a deep impression on me, a memory for life. The island was so green and the people were so kind, I felt that the time ahead of me were going to be good.

The biggest community, Bhola town, is situated at Lat: 22° 40’ 470 N and Lon: 90° 39’ 401 E, see figure 6 on page 12. The island is about 20 * 85 kilometres big and inhabits an estimated population of about 2 million people. The main occupation on the island is farming and fishery. The most common crop on the island is rice, but they harvest a lot of other crops too. My first impression of the situation on the island was that the people seemed to be happier than the people in Dhaka. Later I understood that this was true. The people at Bhola are really poor but they can influence their situation in another way than in Dhaka. They have the opportunities to farm their own land or farm other people’s land as employees. In Dhaka, they don’t have these kind of opportunities.

The reasons that I focused on Bangladesh are three; one, I wrote a paper in 1995 about the floods in Bangladesh and this made me curious about the country. Two, Bangladesh has problems with floods and they have a young and fine-grained coastline vulnerable to erosion. Three, I succeeded to get in contact with a supervisor in Bangladesh, Mr Thord Dahl at the InterLife in Bangladesh. Supervisor in Sweden has university lecturer Margit Werner been (department of earth sciences at Göteborg University). To my help as interpreter on the island of Bhola, I had Mr Tito, a physic student.

Earlier studies have shown that the island of Bhola is vulnerable to coastal/river bank erosion, and has had big problems with this. In the seventies, InterLife in Bangladesh had a fishery project at the east coast of the island of Bhola, along the coastline of the Shahbazpur channel. Now, in present time, the water of the Shahbazpur channel covers this fishing village. It is now situated about one kilometre out in the channel (Oral communication with Mr Thord Dahl).

I got my scholarship in October 1997 and this would be the base for my M.Sc. thesis in physical geography. The study was financed through a grant from Sida (Swedish International Development Agency) via SWEDMAR (Swedish Centre for Coastal Development and Management of Aquatic Resources) in Gothenburg.

# 1. THE AIM WITH THIS STUDY

***The purpose of this project and thesis was to study how coastal transformations had influenced the people on the island of Bhola and vice versa.***

# 2. BANGLADESH

Bangladesh, or the people's Republic of Bangladesh, is situated in the north of the Bay of Bengal where the Indo-Gangetic plain meets the Indian Ocean. The area is highly tectonically active, being at the meeting point of three major tectonic plates. Bangladesh is a part of the world's biggest river-delta. Bangladesh covers an area of 144 000 $km^2$ (about 1/3 of Sweden's size), and 10 090 square kilometres of these are water. 73 % is arable land, 2% consists of permanent crops, 5 % consists of permanent pastures, 15 % consists of forests and woodland and 5 % of others (CIA Worldfactbook July 1997).

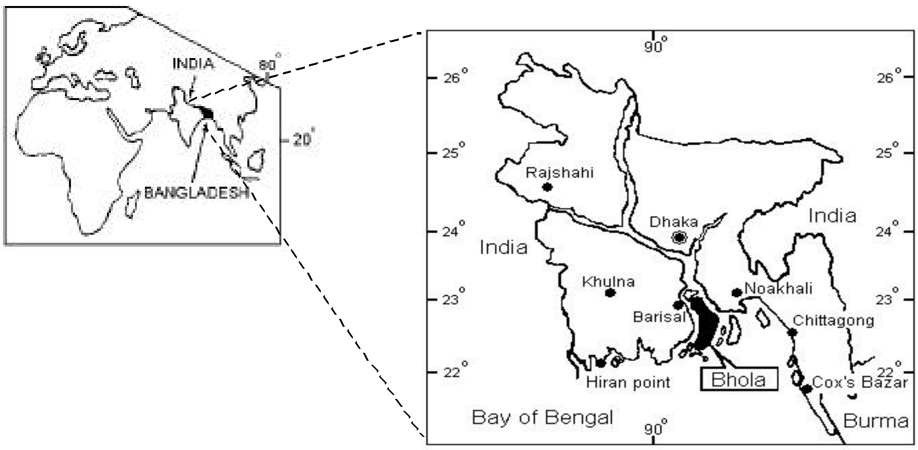



Figure 1: Map over Bangladesh.

Bangladesh has a population of 125 340 261 people where 38 % are younger than 14 years and the population growth rate is 1.82 %, typical for developing countries. The density of population is about 936 persons per $km^2$ (CIA Worldfactbook July 1997). Every cultivable square inch is under cultivation and no new land is available to produce more for an increasing population; on the contrary, the available arable land is shrinking every day to cater for new settlements and physical infrastructure. Thus there would be hardly only breathing space in this tiny delta, let alone decent living or more land to feed an ever-increasing population.

The major part of the population is living in the coastal areas and close to the rivers. Bangladesh is an agrarian country with farming and fishing as the most important sources for people's livelihood. Agriculture employs around 60 % of the civilian workforce, and around 80 % of the population are rural, mainly inhabiting the floodplain areas (Viles and Spencer 1995, p 296). The people are very dependent on the rivers because the river is a very important source for them.

Bangladesh is a mostly flat alluvial plain, with hills in the south-east and in the north-east. North of Dhaka, the capital city, the country is like a big basin and this is the most vulnerable area for floods in the country.

Since the independence, Bangladesh has faced one form or another of natural disasters almost every year. These hazards take the form of floods, droughts and cyclones. Due to the immediate impact of, and international media interest in floods and cyclones, minor hazards have received less attention both from the government and outside agencies and observers. Riverbank erosion is one of these minor hazards.

Climate

Bangladesh has a tropical monsoon climate. Four main seasons are recognised
(Brammer 1996, p 15 ff.).

- ***The pre-monsoon season***, March-May, has the highest temperatures and evapotranspiration rates. Occasional line squalls (heavy thunderstorms with strong winds) occur. Tropical cyclones (typhoons) are liable to affect coastal areas.
- ***The monsoon season***, June-September, is the period of the highest rainfall, humidity and cloudiness. More than 80 % of the annual rainfall normally occur during this period.
- ***The post-monsoon season***, October-November, is hot and humid, but sunny, with heavy dew at night. There are occasional thunderstorms. Tropical cyclones are liable to affect coastal areas.
- ***The dry season***, December-February, is relatively cold, dry and sunny. There are usually a few winter rains, but the occurrence is uncertain.

The predominant wind direction reverses from south-west in the rainy season (Jun-Sep) to north-east in the dry season (Dec-Feb). Each year the monsoon season brings floods to about 18 % of the country (Viles and Spencer 1995, p 293).

Cyclones/storms

During the 80-year period, 1891-1970, 363 storms with winds stronger than 34 knots formed over the Bay of Bengal. Their distributions by months had two peaks. May, with 39 storms and November with 68 storms. Storms in the Bay generate surges with significant, often devastating, impact on low-lying coastal lands, particularly in the north and west (Brink and Robinson 1998, p 529). Bangladesh has about 7 to 10 cyclones every year. When cyclones occur at the same time as the floods, the devastation is enormous. This happened in 1970 when 250 000 people died and big economic values were lost in buildings, land and cattle (Utrikespolitiska institutet 1994, p 5).

Bangladesh through its natural intricate network of rivers and creeks, drains a catchment of about 1.5 million square kilometres of which only about 7 % lies within its territorial limits.

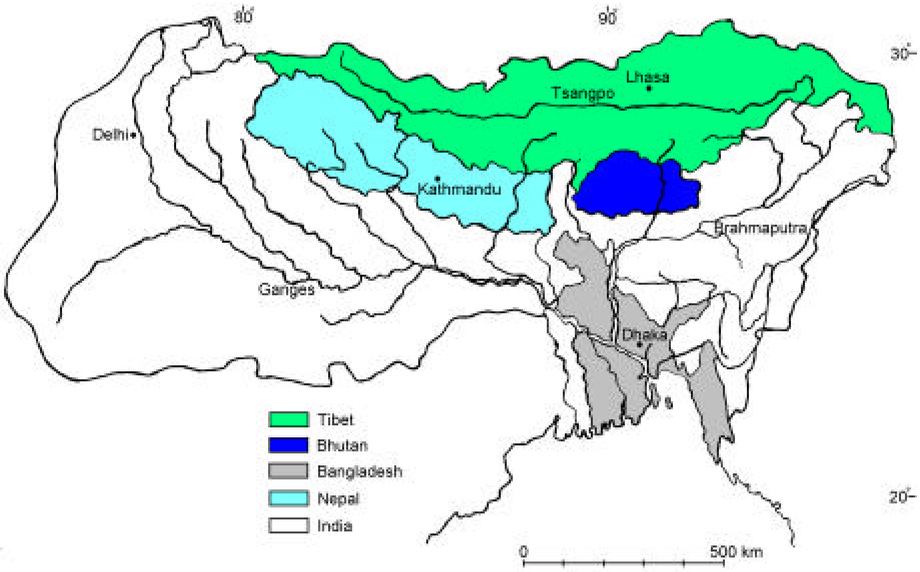



Figure 2: Ganges and Brahmaputra with tributary rivers.
Source: Geographical Journal vol. 156, 1990.

This has on one hand resulted in an endowment of excess water that disrupts normal life during part of the year, and on the other deprived Bangladesh of any control of the huge volume of water that debauches into the Bay of Bengal everyday over it's surface. The Bay of Bengal receives $10^{12}$ $m^3$ water each year, north of 15° N, from Bhramaputra and Ganges and about 70 * $10^{10}$ $m^3$ annually net influx (precipitation-evaporation) at the surface (Brink and Robinson 1998, p 528).

# 3. THE BAY OF BENGAL

The Bay of Bengal is an estuary, estuaries are semi-enclosed inlets where saltwater and river water mix. Often, they form in old drowned river valleys. Three basic types of estuaries can be found: Salt wedge, partially mixed and fully mixed. This depends on the relative strengths of river flow and tidal influx (Viles and Spencer 1995, p 159).

Tides

The tidal wave from the Indian Ocean travels rather fast through the depth of the Bay of Bengal and arrives at Cox´s Bazar and Hiran Point at about the same time, (figure 1 on page 3). The shallow area in front of the delta causes some refraction and distortion of the tidal wave. Through a deep tidal inlet in the eastern part of the Bay, the tidal travels fast along the eastern coast while numerous shoals and islands in the west offer frictional resistance to the propagation of waves, resulting in a phase lag between the eastern and western part of the estuary. Due to phase lag and difference in tidal range, an east-west current is developed during the rising tide (Siddiqi, p 139 pp). The tidal waves range around 365 centimetres in the eastern part of the bay, and 410 centimetres in the western part of the bay (Defant 1960, p 486). The flood duration is between 2-3 hours, and the ebb duration completes the 12 hour and 25 min semi-diurnal tidal cycle (Viles and Spencer 1995, p 161).

Water Movement

Water movement in the Bay of Bengal is a very complex phenomenon generally dominated by tidal motion. At deep water, the waves have the shape of sinusoidal waves. As the waves approach the estuary, they transform by frictional damping on the bottom and the wave becomes deformed. The flood tidewaves steepen (the velocity increases) and the ebb tidewaves flatten (the velocity decreases). This phenomenon is important for the net landward transport of sediment (Viles and Spencer 1995, p 161).

Upland Discharge

The Bay of Bengal drains the combined discharges of the Ganges, Bhramaputra and Meghna rivers amounting on the average to 35 000 $m^3/s$, (figure 2). These three rivers drain about 85 % of the total volume of water brought into Bangladesh. There are distinct seasonal fluctuations in flow with extreme discharge in the monsoon. The peak monthly discharge in August-September is about 4 times the mean annual while the lean discharge in February-April period is about a quarter of the mean annual (Siddiqi, p 139).

Sediment Load

The average annual sediment load carried by the rivers to the Bay of Bengal is around 2 billion tons annually (Viles and Spencer 1995, p 294). The Ganges and the Brahmaputra are heavily laden with fine sediments. The Ganges carries fine sediments with a heavy clay load whereas the Brahmaputra particularly transports fine sand and silt in suspension. The Meghna River appears to be a relatively low sediment laden river. Of the rivers, the share of Ganges with annual, average concentration of

1300 mg/l and Brahmaputra with 1000 mg/l is almost equal while the share of Meghna with 100 mg/l is about one-tenth (Siddiqi, p 145).

Biology/Fishing

The rivers of Bangladesh are suitable for breeding and raising fish. Its rivers and seacoast offer opportunities for the usual types of fisheries, mostly in the estuaries of the Bay of Bengal. Among the varieties of fish caught are the marine *rupchanda,* or pomfret, and the freshwater hilsa, related to the shad. Fishing is typically carried out by hand from outrigger canoes. The annual catches of prawns have remained stable despite intensified harvesting. Several species of tuna found in the bay also are important. The tuna fishery is confined to the true oceanic sector of the bay, south of 15 N, since freshwater runoff from the large rivers greatly influences the nearshore waters (Encyclopædia Britannica 1999-01-13).

Precipitation and Temperature

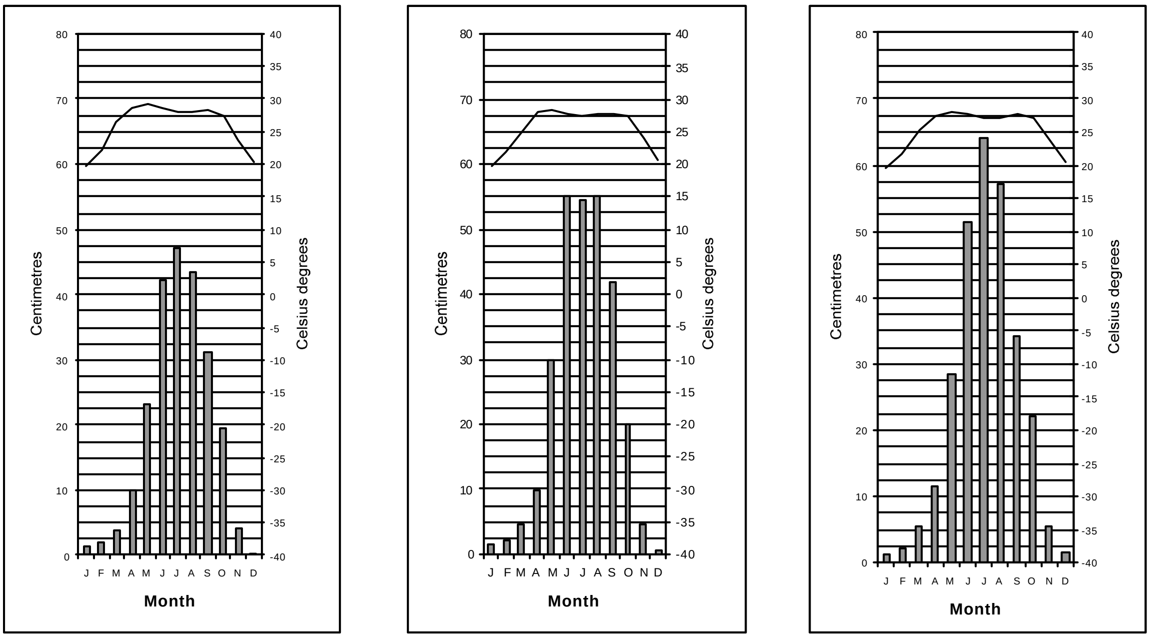



Figure 3: Precipitation in centimetre and temperature in C° at three places situated around the estuary, see figure 1. From left to right, Barisal, Noakhali and Chittagong. Annual total precipitation is for Barisal = 2281 mm, Noakhali = 2804 mm and Chittagong = 2858 mm.

Source: Wernstedt 1972. P 310

# 4. COASTAL EROSION

" About 20% of the world's coast is sandy and backed by beach ridges, dunes, or other sandy depositional terrain. Of this, more than 70% has shown net erosion over the past few decades." (Viles and Spencer 1995, p 1.)

First of all, it's difficult to compare the problem with riverbank erosion in Bangladesh with the same kind of problems in Europe or in the United States. In our part of the world, people are not dependent on the coastal area in the same way as the people who are living in these areas in Bangladesh. When problems with eroding beaches occur, it concerns a few people. When the same problem occurs in the coastal area of Bangladesh, it concerns thousands of people, who have their livelihood on and beside the rivers.

In this paper, coastal and river bank erosion have been regarded as one phenomenon. The reason for this is the environment were this project have been carried out. The study area is located in an estuary were the ocean and the rivers meet and therefore both coastal and river bank erosion occur.

<u>USA</u>

At many places in the United States they have problems with coastal- and riverbank erosion, e.g. along certain areas of the Texas coast, erosion is a severe problem. At the Sargent beach in Matagorda County, only 600 feet of land separate the Gulf and the intercoastal waterway due to erosion. A couple of houses disappeared into the gulf during the phase of big erosion, and this led to a faster schedule for shore protection (Sea Grant Results 1996, p 1).

<u>Africa</u>

Studies of the Nile Delta coast have indicated a shoreline retreat at 58 meters/year between 1944-1989 (Frihy 1992, pp 65). Dramatic erosion has occurred on some beaches of the Nile Delta. This erosion is greatest at the tips of the two great river arms (Rosetta and Damietta). Sea level rise has, by itself, a relatively minor effect on coastal erosion. A study based on two series of aerial photos taken in 1955 and 1983 was also made. The study showed that the shoreline retreat during this 28-year period was 114.9 and 31 meters/year at Rosetta and Damietta (Frihy 1988, pp 597)

<u>Europe</u>

Denmark has great problems with coastal erosion due to longshore transport of sediment, especially at the west coast of Jylland. E.g. the average annual transport of sediments is about 700 000 $m^3$/year along Jyllands west coast (Nielsen & Nielsen 1990, p 132).

In Sweden there is one area with great erosion problems and that is in the south of Sweden, Skåne. The beaches are eroding away and the problem is due to coastal erosion and longshore transport. The problem is biggest around Löderup and Ystad, the most extremely calculated values are 1 to 1.5

meters/year in this area (Olin 1991, p 40). A recent study in the same area showed that about 250 metres of the beach eroded away in the last forty years. Many owners of summer cottages have seen their cottages disappear into the Baltic. The explanations to this erosion are climatechanges and a higher sealevel, more and bigger waves, human influence etc (Jönsson 1998, p 6).

Bangladesh

In a study made between 1987 and 1992 of Landsat images and characteristics of flow and channel behaviours in the Meghna River, the channel widening and changes in thalwegs were extremely predominant in the whole downstream of the Brahmaputra River. The maximum increment of width reached 5 km in the curved stream channel during that 5-year investigation (Muramoto and Fujita 1992, p 89 pp).

The erosion has been severe in the Southeast part of the Bay of Bengal. The accretion of new land has been low and it would take about a hundred years before people could settle on this new land. To accelerate the accretion, possibilities of construction of cross-dams should be explored. Aforestation in the coastal belt and conservation of mangrove forests would help in consolidating the newly accreted land. Investigations have been made to explore the causes of the erosion and the result shows that it is two main types. These are the most common for the problem in the Bay of Bengal: The first one is natural causes of coastal erosion, e.g. sea level rise, variability in sediment supply to the littoral zone, storm waves, longshore sediment transport e.t.c. The second is man induced causes, e.g. removal of subsurface resources, interruption of material in transport, reduction of sediment supplies to the littoral zone, concentration of wave energy on beaches e.t.c. (Alam).

In 1993, an investigation about economic loss due to riverbank erosion was made (Hossain 1993, p 27). About 5 % of the total flood plain area of Bangladesh was directly affected by riverbank erosion, (figure 4).

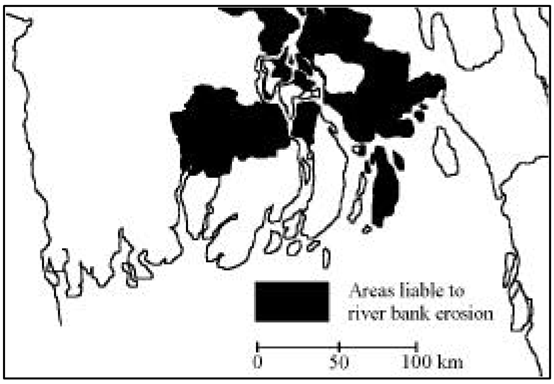



Figure 4: Areas liable to river bank erosion.

Source: Selected parts from Hossain 1993.

Out of 600 upazilas (sub-districts) people in at least 66 upazilas were vulnerable to riverbank erosion. It has been estimated that about 19 millions of the rural population are at risk of riverbank erosion alone in the Padma - Jamuna flood plain region covering more than 12 485 km$^2$. Between 1973 to 1980, the land eroded in the Padma - Jamuna flood plain region was 1198 km$^2$. On the other hand new and fertile land re-emerges from riverbanks over time. But it takes a long time before people can settle on this new land, and it is not sure if they are allowed to do this.

A study was made in a village between 1979-1980 and the same study was made again between 1989-1990 to compare the situation for this village. The aim with this study was to examine the economic changes taking place during this period of years. The village lost almost 16 hectares of farmland, about 20 % of its cultivatable land, between the two surveys, due to the left bank erosion of the river Kalingonga. This resulted in an income loss of about 50 % of crop income. About 45 % of the households in the village were affected in one way or another by riverbank erosion. Big and medium farmer was the most affected group in this village, seen to loss of land. Seen to calorie intake, the landless and poor people are the ones that are most affected by riverbank erosion (Hossain 1993, p 27 pp).

<u>The Island of Bhola</u>

In an earlier paper, the author found that the erosion on the Island of Bhola was biggest near the coast of Tozumuddin, (figure 1), on the east side of the island (Siddiqi et al, p 146 pp). The erosion at this place was about 3.5 kilometres between 1940 to 1963 and about 3 kilometres between 1963 to 1982, (figure 5). Since 1940, the rate of erosion has been nearly constant at about 150 m/year. Siddiqi et al. mean that the undercutting of the riverbank by currents and the consequent bank slumping are the main causes of estuarine bankline erosion. The biggest cause of this erosion is the spring tides during the monsoon period.

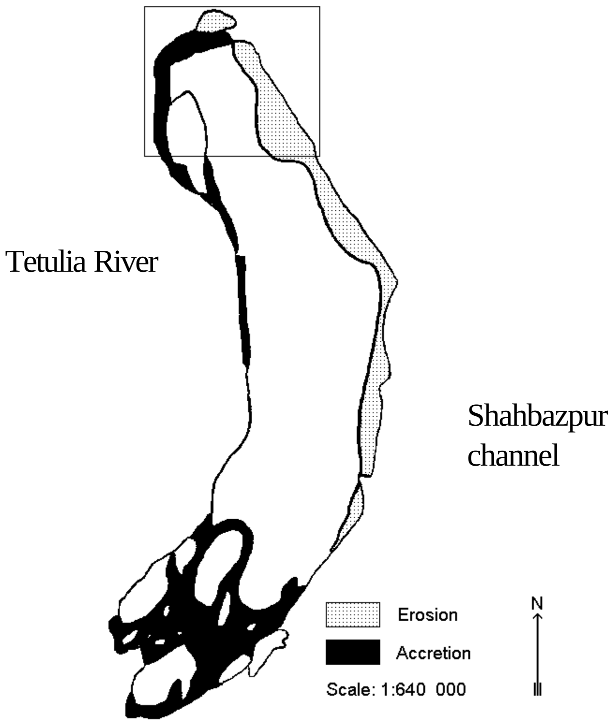



Figure 5: Erosion and accretion on the Island of Bhola between 1963-1982. The marked field represents the study area for this project

Source: Siddiqi et al. p 146.

Most of the erosion was caused by migration of channels and it might be considered as compensatory because erosion and accretion almost simultaneously occur. As an example they point at the erosion on Bhola. New chars in the Shahbazpur channel, char Medua and char Gazaria have compensated the big erosion in Daulatkhan and Tozumuddin, (figure 1). From land use point of view, the newly accreted land is no match for the eroded productive land, because it would take many years for the accreted land to become productive. The socio/economic effects of this erosion can hardly be quantified.

# 5. QUESTIONS

The aim with this project and earlier studies concerning coastal/river bank erosion have resulted in a number of questions. These are:

1. How has the coastline in the northern part of the island of Bhola changed during the last 10 years?

2. Is there any difference between areas affected or unaffected by people?

3. If so, how big is the difference of erosion between these areas?

4. How have people affected the erosion, by clearcutting the forest and building settlements, in the coastal area during the last 10 years?

5. How has this affected the people living in the area?

# 6. STUDY AREA

## The island of Bhola

The study area is located at the northern part of the island of Bhola in the south of Bangladesh, down in the delta of the Meghna River. On the west side of the island of Bhola the Tetulia river flows and on the east side flows the Shahbazpur channel.

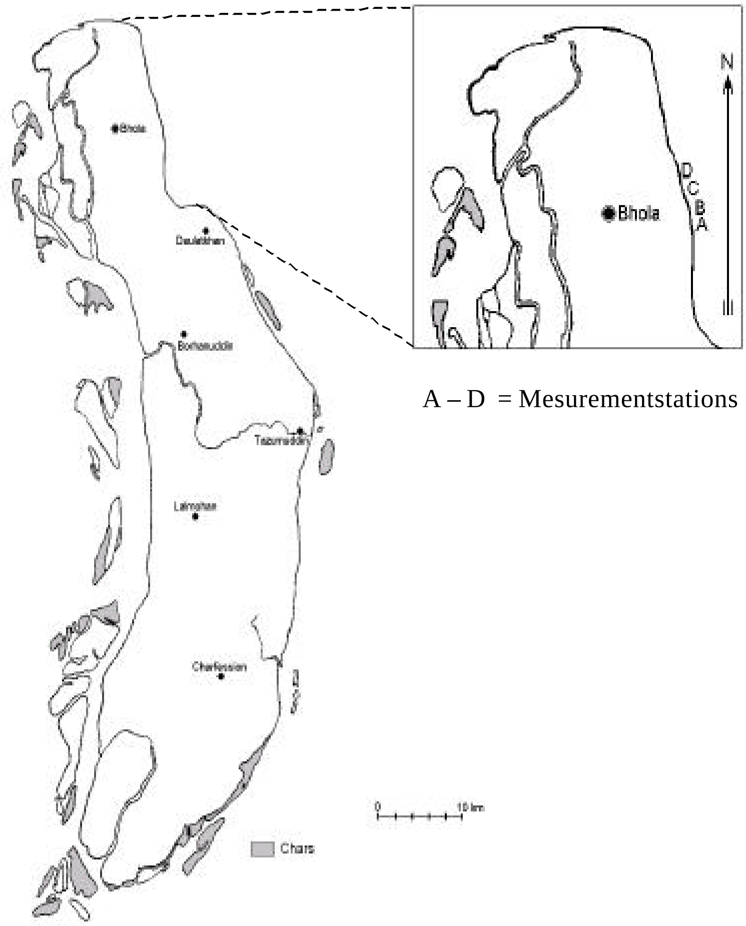



Figure 6: The Island of Bhola and the study area.
Source: Project area map, Bangladesh Water Development Board.

<u>Topography</u>

The island of Bhola is very flat, the highest peak is around 3 meters over the sea level. There are some hills on the island, but many of these are man-made, for example embankments, roads, ponds etc. The northern part has more hills than the southern part of the island. This could be a result of the erosion and accretion.

Physical landscape

The island of Bhola is situated in an area categorised as estuarine floodplains. Estuarine floodplains differ from meander floodplains in being almost level, lacking meander scars and abandoned channels, and having almost uniformly silty deposits (both laterally and vertically). They differ from tidal floodplains in lacking a close network of tidal creeks and in having predominantly silty deposits. There are a few minor rivers, but most of the drainage of older landscapes is affected through man-made canals (khals). Tidal creeks are confined to the seaward margins of young estuarine formations (Brammer 1996, p 40pp).

Estuarine land is forming at present in the Meghna estuary. The land apparently originates as *char* formations within the open estuary, and builds up by slow tidal accretion until such time as a change in the course of estuarine channels either erodes it or abandons it. In the latter case, it may be linked up with adjoining land by the silting up of the intervening channel. Estuarine deposits are predominantly silty, but they actually comprise layers of silt and very fine sand, the two textural grades occurring in separate layers a millimetre or less thick as a result of sorting and deposition under tidal conditions. Overall, the typical deposits are several meters thick. It seems probable that the large-scale sedimentation, which occurs in the Meghna estuary, results from flocculation of the river sediments (Brammer 1996, p 40 pp).

Most of the interior part of the Meghna estuarine floodplain is termed "old" to differentiate it from the actively changing land in the Meghna estuary. The landscape and deposits of the old Meghna estuarine floodplain are very similar to those on the young Meghna estuarine floodplain, but the older sediments are non-calcareous while the younger sediments are slightly calcareous. That is because the older sediments were deposited when the Bhramaputra (in its former channel) was the main source of sediments in the Meghna estuary. The younger deposit is a mixture of calcareous Ganges sediments and non-calcareous Bhramaputra-Jamuna sediments in the lower Meghna, which have occurred in the past 150-200 years since the changes in the Brahmaputra and Ganges channels (Brammer 1996, p 40 pp).

The soil at the island of Bhola is a calcareous alluvium that is saline. It is seasonally flooded, poorly drained and developed in very young medium textured deposits. It occurs extensively on the young lower Meghna Estuarine floodplain (Brammer 1996, p 206).

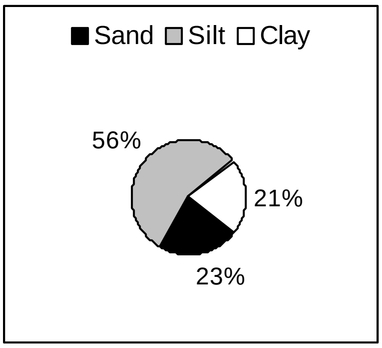



Figure 7: Soil contents on the Island of Bhola.
Source: Brammer 1996, p 206.

Hard sediments do not confine the riverbanks and the huge river and tidal flows continuously generate migration of river bends and channels resulting in erosion of valuable productive lands. Although the loss of erosion at outer bends of the channel is offset by accretion at the inner bends, it takes many years for newly accreted land to become as productive.

Almost along the entire coast, the waveedge consists of a 15 to 20 centimetres high edge when low tide occurs. There is only one place with a higher waveedge and that is up north, in Illisha Ghat. This edge is about 200 centimetres high when it is low tides. Offshore from the edge, not in Illisha Ghat, the bottom consists of mud and it's very difficult to walk out in the water. The general beach-slope-gradient is between 1-3 degrees (Field observations 1998).

All around the island, there are embankments to protect the arable land from floods. There is a distance of 50 to 200 meters between the rivers and the embankment at most places around the island. On the outside of these embankments, the people use the land to cultivate and pasture. The maincrop is rice. There is almost no forest at all on the outside of the embankment. There are only a few groves at some places, the landscape is dominated by single trees. About 5 % of the coastal area could be classified as woodland (Field observations 1998).

Settlements and villages are situated only in the area nearest to the embankment, and there are no settlements on the outside of the embankment. There are no vegetation cover in the coastal area, the soil is bare about 50 meters from the waveedge, onshore (Field observations 1998).

Social structure

The social situation for the people living on the embankments is very difficult. Many of them live illegally on the embankments (owned by the government or landlords), and they don't own the land they are cultivating (if they have land to cultivate). If they cultivate the land that the landlord owns, they have to pay a high price to him for the land. If they are living on the embankment that is in possession of the landlord, they have to pay for this land too. Otherwise they can work it off. This situation can be compared with serfdom and the people are very embarrassed by this situation. It is like a treadmill they cannot get out of (Oral communication with Mr Thord Dahl and Mr John Munchi 1998).

# 7. MATERIAL AND METHODS

## Fieldwork Phase

After arriving to Bangladesh, some theories about how this investigation could be done had to be examined. First of all, a reconnoitre of a study area on the island of Bhola had to be made and some investigations to find areas vulnerable to erosion. Discussions with NGO: s and people at universities in Dhaka were made, both to find earlier studies and to find out were they have/have had big problems with coastal erosion. A couple of places at the east coast of the island of Bhola were found, were it had been both erosion and accretion earlier. One of the criterias was that it should be areas both affected and areas that were not so much affected by human beings.

One interesting area at the east coast of the northern part of the island of Bhola was found and four different stations where made to measure the erosion. The best way to measure erosion was to have an exact distance between the coastline and a fixed point a short distance onshore. To calculate the erosion, a stick was placed in the ground exactly 100 centimetres onshore from the edge of the water. This was made in an area of 50 metres with 5 metres between each stick (figure 8), so there were 10 measurementpoints at every station. Four different stations with a distance of at least 500 metres between each other were created. In this way, more than 2 kilometres of the coast were covered. Observations were made once every day at these stations. The calculations took place during a 24-day period.


X= Measurementstick

Figure 8: Example of a measurementstation
Photo: Magnus Krantz 1998

A survey of the coastal area was also made to make a map over vegetation- and forestcover in the study area. This map was necessary for comparisons with aerial photos and satellite images later, to investigate if there had been any changes in the vegetation- and forestcover in the coastal area.

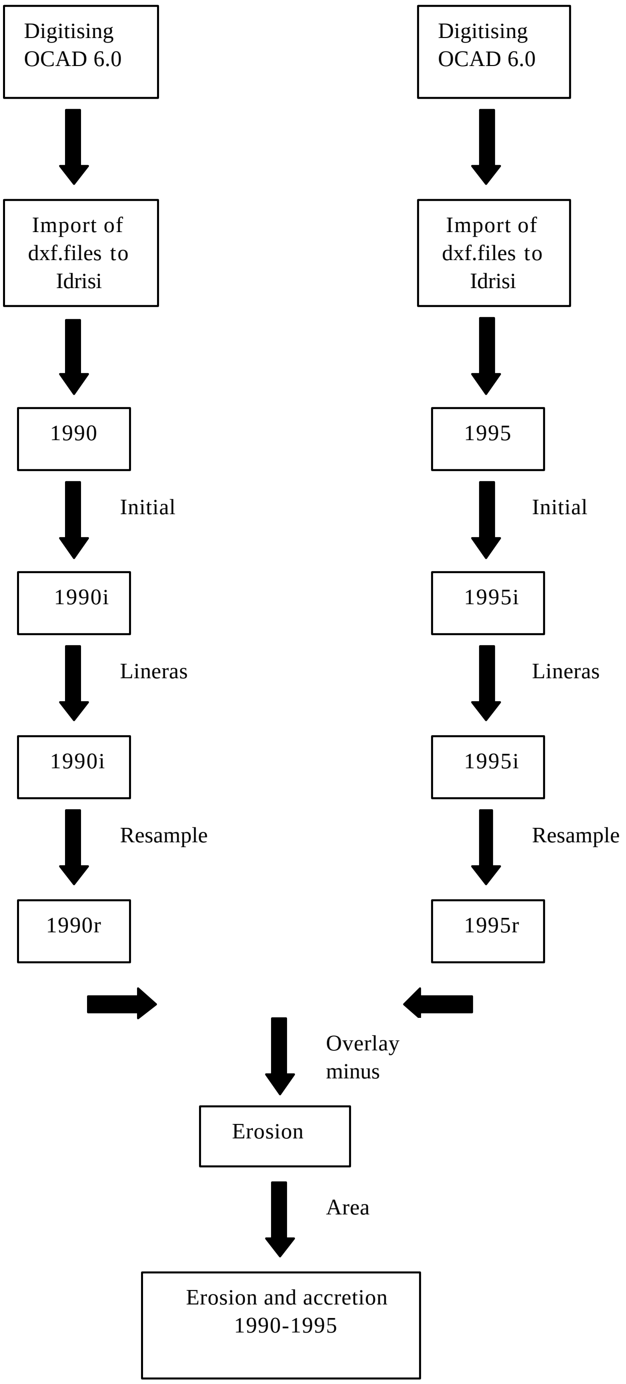
## Interviews

Interviews were made in three villages, (figure 13), the purpose was to investigate how the erosion had affected the people living in these villages, especially how many times they had had to move because of the erosion. To my help, there was an interpreter, Mr Tito. A form with questions were made, the questions were about ***name, family size, occupation, times moved because of erosion, general problems and problems caused by the erosion***.

The interpreter was only allowed to ask these questions, nothing more, and he should try to interpret exactly what the interviewed person told him. Bhola Fishery and Community Development Program (BFCDP) arranged these interviews. The people that were interviewed were all men, because it is not proper for a foreigner to talk with women. You may ask, but you don not get any answer. A fair copy of the interviews was made the same evening, so nothing that had been said would be forgotten. An interview with the technical supervisor at Bangladesh Water Development Board on the island of Bhola was also made. The supervisor would not discuss coastal problems, he thought that this was not a big problem.

### Method for calculation of the erosion and accretion between 1990-1995

This flowchart shows the GIS-operations made to calculate the erosion from satellite images from January 1:st 1990 and February 6:th 1995. To do these calculations, the software "Idrisi for Windows" has been used. A drawing was made of the images, because they had no proper co-ordinate system. The only way to match them together was to use the big river in the middle of the images. This way to work is not as exact as working with digital data, but this was the only way to work with these images. Depending on the digitising operation, some small mistakes can occur. Mistakes that may occur are due to line size during the drawing operation and skilfulness by the person who is digitising.




<u>DXFIDRIS</u> transfers vector data between IDRISI for Windows and DXF formats.

<u>INITIAL</u> creates a new raster image with the same user-defined value in each cell.

<u>LINERAS</u> converts vector lines to their raster equivalents. In this conversion process, an image file is updated with vector line attribute values in overlapping areas of the image and vector files.

<u>RESAMPLE</u> registers the data in one grid system to a different grid system covering the same area. The process uses polynomial equations.

<u>OVERLAY</u> produces a new image from the data of two input images. New values result from applying one of the nine possible operations to the two input images, referred to as the first and second images during program operation.

<u>AREA</u> measures the areas associated with each integer category on an integer image. Output can be in the form of a summary table, a new image where each pixel takes on the area of the category to which it originally belonged, or an attribute values file listing integer categories and their areas.

# 8. RESULTS

The results are going to be presented as follows; first the erosion during a 24 day-period and the erosion and accretion between 1990-1995. After that the difference in the vegetation cover in the coastal area between 1989 and present time. Finally there are the results from the interviews that were made.

During the field period, the weather was very hot with maximum temperatures of 35° C and the precipitation was low with only three rains. The pre-monsoon period began and the low amount of precipitation is normal for this season. According to the local people, the temperature was low for this season, usually it is hotter.

## Erosion during a 24 day-period

In the following figures, some bars are black and some are white. The black ones represent days when measurements were made. The white ones represent days when measurements could not be done. The white ones represent average erosion and are calculated from the total erosion at day 15. The stations are marked on figure 13 at page 21.

Station A

This area has a thin vegetation and grass cover. Inland from this area, a couple of ricepaddies are situated. The beach slope gradient is almost zero and the bottom is very soft. The riverbank consists to 99 % of silt and finer material, the edge is hard and shows some signs of rills and gully erosion.

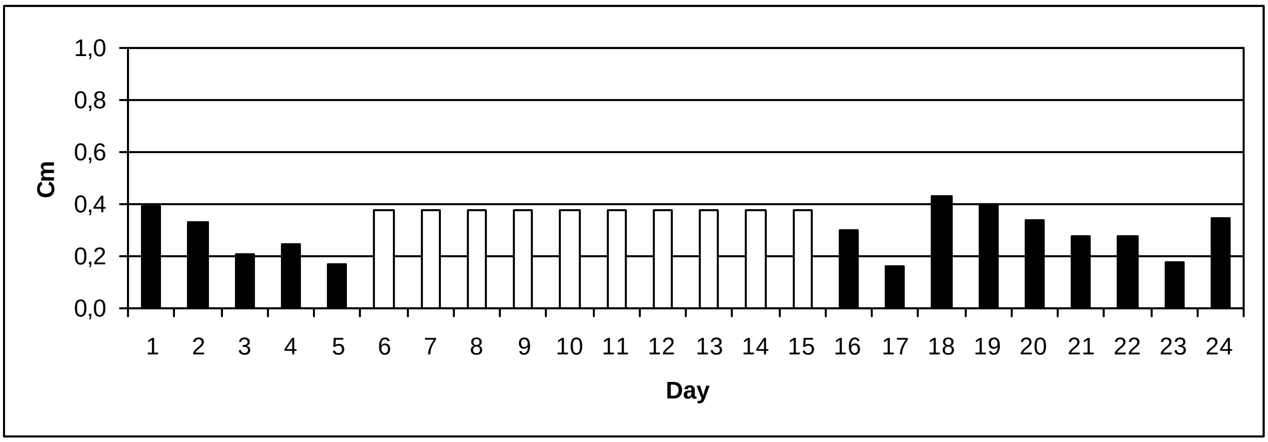



Figure 9: The figure shows the average erosion at station A from day to day in centimetres.

Station B

This area is not as much used by the people as the area in station A. This area has a thin grasscover. The beach slope gradient is almost zero and the bottom is harder than it was in station A. The riverbank consists of silt with a small amount of coarser sediments. There are just a few signs of erosion at this edge.

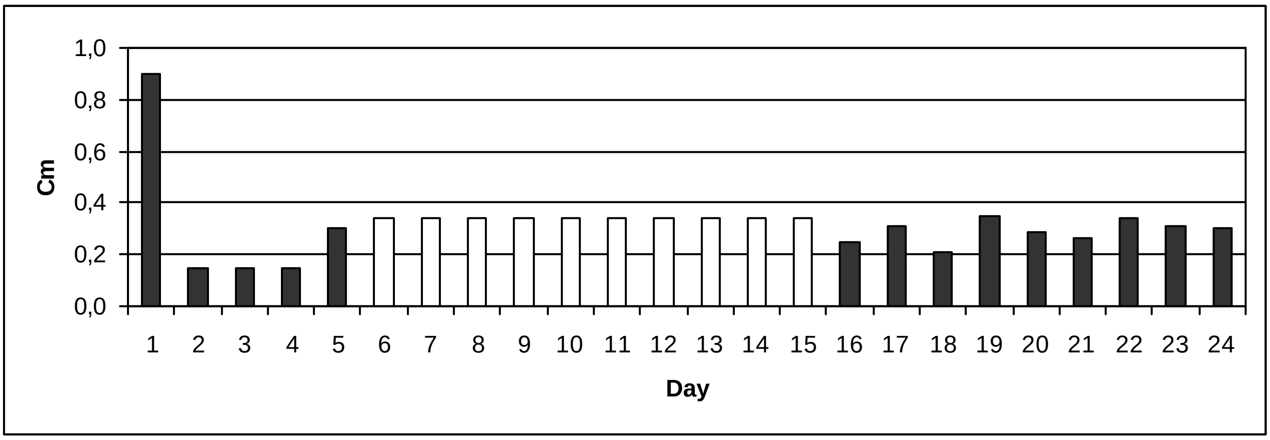



Figure 10: The figure shows the average erosion at station B from day to day in centimetres.

Station C.

The area looks almost the same as in station B. This area also has a thin grasscover, but thinner than in station B. The beach slope gradient is about 2 degrees. The bottom is quite hard and the riverbank consists of silt. There are some small signs of erosion at this edge.

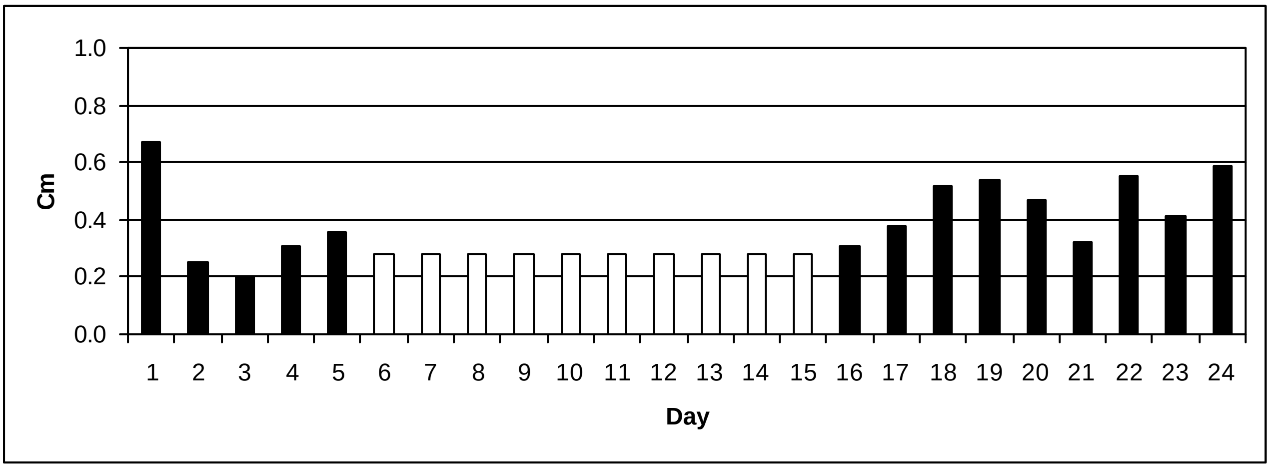



Figure 11: The figure shows the average erosion at station C from day to day in centimetres.

Station D.

The area has no vegetation or grass cover and is intensively used by the people. This area is situated about hundred metres from a small village, and they are fishing from land with their nets. The beach slope gradient is almost 3-4 degrees and the riverbank consists of 100 % silt. The bottom is really muddy and difficult to walk on. The edge shows big signs of erosion, especially soilcreep and gully erosion.

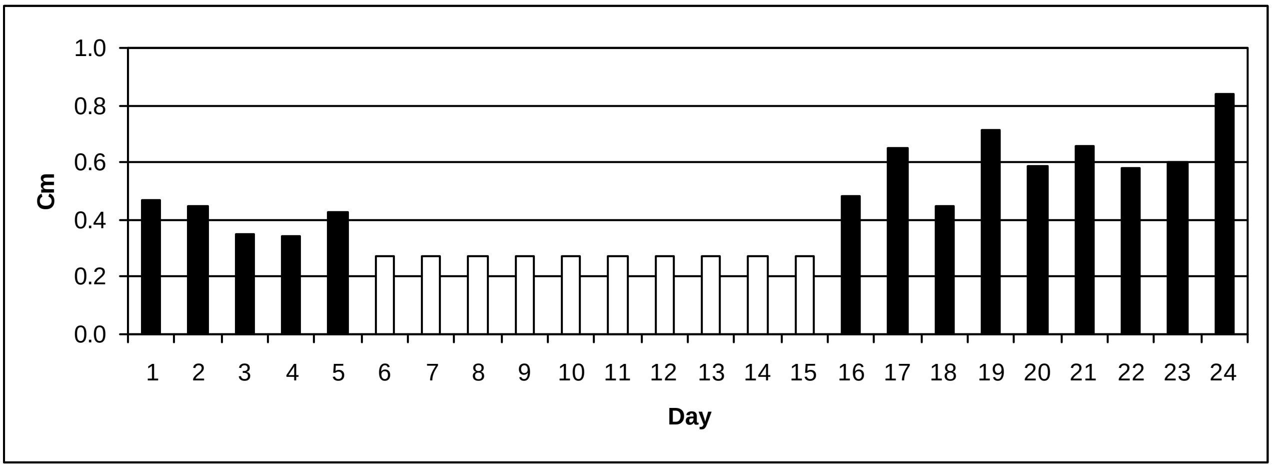



Figure 12: The figure shows the average erosion at station D from day to day in centimetres.

The total erosion varies between 7.5 centimetres to 10.4 centimetres at the stations during the 24-day fieldstudy. The erosion was quite uniform at station A, B and C, and of a higher magnitude at station D. Station A, B and C had some vegetation- or grass-cover that protected the river bank from erosion and human influence, station D had no vegetation cover at all that protected the waveedge. This is because the people in the area at station D intensely use this area of concern for fishing and for cattle. Another big difference between the stations is that A, B and C consist of quite hard-consolidated sediments, and are almost flat. Station D was quite soft and had a steeper beach slope gradient than the others. Station D also showed much more signs of erosion than the other did.

A calculation was also made of the erosion over one year, based on the measurement values. This should give an erosion of:

Station A: **7.9** cm — this gives a daily erosion of 0.33 centimetres and an annual erosion of **120.4** centimetres/year (0.33*365)

Station B: **7.5** cm — this gives a daily erosion of 0.31 centimetres and an annual erosion of **113.1** centimetres/year (0.31*365)

Station C: **8.2** cm — this gives a daily erosion of 0.34 centimetres and an annual erosion of **124.1** centimetres/year (0.34*365)

Station D: **10.4** cm — this gives a daily erosion of 0.43 centimetres and an annual erosion of **156.9** centimetres/year (0.43*365)

## Erosion and accretion between 1990-1995

This part is based on satellite images during a period of five years. As basis for these calculations, Landsat TM satellite images have been used. The images are from two different years, 1990 and 1995. These images are bought from SPARRSO (Bangladesh space organisation) and are in the scale of 1:100 000. The images have been digitised in OCAD 6.0 and calculated in Idrisi for windows. The results show that the erosion has been big at the east side of the island of Bhola. At the west side and in the northern part of the island, the accretion has been big.

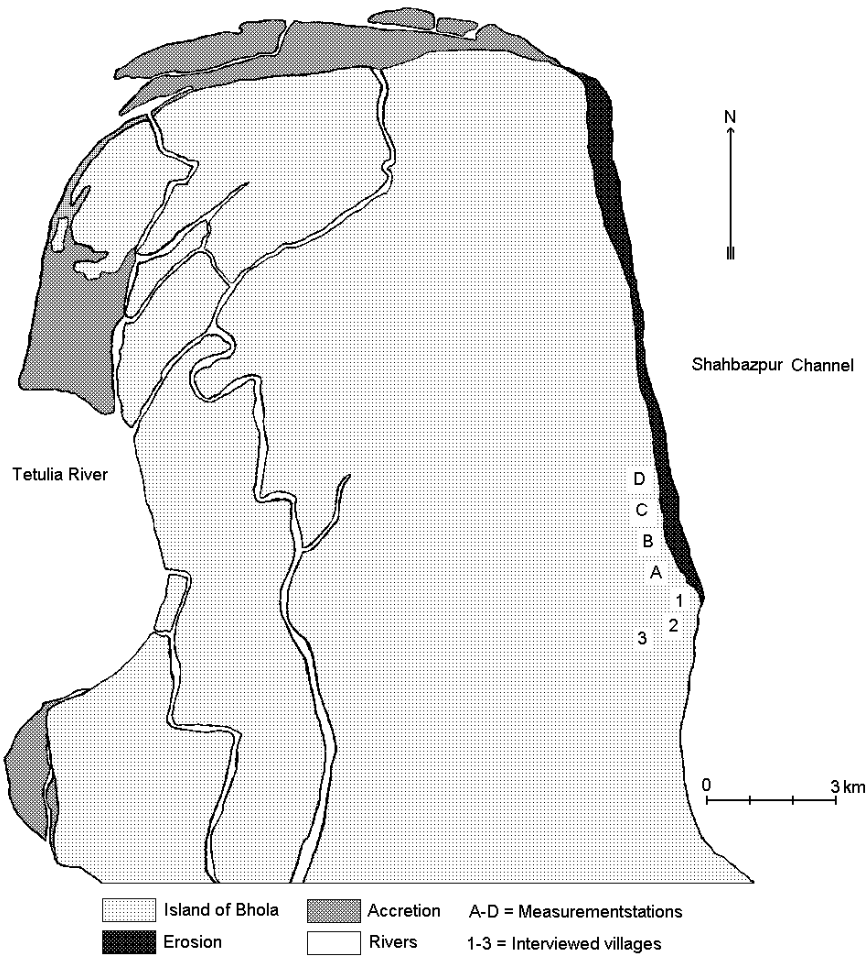



Figure 13: Shows the erosion, the accretion and the total landmass in an area of the northern part of the island of Bhola between 1990-1995.

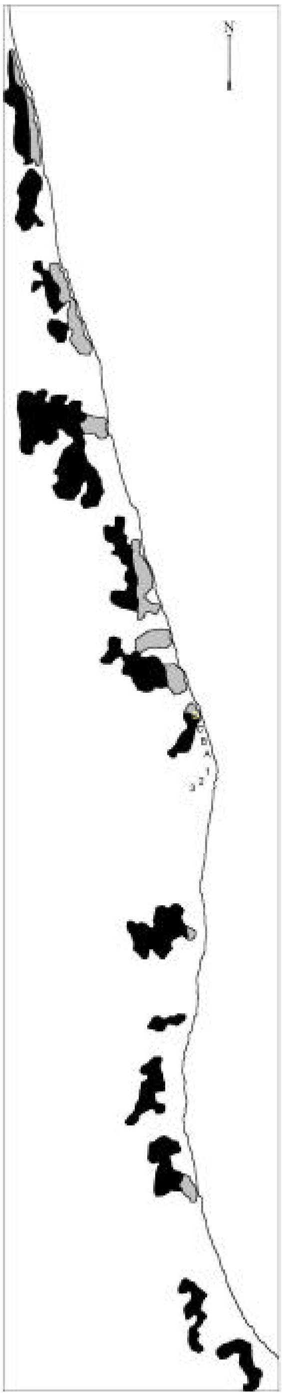
Table 1: Shows the erosion, the accretion and the total landmass in an area of the northern part of the island of Bhola between 1990-1995.

| | |
|---|---|
| Total landmass 1990 | 240.9 $km^2$ |
| Erosion 1990-1995 | 4.3 $km^2$ |
| Accretion 1990-1995 | 20.9 $km^2$ |
| Total landmass 1995 | 257.5 $km^2$ |

24 points at the map were measured and a calculation was made. The purpose of this was to find one maximum, one minimum and one average value for the erosion during this 5-year period. The **maximum** value was 600 meters in a period of 5 years, this gives an annual erosion of **120** metres. The **minimum** value was 130 metres, which gives an annual erosion of **26** metres. The **average** value was 342 metres and gives an annual erosion of **68.4** metres.

## Differences in the vegetation cover during 1989 - 1998

A big problem was the quality of the LANDSAT TM images that were bought. The resolution was not good enough to do a study of changes in the vegetation cover. The SPOT-image from 1989 was good, and with this and visual studies, some investigations could be done. These calculations are made from a hand drawn picture that was made in the field. It has been really difficult to compare the SPOT-image with this drawn picture, and therefore the result is not as accurate as wished. The map, (figure 14), gives a good view of changes in vegetation and can be compared with the result on figure 13. The biggest changes in vegetation have occurred in the north of the investigated area. There have not been any bigger changes in the south of the area, but there was not that much forest in 1989 either.



The grey field represent vegetation that have been clearcutted during 1989-1998

The black field represent vegetation in 1998

1-3 Interviewed villages
A-D Measurementstations

Figure 14: Shows the changes in vegetation cover during 1989-1998

## Interviews

Interviews were made in three villages, for location see figure 13. The purpose was to investigate how the erosion had affected the people living in these villages. Especially how many times they had had to move because of the erosion. These interviews are categorised after problem-sector: Common problems for these three villages, problems for fishermen and farmers. The most important thing was to investigate how the erosion had affected the people living in these villages. Some other interesting problems that affect these people were also found, and this gives a good picture of the situation these people have to deal with.

Common problems:

The most common problem for these villages is that they think that the landlord takes advantage of them. They have to pay high rates at their loans, and if they can not pay, the landlord takes the harvest or a part of it. They felt that they could not do anything, because many of them live illegal by the embankment. If the landlord tells them to move, they have to. This is a kind of serfdom. There is a dispute about the ownership of the land where the embankments are. These villages are in a perpetual state of feud with the landlord, and he has the officials on his side, about the ownership and rights to the land. This have led to problems with settlements, the people are afraid that the landlord shall transfer them compulsory (Oral communication with Mr John Munchi). In some cases they are employed by the landlord and have to buy crops from him to sell at the market. This has led to problems with capital; they have to pay almost the same price to the landlord as they get at the marketplace.

Another big problem for these villages is health and medication. They have to travel a long way to the nearest hospital (Bhola town) and they can in many cases not afford the medicine that is required. They also have a big problem to get enough drinking water. They have no tap in the villages and have to walk a long distance to get water. The situation is bad, a lot of people have diarrhoea, and they meant that saline water was the main reason. They also said that they have a big sanitation problem due to this water problem.

Village number 1:

Table 2: Shows name, family size, occupation and how many times they have had to move due to the coastal erosion.

| Name | Family size | Occupation | Moved/in years |
|---|---|---|---|
| Mohammad Idris | 6 | Fisherman | 10/45 |
| Hussein Mofaddel | 8 | Fisherman | 3/28 |
| Amir Hussain | 8 | Carpenter | 3/30 |
| Madjaral Hasslan | 5 | Salesman | - |
| Asmat Ali | 4 | Messenger | 2/20 |
| Samtul Alum | 4 | Salesman | 1/15 |
| Dolor Hussain | 5 | Messenger | 2/15 |
| Nonowi | 4 | Fisherman | 1/22 |
| Nassir Ahmed | 6 | Farmer | 1/20 |
| Alahi Box | 9 | Farmer | 5/20 |
| Habdul Khalam | 6 | Fisherman | 2/14 |
| Abdul Gasen | 8 | Fisherman | 2/20 |

The people in this village have had to move about 3 times in average over a period of 23 years.

Problems for the fishermen:

The biggest problem for the fishermen in this village is robbery and stolen nets. At night-time robbery with shotguns is a common problem. Fishing equipment, engines and caughts are the most attractive things for the robbers. The fishermen have joined teams so that they can protect each other at night-time. Another problem, due to erosion and accretion, is new chars that make it difficult to navigate and sometimes lead to grounding. They also think that the sediment load takes a lot of nets because of the weight. Ice is a problem for these fishermen, the ice has been too expensive and they need the ice for the transport of fish to the marketplace. Of the people interviewed, the fishermen were the only ones that were happy about the floods. The fishing is much easier and gives bigger caughts during the floods.

Problems for the farmers:

The farmers' biggest problems are caused by climatic reasons. During the floods, they lose a big part of their harvest. During the dry part of the year, they have problems with drought and irrigation. They also said that the price for artificial manure is too high, they can not afford it. Insects and bugs is another problem for the farmers, they take a part of the harvest every year.

Village number 2:

Table 3: Shows name, family size, occupation and how many times they have had to move due to the coastal erosion.

| **Name** | **Family size** | **Occupation** | **Moved/in years** |
|---|---|---|---|
| Mohammad Refic | 5 | Fish salesman | 3/20 |
| Lokman | 7 | Tailor | 6/30 |
| Luhulamin | 6 | Fisherman | 3/35 |
| Shohed Madji | 7 | Fisherman | 6/24 |
| Haniv | 7 | Fisherman | 3/35 |
| Mohammad Salem | 13 | - | 2/26 |
| Manic | 9 | Fish salesman | - |
| Abdul Ohab | 5 | Salesman | 5/40 |

The people in this village have had to move about 4 times in average over a period of 30 years.

Problems for the fishermen:

The fishermen in this village have a big problem caused by the accretion. The village is situated about 700 metres from the Shahbazpur channel. Earlier they had a canal to get their boats out to the river, but now, due to accretion, the canal is dry. The canal has been filled with sediment and they can only sail in the canal when the floodseason occurs. They have discussed this problem with the Bangladesh Water Development Board, but they cannot do anything because of bad liquidation. Another problem for these fishermen is to get new fishingequipment to replace the stolen. The main reason is their financial situation. These people have to pay 6 % of the catch to each employee that they have.

They also have to give 12 % of the catch to the landlord in landrate. The result of this is bad economy and a growing financial problem.

Village number 3:

Table 4: Shows name, family size, occupation and how many times they have had to move due to the coastal erosion.

| Name | Family size | Occupation | Moved/in years* |
|---|---|---|---|
| Abdul Manman | 7 | Farmer | 1/10 |
| Motahar Udin | 7 | Farmer | 2/20 |
| Shadjahan | 10 | Fisherman | 2/21 |
| Shadjahan Shonokal | 7 | Goldsmith | 2/22 |
| Abutahed | 8 | Carpenter | 2/36 |
| Shalom | 6 | Salesman | 3/28 |
| Hassem | 7 | Fisherman | 3/24 |
| Abdul Odod | 8 | Fisherman | 2/15 |
| Barek | 5 | Fisherman | 3/18 |
| Abdul Malek | 9 | Fisherman | 1/10 |
| Abdul Jolik | 7 | Farmer | 2/20 |

The people in this village have had to move about 2 times in average over a period of 20 years.

Problems for the fishermen:

Robbers have killed a couple of fishermen in this village. The fishermen mean that the police department does not do enough to stop this robbery. The fishermen said that the robbers pay the police so that they should not do anything about this problem. One man, Hassem, lives at the beach. He has been attacked several times by robbers at night-time, they have stolen all his things and he cannot buy new things because he does not have any income.

Problems for the farmers

The ownership of the land causes problems for the farmers. If they hire land and the harvest fail (due to floods, cyclone, e.t.c.) they have to pay rent anyway. This has become a big financial problem for some farmers, they will never make a profit on their harvests. Another problem is that the soils have been saline, they cannot cultivate what they would like to. They can only cultivate crops that are resistant to this saline soil. They also have a problem to find pasturage for the cattle.

# 9. DISCUSSION

As mentioned earlier in this paper, coastal erosion is a world-wide and big problem. The erosion gives big socio/economic consequences and causes people to move from affected areas. At the island of Bhola, the effects of the erosion hit the people really hard. Due to their poverty they have big problems to find areas that is not vulnerable to this coastal erosion, in many cases they have to fight both against the erosion and the landlord in the area.

## Erosion during a 24 day-period

The magnitude of erosion varies between **7.5** centimetres to **10.4** centimetres during the fieldstudy over 24 days.

The variation in magnitude of erosion depends on the different grade of vegetationcover, beachslopegradient, soil compaction and the grade of influence by human beings. Station D had the highest rate of erosion. This station had no vegetationcover that protected the riverbank, and the sediments in the waveedge were firm, had fine coarse and not so hard consolidated. This station also had the steepest beachslopegradient and was quite heavily used by the people living in the area. Station B was the one that had the smallest magnitude of erosion. This station had the thickest vegetationcover that protected the riverbank, the coarsest sediments, an almost flat beachslopegradient and was not so much used by the people.

There was a big problem to measure the tides. There are no meteorological stations at Bhola so it is difficult to calculate the magnitude of the tide. Instead, weather-observations made during the fieldstudy at the island of Bhola have been used.

There were three days with really bad weather, heavy rain and strong winds. There was heavy rain at day number 1, 17 and 24, the precipitation was about 20 – 30 mm during these rains. During these days, peaks in magnitude of erosion can be recognised at the measurementstations. At day number 1, all stations show high erosion. At day number 17, all stations except station A show a higher value of erosion than the day before. At day 24, all stations except station B show a higher value of erosion than the day before. The explanation of these values, at station A day 17 and station B at day 24 is that the soil has been saturated.

Precipitation is an important factor that increases the rate of erosion in dry areas. There was an obvious difference between days without precipitation and days with precipitation. It was found that the day after that precipitation had occurred, the erosion was high. This is due to the saturation of the soil. When the soil gets saturated it is more vulnerable to erosion than otherwise. This happened three times, at day 1, 17 and 24. The values for these days and the days after the precipitation were higher than before the precipitation. The conclusion is that the precipitation plays an important role for the magnitude of erosion.

It is difficult to compare these values with others. This study is made over a short period, earlier scientists have made their studies over a couple of years. Another important factor is the season. Some local farmers could not understand why this study of the erosion was made at that time. They meant that they only had problems with erosion during the floodseason and not in the dry season. They also said that the erosion was very big during the floods and it was only a problem during that time. Calculated values for the erosion over one year was made to compare with earlier studies. It is difficult to do a calculation like this, because there is much bigger erosion during the floodseason than during the dry season. The same problem should occur if the values were from the floodseason, but opposite. The only way to get a really true value for the erosion over a year would be to make measurements over a period of one year. Most scientists have values over at least one year and this makes the comparison difficult.

## Erosion and accretion between 1990-1995

These calculations are made from Landsat TM images from 1990 and 1995.

According to the area, the erosion was **4.3 $km^2$** at the east side of the island of Bhola between 1990 to 1995. Siddiqi et al found that the erosion at the east coast of Bhola was about 3.5 kilometres between 1940 to 1963 and 3 kilometres between 1963 to 1982, (figure 5). Their study was made over a period of 19 years and this gives an annual erosion of 152 (1940-1963) and 158 meters (1963-1982).

During the period 1990 to 1995, the erosion has been 600 metres at its maximum. This gives an annual **maximum** erosion of **120 meters**. The **minimum** annual erosion has been **26 meters**. The **average** erosion was calculated over the whole area and the value for this is **68.4 metres**. The conclusion that can be made from this is that the erosion has decreased since 1982 at the east coast at the island of Bhola.

There may be many reasons to explain this phenomenon, and one of them can be that the magnitude of stream currents have decreased and also changed their directions since 1982. But this is just a theory, there is not any papers regarding to this.

The accretion has been big during 1990 to 1995, **20.9 $km^2$**, (figure 13). New land is coming up in the north and on the west coast of the island of Bhola. Siddiqi et al does not present any values for accretion in their study so it is not possible to compare with that study. They only wrote that the erosion has been compensated with this new land. They have chosen to present their results with a map, and the map shows that the accretion has been big. As authors had written earlier, this new land is quite useless. It will take a very long time before human beings and cattle can use it.

One of the explanations to this accretion in the north and at the west side of the island of Bhola is the difference in current conditions between the Shahbazpur channel and the Tetulia River. The Tetulia River runs between the west side of the island of Bhola and the main coast of Bangladesh. This reduces the flow velocity and the river has not the same eroding force as at the east side where the Shahbazpur channel flows. At the west side, the flow is decreased and the current is so low that sedimentation can occur and this is, according to this study, the explanation to the accretion of new land at the west side and in the north of the island of Bhola. At the east coast, the eroding force is so big that sedimentation fails. This gives these circumstances that cause erosion at the east side of the island and accretion at the west side of the island.

In an earlier paper, Pramanik discusses this thesis about erosion at east sides and accretion at west sides of islands in the Bay of Bengal. The flow currents in the Bay of Bengal that are westward cause this phenomenon. The flow currents are heading towards the swatch of no ground, a submarine canyon 24-km south of the Bangladesh coast. The result of this is that the islands in this region are subjects mostly to erosion at their east sides and accretion at their west sides. The islands get the shape of a banana, bending with their southern parts westward, (figure 5).

The Nile delta and its rate of erosion has been chosen for comparison with the values that was calculated during this study. The stations in the Nile delta and in the delta of Bay of Bengal are quite similar and both are situated at riverbanks in big rivers.

There is a relatively big difference in rate of erosion between those two stations. Rosetta had an annual shoreline retreat of 114.9 meters and this is almost the same as the maximum value for this study (120 meters). According to the average erosion at the island of Bhola, 68.4 metres, the erosion in the Nile delta is much higher. I do not know if Frihy's value is a maximum or average value and this makes it difficult to make a fair comparison (Frihy 1988, pp 597).

An earlier study at one other station in the Nile Delta, Damietta, has indicated a shoreline retreat of 58 meters/year between 1944-1989 (Frihy 1992, pp 65). This value is almost as high as the one in this study, but it is still difficult to compare. The study showed that the sea level rise has, by itself, a relatively minor effect on coastal erosion. Frihy made a study based on two series of aerial photos taken in 1955 and 1983. The study showed that the shoreline retreat during this 28-year period was 114.9 and 31 meters/year at Rosetta and Damietta (Frihy 1988, pp 597).

## Differences in the vegetation cover during 1989 – 1998

There have been some changes in the vegetation cover since 1989, and they have been biggest in the northern part of the studyarea. If a comparison is made between the changes in vegetation cover (figure 14) and the erosion (figure 13), some conclusions can be made. There is a clear connection between erosion and loss of trees. Where the erosion has been high, loss of trees/forest has occurred. The reason may be clearcutting of forest by human beings or erosion. The land may have eroded away and the trees have been swept out in the river during the period. If there has been clearcutting, human beings have accelerated the erosion and made the riverbanks more vulnerable to erosion. But it is too difficult to say what happened. With one more SPOT-image, it had been possible to make a better investigation about the connection erosion-clearcutting.

## Interviews

The purpose with the interviews were to investigate how the people living by the embankments, especially the fishermen and their families, have had to move because of problems with the erosion.

The result showed that the people living at the embankment have had to move **2 to 4 times** in a period of **20 to 30 years** because of problems with the erosion. They had to move because they lost their land and houses due to the erosion, and this have caused them big problems with new settlements and opportunities to have a good and solid livelihood. In most cases, these people have been landless and forced to live illegal by the embankments. They are now living almost in serfdom.

It was a problem to investigate how far they have had to move every time. The people that were interviewed were not sure about which year they had to move or how far. They all knew that they had only moved around in the neighbourhood and always close to the river. One theory is that they have always lived in the margin between the river and the farmland. The farmland is in possession by the landlord or other farmers, and that makes it illegal to settle on. The people who have been landless cannot move farther away, than to this margin between the river and the farmland. This makes them vulnerable for erosion and floods, and if the erosion does not stop, they have to move again.

- The people in village number 1 have had to move about 3 times in average over a period of 23 years.
- The people in village number 2 have had to move about 4 times in average over a period of 30 years.
- The people in village number 3 have had to move about 2 times in average over a period of 20 years.

Hossain's study showed that about 45 % of the households were affected in one way or another by erosion in the village he investigated (Hossain 1993, p 27). This investigation shows that the erosion in one way or another affected almost everyone in the villages. Hossain also wrote that 20 % cultivatable land was lost in the village. It is difficult to say how much land the villages in this investigation have lost. One thing is clear, they have lost big values in land and households.

There were a lot of different problems that these people had to deal with. Many of these problems were typical for undeveloped countries, water, sanitation, health and money e.t.c

One of the villages had a really big problem caused by the high sedimentation that occurs. They could not get their boat to the river so that they could do their fishing, their only source of income. The reason for this was that the canal that connects the village with the Shahbazpur River was dry and full of sediments deposited during the flood season. They had tried to dig this canal out, but it was too much work and they had not energy enough to do this. This was a really big problem for them, they have not food enough to feed their families during the dry season. They could not get any money either, so they have to take their children out of school and they could not afford enough money to repair their houses etc.

Pirates had robbed a couple of fishermen during night-time and stolen their fishingequipment, caughts, boats and a couple of them had been shot. This was a big problem for them, they were afraid at night-time and a couple of them had quit their professions. They had also tried to fish together in teams but it had not worked out, they got robbed anyway. They felt really frustrated, because they had talked with the local police department about this problem but nothing happened. Many of the policemen were corrupt, and bought by the pirates.

## Solutions to stop the erosion

There is not so much work going on to stop the erosion in the Bay of Bengal, island of Bhola. In the end of the fifties, the government built a crossdam between the Noakhali mainland and Ramgati Island to protect the island from erosion. This crossdam was a success, accretion occurred and the

Island is now much bigger (Alam). There have been some discussions concerning a crossdam between the Island of Bhola and the mainland, and Siddiqi et al mean that this is a good solution. This discussion started in the eighties, but there has not happened much with this crossdam since the discussion.

In present time, a Dutch company (DEFT) is working on a new solution to try to stop the erosion at the Northeast coast of the Island of Bhola. They are building reinforced concrete plates that shall stabilise the coast and protect it from riverbank undercutting, (figure 15). These plates are about 100*100 and 10 centimetres thick, and armoured into the ground to stabilise and protect the ground from erosion. The local engineer did not believe in this project, he thought that Meghna (the Shahbazpur channel) was too strong for this construction. It seems like this solution is a really short-time solution. The erosion is 68.4 metres every year, and in 5 years this place will be under water. The currents will undercut the concrete plates and sweep it away out in the river.

Figure 15: Shows the reinforced concrete plates that DEFT are building. Photo: Magnus Krantz 1998

The oldest solution, embankments, is not a solution to protect riverbanks from erosion. It is a solution to protect people from floods, but it helps to protect the riverbank too. The embankments are an extra shelter for the riverbanks and give a minor delay in the rate of the erosion. One big problem with these embankments is to afford money to maintain their quality. Some of them are in a really bad shape, broken, and the people are trying to rebuild them.

The government has for some a time built a lot of cyclonshelters all around the coastal area. These cyclonshelters are built as big concrete towers, for people to take cover in during cyclones. They do not build anything that will protect the riverbanks or stop the erosion. Is this erosion not a big problem for the government?

# 10. CONCLUSIONS

The aim with this study was to investigate how coastal transformations had influenced the people on the island of Bhola and vice versa. A calculation of the coastal erosion, on affected areas and areas not so much affected by human beings, over a period of ten years should also be carried out.

Two types of investigations were made, one over 24-days and one over 5 years. The results from the 24-day investigation, show that the rate of erosion vary between **0.31** to **0.43 centimetres** each day. This gives annually values from **113.1** to **156.9 centimetres**. This study shows that the precipitation is important as an eroding agent in the process, because it saturates the soil and makes it vulnerable to erosion.

The investigation over 5 years showed that the erosion had been **4.3 $km^2$** during this period, and that it took place at the east coast of the island. The accretion was **20.9 $km^2$** during the same period, and took place up in the north and at the west coast of the island. The annual erosion has a maximum value of **120 metres** and an average value of **68.4 metres.** These values are almost the same as values that scientists got in the Nile Delta. Earlier studies have showed that the newly accreted land is quite useless in the beginning, so for a short period this land loss is a big problem until the new land can be cultivated.

In areas more affected by people, the erosion is higher than in areas that are not so much affected by people.

There is a difference in magnitude between the stations but the difference is not so big. One explanation can be that it takes a longer time than 24-days to get a more exact value of the erosion, between different areas.

There have been changes in vegetation cover during the period 1989 to 1998. A clear connection can be recognised between erosion and loss of vegetation. What this loss of vegetation is caused by is difficult to say, more basic data is needed.

The erosion has had a big effect on the people living in the coastal area on the Island of Bhola. People living by the embankment have had to move between 2 to 4 times during a period of 20 to 30 years. Especially the fishermen and their families, who live in the coastal area, have had to move several times because of the erosion. Many of these people have been landless and are now living in serfdom.

What are the government and NGO: s doing to stop this erosion?

The government does not do much to stop this erosion. There are not any plans to stop the erosion or deal with this problem. Earlier scientists have discussed some solutions that the government is planning to do. There are some NGO-projects going on, on the Island of Bhola in present time, but it will take several years before the result can be recognised.

## Final remarks

In a country with 936 persons per $km^2$ and with a great discharge of water brought through the country, Bangladesh and its people are vulnerable to riverbank and coastal erosion. The major part of the population is living in the coastal area and close to the rivers. The country is agrarian and very dependent on farming and fishing. When erosion occurs, loss of big areas of farmland resuls in devastating effects. There are not any solutions to deal with these problems in present time, hopefully something will happen soon. The Island of Bhola is representative for the country, some of the results in this paper may occur at other places in Bangladesh.

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# APPENDIX

## Erosion during a 24-day period

Erosion from day to day at each station, the numbers represent the erosion in centimetres:

### Station A

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0,8 | 0,4 | 0,3 | 0,2 | 0,2 | 0,4 | 0,1 | 0,3 | 0.5 | 0,2 | 0,3 | 0,1 | 0,3 | 0,4 | 8.3 |
| Point 2 | 0 | 0,5 | 0,4 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,1 | 0.6 | 0,1 | 0,2 | 0,2 | 0,3 | 0,4 | 8.5 |
| Point 3 | 0 | 0,7 | 0,3 | 0,1 | 0,1 | 0,2 | 0,2 | 0,1 | 0,6 | 0,2 | 0,2 | 0,5 | 0,7 | 0,1 | 0,3 | 8,1 |
| Point 4 | 0 | 0,3 | 0.5 | 0,1 | 0,2 | 0,1 | 0,1 | 0,3 | 0,6 | 0,5 | 0 | 0,2 | 0,7 | 0,2 | 0,5 | 8 |
| Point 5 | 0 | 0 | 0.2 | 0.3 | 0.3 | 0,3 | 0,2 | 0,1 | 0,4 | 0,7 | 0,3 | 0,2 | 0,4 | 0,2 | 0,2 | 7,9 |
| Point 6 | 0 | 0.5 | 0.3 | 0,2 | 0,1 | 0,2 | 0,4 | 0,2 | 0,7 | 0,3 | 0,3 | 0,2 | 0,1 | 0,2 | 0,2 | 7.5 |
| Point 7 | 0 | 0 | 0.2 | 0.4 | 0,4 | 0,2 | 0,2 | 0 | 0,3 | 0,2 | 0,5 | 0,3 | 0,2 | 0,2 | 0,4 | 7.6 |
| Point 8 | 0 | 0.3 | 0.3 | 0.2 | 0,3 | 0,1 | 0,2 | 0,4 | 0,3 | 0,4 | 0,7 | 0,5 | 0 | 0 | 0,2 | 7.5 |
| Point 9 | 0 | 0.2 | 0.5 | 0.1 | 0,2 | 0,1 | 0,4 | 0 | 0,5 | 0,4 | 0,6 | 0,3 | 0,1 | 0,1 | 0,5 | 7.8 |
| Point 10 | 0 | 0.6 | 0.2 | 0.1 | 0,4 | 0 | 0,6 | 0,1 | 0,5 | 0,2 | 0,5 | 0,1 | 0,3 | 0,2 | 0,4 | 7,9 |
| **Average** | 0 | 0,39 | 0,33 | 0,21 | 0,25 | 0,17 | 0,3 | 0,16 | 0,43 | 0,4 | 0,34 | 0,28 | 0,28 | 0,18 | 0,35 | 7,91 |

### Station B

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0.7 | 0.3 | 0.2 | 0.2 | 0.5 | 0.1 | 0.3 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 7.3 |
| Point 2 | 0 | 0.9 | 0.2 | 0.1 | 0.3 | 0.5 | 0.2 | 0.1 | 0.2 | 0.4 | 0.2 | 0.1 | 0.3 | 0.3 | 0.5 | 7.3 |
| Point 3 | 0 | 0.8 | 0.1 | 0.1 | 0.1 | 0.3 | 0.1 | 0.2 | 0 | 0.5 | 0.2 | 0.5 | 0.2 | 0.3 | 0.7 | 7.6 |
| Point 4 | 0 | 0.6 | 0.1 | 0.2 | 0.1 | 0.3 | 0 | 0.1 | 0.5 | 0.4 | 0.2 | 0.3 | 0.1 | 0.3 | 0.3 | 7.4 |
| Point 5 | 0 | 1 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.7 | 0.1 | 0.3 | 0.4 | 0.2 | 0.4 | 0.5 | 0.2 | 7.7 |
| Point 6 | 0 | 1.2 | 0.1 | 0.1 | 0.1 | 0.3 | 0.7 | 0.3 | 0.3 | 0.1 | 0.5 | 0 | 0.4 | 0.4 | 0.2 | 7.8 |
| Point 7 | 0 | 0.7 | 0.2 | 0.2 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 0.2 | 0.4 | 0.1 | 0.5 | 0.1 | 0.2 | 7.3 |
| Point 8 | 0 | 0.8 | 0.2 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 0.3 | 0.4 | 0.2 | 0.4 | 0.5 | 0.2 | 0.3 | 7.9 |
| Point 9 | 0 | 1.1 | 0 | 0.2 | 0.1 | 0 | 0.2 | 0.2 | 0 | 0.6 | 0.3 | 0.5 | 0.4 | 0.2 | 0 | 7.3 |
| Point 10 | 0 | 1.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 0.1 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.2 | 7.9 |
| **Average** | 0 | 0.9 | 0.15 | 0.15 | 0.15 | 0.3 | 0.25 | 0.31 | 0.21 | 0.35 | 0.29 | 0.26 | 0.34 | 0.31 | 0.3 | 7.55 |

### Station C

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0 | 0.3 | 0.3 | 0.5 | 0.4 | 0.3 | 0.4 | 0.3 | 0.4 | 0.5 | 0.3 | 0.5 | 0.7 | 0.4 | 8.1 |
| Point 2 | 0 | 0.2 | 0.2 | 0.2 | 0.5 | 0.4 | 0.1 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 8.1 |
| Point 3 | 0 | 0.9 | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 | 0.2 | 0.5 | 0.5 | 0.6 | 0 | 0.7 | 0.3 | 0.5 | 7.9 |
| Point 4 | 0 | 0.4 | 0.4 | 0.3 | 0.2 | 0.2 | 0.5 | 0.4 | 0.5 | 0.4 | 0.6 | 0.1 | 0.8 | 0.1 | 0.8 | 8.1 |
| Point 5 | 0 | 0.8 | 0.4 | 0.1 | 0.1 | 0.4 | 0.5 | 0.6 | 0.7 | 0.3 | 0.5 | 0.3 | 0.5 | 0 | 0.6 | 7.9 |
| Point 6 | 0 | 1.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.2 | 0.2 | 0.4 | 0.8 | 8.2 |
| Point 7 | 0 | 1 | 0.3 | 0 | 0.3 | 0.4 | 0.4 | 0.3 | 0.5 | 0.8 | 0.1 | 0.3 | 0.6 | 0.4 | 0.8 | 8.4 |
| Point 8 | 0 | 0.9 | 0.2 | 0.2 | 0.3 | 0.4 | 0.3 | 0.4 | 0.7 | 0.5 | 0.4 | 0.4 | 0.7 | 0.5 | 0.4 | 8.4 |
| Point 9 | 0 | 0.7 | 0.2 | 0.1 | 0.5 | 0.4 | 0.2 | 0.3 | 0.6 | 0.9 | 0.4 | 0.5 | 0.5 | 0.6 | 0.5 | 8.5 |
| Point 10 | 0 | 0.7 | 0.2 | 0.4 | 0.4 | 0.5 | 0.2 | 0.4 | 0.5 | 0.6 | 0.6 | 0.6 | 0.5 | 0.6 | 0.5 | 8.7 |
| **Average** | 0 | 0.67 | 0.25 | 0.2 | 0.31 | 0.36 | 0.31 | 0.38 | 0.52 | 0.54 | 0.47 | 0.32 | 0.55 | 0.41 | 0.59 | 8.23 |

**Station D**

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0.7 | 0.4 | 0.2 | 0.3 | 0.3 | 0.4 | 1 | 0.3 | 0.3 | 0.3 | 1.1 | 0.8 | 0.4 | 0.7 | 10 |
| Point 2 | 0 | 0.8 | 0.5 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.4 | 0.7 | 0.4 | 0.6 | 0.8 | 0.7 | 0.5 | 10 |
| Point 3 | 0 | 0.3 | 0.6 | 0.5 | 0.2 | 0.5 | 0.5 | 0.6 | 0.4 | 0.4 | 0.7 | 0.7 | 0.1 | 0.6 | 1.3 | 9.9 |
| Point 4 | 0 | 0.4 | 0.4 | 0.4 | 0.3 | 0.5 | 0.4 | 0.3 | 0.6 | 0.4 | 1 | 0.4 | 0.6 | 0.4 | 0.5 | 9.8 |
| Point 5 | 0 | 0 | 0.4 | 0.6 | 0.5 | 0.6 | 0.3 | 0.7 | 0.8 | 0.5 | 0.1 | 0.5 | 0.7 | 0.5 | 1.1 | 10.1 |
| Point 6 | 0 | 0.3 | 0.4 | 0.5 | 0.6 | 0.4 | 0.4 | 0.8 | 0.6 | 1 | 0.4 | 0.8 | 0.7 | 0.5 | 0.9 | 10.9 |
| Point 7 | 0 | 0.6 | 0.3 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.9 | 0.3 | 0.7 | 0.5 | 0.9 | 0.9 | 10.5 |
| Point 8 | 0 | 0.5 | 0.5 | 0.2 | 0.4 | 0.4 | 0.6 | 0.6 | 0.3 | 0.6 | 0.8 | 0.4 | 0.7 | 0.7 | 0.8 | 10.5 |
| Point 9 | 0 | 0.5 | 0.5 | 0.2 | 0.2 | 0.5 | 0.6 | 0.8 | 0.4 | 1 | 0.9 | 0.6 | 0.3 | 0.7 | 1 | 11 |
| Point 10 | 0 | 0.6 | 0.5 | 0.3 | 0.2 | 0.3 | 0.7 | 0.7 | 0.3 | 1.3 | 1 | 0.8 | 0.6 | 0.6 | 0.7 | 11.3 |
| **Average** | 0 | 0.47 | 0.45 | 0.35 | 0.34 | 0.43 | 0.48 | 0.65 | 0.45 | 0.71 | 0.59 | 0.66 | 0.58 | 0.6 | 0.84 | 10.41 |

## Erosion during a 24-day period

The Erosion at each station during the fieldstudy. The numbers show the accumulated erosion for every day in centimetres:

**Station A**

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0.8 | 1.2 | 1.5 | 1.7 | 1.9 | 5.7 | 6.1 | 6.2 | 6.5 | 7 | 7.2 | 7.5 | 7.6 | 7.9 | 8.3 |
| Point 2 | 0 | 0.5 | 0.9 | 1.2 | 1.4 | 1.7 | 5.9 | 6.2 | 6.5 | 6.6 | 7.2 | 7.3 | 7.5 | 7.7 | 8 | 8.4 |
| Point 3 | 0 | 0.7 | 1 | 1.1 | 1.2 | 1.4 | 5.2 | 5.3 | 5.4 | 6 | 6.2 | 6.4 | 6.9 | 7.6 | 7.7 | 8 |
| Point 4 | 0 | 0.3 | 0.8 | 0.9 | 1.1 | 1.2 | 4.9 | 5 | 5.3 | 5.9 | 6.4 | 6.4 | 6.6 | 7.3 | 7.5 | 7.8 |
| Point 5 | 0 | 0 | 0.2 | 0.5 | 0.8 | 1 | 5.1 | 5.3 | 5.4 | 5.8 | 6.5 | 6.8 | 7 | 7.4 | 7.6 | 7.8 |
| Point 6 | 0 | 0.5 | 0.8 | 1 | 1.2 | 1.4 | 5 | 5.4 | 5.6 | 6.3 | 6.6 | 6.9 | 7.1 | 7.2 | 7.4 | 7.6 |
| Point 7 | 0 | 0 | 0.2 | 0.6 | 1 | 1.2 | 5.3 | 5.5 | 5.5 | 5.8 | 6 | 6.5 | 6.8 | 7 | 7.2 | 7.6 |
| Point 8 | 0 | 0.3 | 0.6 | 0.8 | 1.1 | 1.2 | 4.8 | 5 | 5.4 | 5.7 | 6.1 | 6.8 | 7.3 | 7.3 | 7.3 | 7.5 |
| Point 9 | 0 | 0.2 | 0.7 | 0.8 | 1 | 1.1 | 4.9 | 5.3 | 5.3 | 5.8 | 6.2 | 6.8 | 7.1 | 7.2 | 7.3 | 7.8 |
| Point 10 | 0 | 0.6 | 0.8 | 0.9 | 1.3 | 1.3 | 5 | 5.6 | 5.7 | 6.2 | 6.4 | 6.9 | 7 | 7.4 | 7.6 | 8 |

**Station B**

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0.7 | 1 | 1.2 | 1.4 | 1.9 | 5.3 | 5.4 | 5.7 | 6 | 6.2 | 6.3 | 6.4 | 6.6 | 6.9 | 7.3 |
| Point 2 | 0 | 0.9 | 1.1 | 1.2 | 1.5 | 2 | 5 | 5.2 | 5.3 | 5.5 | 5.9 | 6.1 | 6.2 | 6.5 | 6.8 | 7.3 |
| Point 3 | 0 | 0.8 | 0.9 | 1 | 1.1 | 1.4 | 4.9 | 5 | 5.2 | 5.2 | 5.7 | 5.9 | 6.4 | 6.6 | 6.9 | 7.6 |
| Point 4 | 0 | 0.6 | 0.7 | 0.9 | 1 | 1.4 | 5.3 | 5.3 | 5.4 | 5.9 | 6.3 | 6.5 | 6.8 | 6.9 | 7.2 | 7.5 |
| Point 5 | 0 | 1 | 1.2 | 1.4 | 1.6 | 1.9 | 4.7 | 4.9 | 5.6 | 5.7 | 6 | 6.4 | 6.6 | 7 | 7.5 | 7.7 |
| Point 6 | 0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.8 | 4.9 | 5.6 | 5.9 | 6.2 | 6.3 | 6.8 | 6.8 | 7.2 | 7.6 | 7.8 |
| Point 7 | 0 | 0.7 | 0.9 | 1.1 | 1.2 | 1.5 | 5.1 | 5.3 | 5.5 | 5.8 | 6 | 6.4 | 6.5 | 7 | 7.1 | 7.3 |
| Point 8 | 0 | 0.8 | 1 | 1.1 | 1.3 | 1.6 | 4.8 | 5.2 | 5.6 | 5.9 | 6.3 | 6.5 | 6.9 | 7.4 | 7.6 | 7.9 |
| Point 9 | 0 | 1.1 | 1.1 | 1.3 | 1.4 | 1.4 | 4.9 | 5.1 | 5.3 | 5.3 | 5.9 | 6.2 | 6.7 | 7.1 | 7.3 | 7.3 |
| Point 10 | 0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.7 | 4.5 | 4.9 | 5.5 | 5.6 | 6 | 6.4 | 6.8 | 7.2 | 7.8 | 8 |

**Station C**

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0 | 0.3 | 0.6 | 1 | 1.4 | 4.2 | 4.5 | 4.9 | 5.2 | 5.6 | 6.1 | 6.4 | 6.9 | 7.6 | 8 |
| Point 2 | 0 | 0.2 | 0.4 | 0.6 | 1.1 | 1.5 | 4 | 4.1 | 4.6 | 5 | 5.5 | 6 | 6.5 | 7 | 7.5 | 8.1 |
| Point 3 | 0 | 0.9 | 1.1 | 1.3 | 1.4 | 1.6 | 4.3 | 4.6 | 4.8 | 5.3 | 5.8 | 6.4 | 6.4 | 7.1 | 7.4 | 7.9 |
| Point 4 | 0 | 0.4 | 0.8 | 1.1 | 1.3 | 1.5 | 3.9 | 4.4 | 4.8 | 5.3 | 5.7 | 6.3 | 6.4 | 7.2 | 7.4 | 8.2 |
| Point 5 | 0 | 0.8 | 1.2 | 1.3 | 1.4 | 1.8 | 3.9 | 4.4 | 5 | 5.7 | 6 | 6.5 | 6.8 | 7.3 | 7.3 | 7.9 |
| Point 6 | 0 | 1.1 | 1.2 | 1.4 | 1.6 | 1.9 | 4.5 | 4.8 | 5.1 | 5.6 | 6.1 | 6.6 | 6.8 | 7 | 7.4 | 8.2 |
| Point 7 | 0 | 1 | 1.3 | 1.3 | 1.6 | 2 | 4.2 | 4.6 | 4.9 | 5.4 | 6.2 | 6.3 | 6.6 | 7.2 | 7.6 | 8.4 |
| Point 8 | 0 | 0.9 | 1 | 1.2 | 1.5 | 1.9 | 4 | 4.3 | 4.7 | 5.4 | 5.9 | 6.3 | 6.7 | 7.4 | 7.9 | 8.3 |
| Point 9 | 0 | 0.7 | 0.9 | 1 | 1.5 | 1.9 | 4 | 4.2 | 4.5 | 5.1 | 6 | 6.4 | 6.9 | 7.4 | 8 | 8.5 |
| Point 10 | 0 | 0.7 | 0.9 | 1.3 | 1.7 | 2.2 | 4.2 | 4.4 | 4.8 | 5.3 | 5.9 | 6.5 | 7.1 | 7.6 | 8.2 | 8.7 |

**Station D**

| Day | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 1-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point 1 | 0 | 0.7 | 1.1 | 1.3 | 1.6 | 1.9 | 4.6 | 5 | 6 | 6.3 | 6.6 | 7 | 8.1 | 8.9 | 9.3 | 10 |
| Point 2 | 0 | 0.8 | 1.3 | 1.5 | 1.7 | 2 | 5 | 5.4 | 5.9 | 6.3 | 7 | 7.4 | 8 | 8.8 | 9.5 | 10 |
| Point 3 | 0 | 0.3 | 0.9 | 1.4 | 1.6 | 2.1 | 4.8 | 5.3 | 5.7 | 6.1 | 6.5 | 7.2 | 7.9 | 8 | 8.6 | 9.9 |
| Point 4 | 0 | 0.4 | 0.8 | 1.2 | 1.5 | 2 | 5.2 | 5.6 | 5.9 | 6.5 | 6.9 | 7.9 | 8.3 | 8.9 | 9.3 | 9.8 |
| Point 5 | 0 | 0 | 0.4 | 1 | 1.5 | 2.1 | 4.9 | 5.2 | 5.9 | 6.7 | 7.2 | 7.3 | 7.8 | 8.5 | 9 | 10.1 |
| Point 6 | 0 | 0.3 | 0.7 | 1.2 | 1.8 | 2.2 | 4.8 | 5.2 | 6 | 6.6 | 7.6 | 8 | 8.8 | 9.5 | 10 | 10.9 |
| Point 7 | 0 | 0.6 | 0.9 | 1.3 | 1.8 | 2.3 | 4.9 | 5.4 | 5.9 | 6.3 | 7.2 | 7.5 | 8.2 | 8.7 | 9.6 | 10.5 |
| Point 8 | 0 | 0.5 | 1 | 1.2 | 1.6 | 2 | 5 | 5.6 | 6.2 | 6.5 | 7.1 | 7.9 | 8.3 | 9 | 9.7 | 10.5 |
| Point 9 | 0 | 0.5 | 1 | 1.2 | 1.4 | 1.9 | 4.7 | 5.3 | 6.1 | 6.5 | 7.5 | 8.4 | 9 | 9.3 | 10 | 11 |
| Point 10 | 0 | 0.6 | 1.1 | 1.4 | 1.6 | 1.9 | 4.6 | 5.3 | 6 | 6.3 | 7.6 | 8.6 | 9.4 | 10 | 10.6 | 11.3 |

**List of words**

| | |
|---|---|
| BFCDP. | Bhola Fishery and Community Development Program. |
| SWEDMAR | Swedish Centre for Coastal Development and Management of Aquatic Resources |
| LANDSAT TM | Satellite images from EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS), The first Landsat satellite was launched in 1972. |
| SPARRSO | Bangladesh governmental space organisation |
| Chars | Upgrounding land in the rivers. |
| Khals | Canals |
| Upazilas | Sub-districts at community level. |
| SPOT | “Système Pour l'Observation de la Terre” is a project of the French Space Agency and the world's first commercial satellite remote sensing system. |

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