MORPHOLOGICAL CHANGES ALONG BANGLADESH COAST DERIVED FROM SATELLITE IMAGES

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Being a low laying deltaic country, the morphological changes of the coastal zones of Bangladesh become a major social, economic and environmental concern. In this study, images of Landsat satellite during 1989-2010 are analyzed to detect the variation of shoreline positions. The western-central coast has been divided into different segments and changes have been observed in the south face. Shoreline change rates have been analyzed for two period 1989-2000 and 2000-2010. Every segment has been facing more changes in the previous decade 1989-2000 as compared to the recent decade 2000-2010. Segments covered with mangrove are facing more changes compared to flat sandy beach which is contradicting with general consensus that mangrove stabilize the land.

Key Words: *Shoreline, Bangladesh Coast, Erosion, Accretion, Satellite Image.*

1. INTRODUCTION

Being a low laying deltaic country, the morphology of Bangladesh coastal zone is quite unstable and changing time to time due to erosion and accretion. The coast is known as a zone of vulnerabilities besides its distinctive importance for natural resources and ecosystems. Natural threats, such as erosion, water logging, increase in water and soil salinity, risks from climate change like sea -level rise, cyclone etc., have adversely affected the morphology of coastal zone and slowed down the pace of social and economic developments in this region (CZPo, 2005; Barua et al., 2010). The changing features of the coastal zones of Bangladesh become a major social, economic and environmental concern.

The objective of the study is i) to detect the shoreline position from satellite images, ii) to provide a regional overview of coastal accretion and erosion along the western-central Bangladesh coast over two decade, specially focus on the areas with mangrove forest, iii) to assess whether mangrove dominated shoreline has different behavior from others, and iv) to identify the relationship between the morphological changes, geomorphological as well as oceanographical factors.

2. STUDY AREA

The southernmost part of Bangladesh is bordered by about 710 km long coast line of Bay of Bengal which covers 19 districts out of 64 districts of the country (CZPo, 2005). Bangladesh coastal zone can be divided into three regions namely western, central and eastern coastal region. Figure 1 shows (a) main river system, and (b) the study area, western-central coastal zone of Bangladesh. To understand and discuss local situation, study area has been divided into different segments as A, B, C,

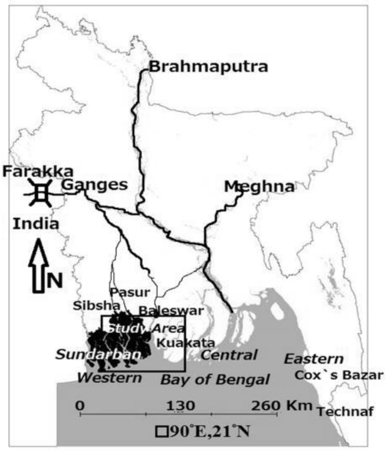

Fig.1 (a) Bangladesh map showing main rivers system.
□Wave hind cast data location.Ħ Barrage.

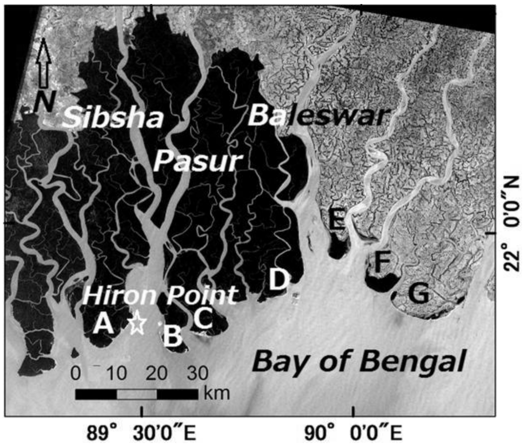

Fig.1 (b) Western coastal zone of Bangladesh and Segment A, B, C, D, F and G. Base image: Landsat 4, Band 1, 2 and 3, 1989/1/12.☆Tide station.

D, E, F and G. The dark portions in Fig.1 (b) represent the land covered with mangrove forest and bright portion denotes agricultural land or bare land without mangrove forest.

Soil characteristics of the western coastal zone are silty loams or alluvium (Islam, 2003). Two rivers named Sibsha and Pasur diverted from Ganges flow through this area and falling into Bay of Bengal. The area lies at 0.9 to 2.1 m above mean sea level (Iftekhar & Islam, 2004). Mangrove supports feeding and breeding grounds for fish and shrimps species, enriching the area in bio-diversity. Segments A, B, C and D are located in this region and covered with mangrove forest popularly known as Sundarban based on the name of Sundari trees.

The central zone receives a large volume of discharge from the Ganges-Bhrahmputra-Meghna (GBM) river system, and the land is formed from silty deposition (Allison et al., 2003). Because of the sediment supply and strong river current, the morphology of the zone is very dynamic and erosion and accretion rates in the area are very high. Segments E, F and G located at border of western-central region. Kuakata (G) is an attractive sandy beach located in this region and famous for tourism. The Baleswar River is falling into Bay of Bengal at western side of the segment G and the eastern side of the segment is dominated by the GBM system.

Eastern coastal zone are dominated by submerged sands and mudflats (Islam, 2001) and has a long sandy beach of 145 km extending from Cox's Bazar to Tecknaf. Except the Eastern zone, all parts of the coastal zones are plain land with extensive river networks and accreted land.

Table 1 Satellite data and tide level at the images acquisition date measured at Hiron point station.

Sl. No.	Satellite Name	Acquisition Date	Tide level (mm)
1	Landsat 4 TM	1989/1/12	-780
2	Landsat 5 TM	1993/12/17	-340
3	Landsat 5 TM	1995/11/21	N/A
4	Landsat 7 ETM+	1999/11/8	1100
5	Landsat 7 ETM+	2000/11/26	850
6	Landsat 7 ETM+	2001/11/29	1080
7	Landsat 7 ETM+	2002/12/18	530
8	Landsat 7 ETM+	2003/11/19	-240
9	Landsat 7 ETM+	2004/12/7	-570
10	Landsat 7 ETM+	2006/12/29	-1030
11	Landsat 7 ETM+	2007/11/30	620
12	Landsat 7 ETM+	2008/10/31	790
13	Landsat 7 ETM+	2009/12/21	-20
14	Landsat 7 ETM+	2010/12/24	530

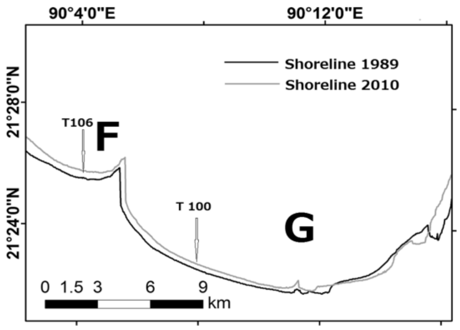

Fig.2 Shoreline positions of segment F and G in 1989 and 2010.

3. DATA PROCESSING

The mid and near infrared spectral bands of satellite images have strong reflectance by soil and vegetation and absorbance by water, which make possible to separate the land from water and can be used to detect the shoreline position (Kuleli, 2010). Alesheikh, et al. (2007) showed that the mid infrared band 5 of Landsat TM and ETM+ is suitable for extracting the land-water interface. In this study, 14 images from the Landsat USGS archive (http://glovis.usgs.gov/) have been analyzed to detect the variation of shoreline positions as shown in Table 1. Most of the images have been acquired in dry season, November and December. Hourly tide level data from 1989-2010 has been collected from BIWTA (Bangladesh Inland Water Transport Authority) for nearby tide station Hiron

Point. Tide levels at the image acquisition times are shown in Table 1 and it shows that the tide level difference is approximately 2 m.

In the first step, geo-registration was done to adjust the geographic position of the images. Then edge detection was applied to the distribution of pixels intensities of band 5 to locate the shoreline position. At each segment, shorelines have been detected in the south face of the land at a spacing of 30 m alongshore from west to east. Finally to refine the result of detected shoreline position, manual inspection has been carried out to clear the erroneous data.

Figure 2 shows the detected shorelines position of segment F and G in the observation year 1989 and 2010. The diagram shows that at most of the places, the shoreline position retreated landward except at a small portion of eastern part of 90°12`E where the shoreline moved seaward.

Shoreline changes have been detected along transection line in N-S direction. Rate of shoreline variation is estimated by linear regression of shoreline positions at every transect. Figure 3 shows an example of shoreline position variation at

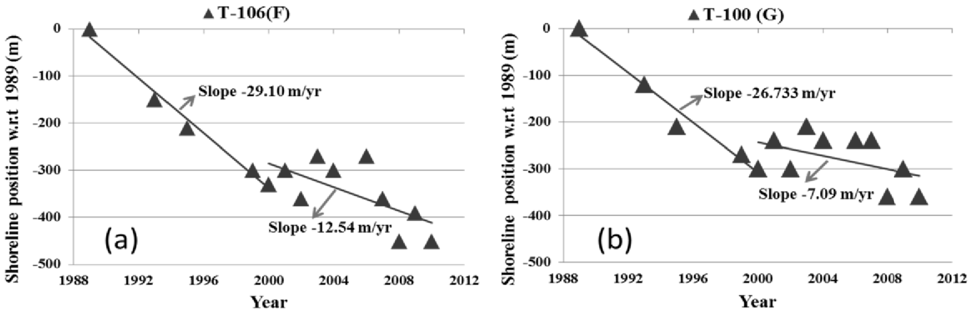

Fig.3 Variation of shoreline position at (a) T-106, Segment F, and (b) T-100, segment G. Negative position means landwards position with respect to position of 1989.

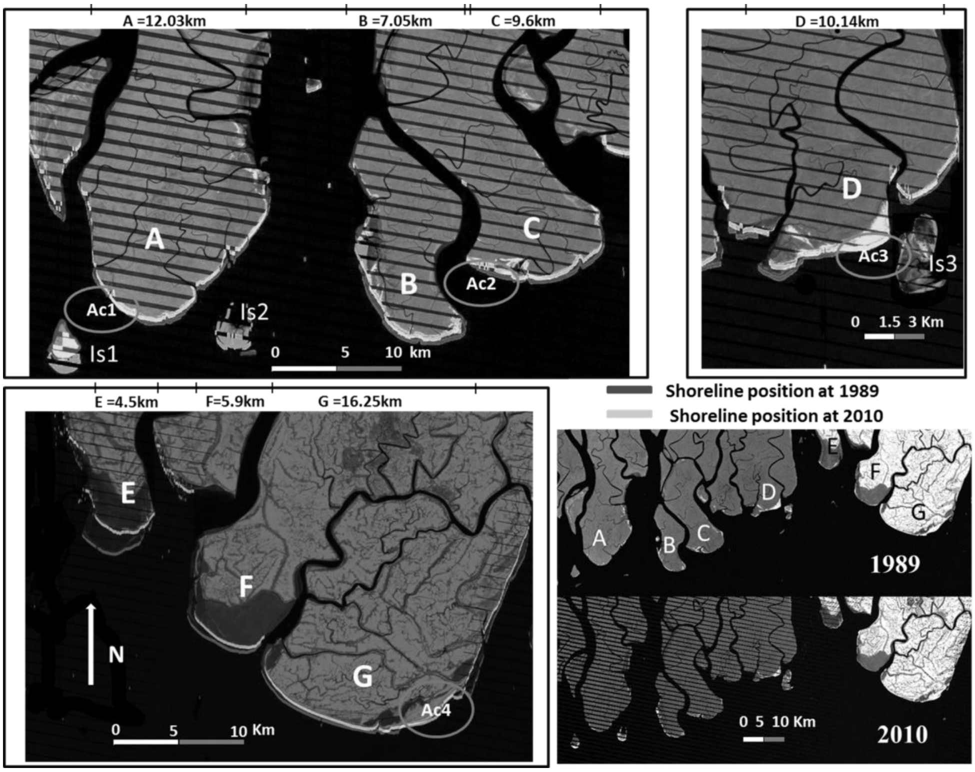

Fig.4 Shoreline positions of 1989 and 2010. Band 5 of 2010/12/24 acquisition is displayed as base image. Over view of 1989 and 2010 images are shown in bottom right panel. Oblique strips of the upper images are due to the Landsat 7 malfunction.

two locations of segment F and G with the rate of changes. Vertical axis shows relative position of the shoreline with respect to the shoreline position of 1989. Figure 3 shows that the erosion rate has been reduced after 2000 compared to the previous years.

4. RESULTS

4.1 Shoreline Changes

Figure 4 shows shoreline positions for 1989 and 2010 of different segments and band 5 overview images in the right bottom panel.

Shoreline of segment A, B, C and D, covered with mangrove, are affected by erosion that pushed the shoreline back from its early position. The shoreline of zones Ac1, Ac2 and Ac3 are experiencing no changes of shoreline during the period of 1989-2010. One island Is2 appears in eastern front of segment A in 2010. Land areas of island Is1 in the western front side of segment A and island Is3 at the eastern front of segment D increased by approximately 30%.

Shorelines of segment E and F, having small mangrove portion in the tip, are continuously retreating landward. Segment E is experiencing largest changes of its shoreline positions compared to other segments. Segment G, sandy beach, is also losing land except the portion Ac4 at eastern side which gained land.

From Fig.4, it can concluded that most of the shoreline positions in 1989 were more seaward compared to those of in 2010.

4.2 Shoreline Change Rate

Figure 5 shows the distribution of the shoreline change rate for two periods: 1989-2000 and 2000-2010. Among the two periods, former period was experiencing higher change rate of shoreline positions. It is approximately three times larger than the latter period. Average rate of changes for two decade has been tabulated in the bottom row of the Fig.5.

Most of the area was eroded, except some portions (Ac1, Ac2, Ac3, and Ac4) that are experiencing accretion in the recent decade 2000-2010. The average rate of change over the whole period of segment covered with mangrove (A, B, C, D) is -18 m/yr whereas the flat sandy beach (G) is -9 m/yr. This result is contradicting with the general consensus that mangrove forest is stabilizing the beach and protecting shore erosion. Maximum average change rate -72 m/yr is observed at segment E where the tip of the land is also covered with mangrove. Segments E and F are continuously losing land in both decades and no accumulations have been observed in these two segments.

5. DISCUSSION

It has been observed from Fig.5 the mangrove portions A, B, C, and D are facing more changes compared to sandy open beach, segment G. Two rivers Sibsha and Pasur flow through this area and falling into Bay of Bengal, which receive water

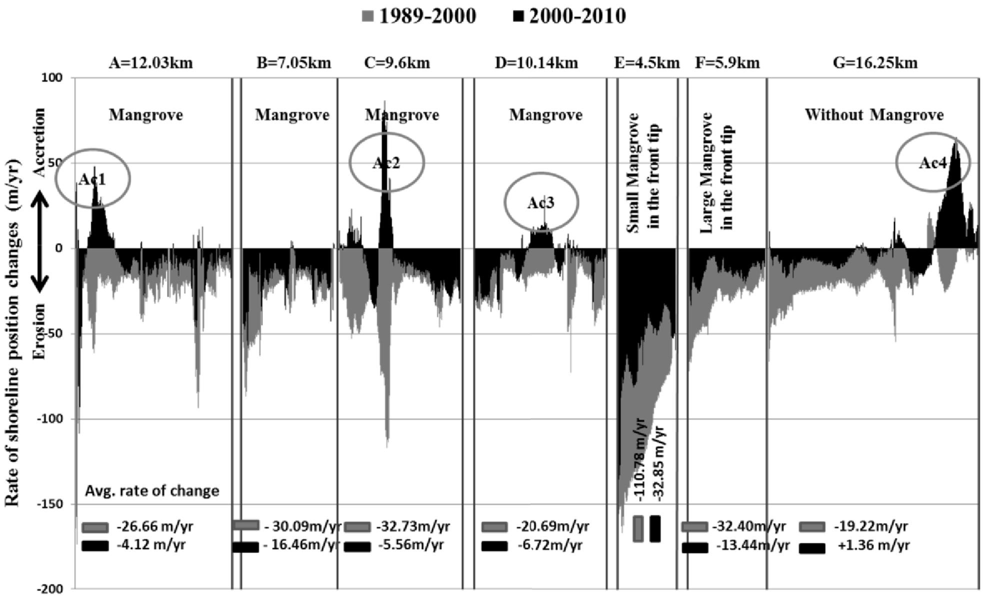

Fig.5 Distribution of shoreline change rates of the two periods: 1989-2000 and 2000-2010. Negative rate corresponds to erosion. The average rate of changes of the segments is shown in the bottom row.

from Ganges. The reduction of Ganges water after the construction of Farakka Barrage in India at 1975 in the upstream, the fresh water discharge through Pasur and Sibsha has been decreased and at the same time salinity increased dramatically at western coastal zones (Islam and Gnauck, 2008). This may impact coastal ecosystems and reduction of sediment supply by the rivers. The possible effects of increased salinity on the ecosystem of the Sundarban are the dying of tops of Sundari trees, retrogression of forest types, slow forest growth, and reduced productivity of forest sites (MPO 1986). These may lead to coastal retreat and weakening of mangrove forest.

Wave hind cast data from 1989-2010 have been analyzed to find out the effect of wave action over erosion and accretion along the coast. Hind cast wave data, significant wave height, wave period, and wave direction have been taken from the ECMWF ERA-Interim archive (http://data-portal.ecmwf.int /data/d/interim_daily/). The ERA wave dataset provides data for 00h, 06h, 12h and 18h UTC each day on a 1.5° by 1.5° longitude -latitude grid, covering the whole globe.

Figure 6 shows significant wave height and wave direction for the period 1989-2010 at a grid 90° E, 21° N, which is the closest data to segment E, F and G (See Fig.1(a)). The 90 degree wave indicates the waves coming from the eastern and 180 degree from the southern. Incident waves from the south-south-west are dominating along the coast. The prevailing waves may yield sediment transport from west to east which supports the fact that shoreline change rate of the west side of every segment is facing larger changes compared to the east side. Further, the accumulation zones Ac1 and Ac2 are in the western face of the segments A and C, and are in the down-wave of the prevailing waves sheltered behind island Is1 and segment B, respectively.

The comparison of wave height for the two decade didn't show any significant difference. So it cannot be said that only wave action is responsible for higher rate of erosion in the period 1989-2000.

6. CONCLUSION

Satellite remote sensing data have been analyzed to identify the morphological changes of western -central coastal zone of Bangladesh. The regional overview of shoreline changes rate analysis over the past decade shows that erosion was the dominant in the whole area. In recent decade, at some portion of shorelines, accretion has been observed. Shoreline change rate at mangrove portion (Segment A, B, C and D) was larger compared to sandy open beach

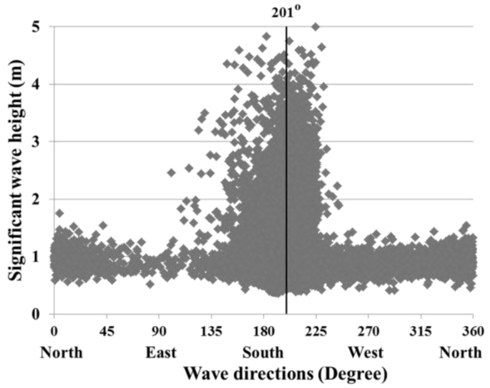

Fig.6 Wave height and wave direction at (90° E, 21° N). Solid line represents center of gravity of the distribution.

Kuakata (Segment G). Also shoreline change rate of every segment is higher in the western face rather than eastern faces. The roles of river discharge and south-south-west waves have been discussed to infer the mechanism of shoreline dynamics of the area.

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