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Mapping of Coastal Morphological Changes of Bangladesh Using RS, GIS and GNSS Technology

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ABSTRACT

Conventional methods for collecting information about coastal area including all off-shore Islands (OSI) of The Bay of Bengal (BoB), Bangladesh are relatively costly and time consuming. Remote Sensing (RS) observation with its unique capability to provide cost-effective support in compiling the latest information about the environment of coastal area, while Global Navigation Satellite System (GNSS) use to collect ground control point from field to increase the accuracy of geo-referenced RS data and GIS facilitates uses for multidisciplinary analysis and decision support. Integrated analysis comes under the economic jurisdiction of Bangladesh for exploration, exploitation, conservation and management of its marine resources.

Landsat MSS (80 m) data of 1973, Landsat TM (30 m) data of 1989 & 2010 and DMC (22 m) data of 2012 were used to generate digital data base of different time period, analysis of plain & tidal land, erosion & accretion, water channel behavior and finally produce digital map of coastal area.

For land water layer generation, near-infrared band of (0.76 to 0.90 µm) has been used to develop an algorithm. In this study DN values of water in band 4 of Landsat-TM have been collected carefully from the histogram of the selected images and applied the collected values in the developed algorithm. For generation of erosion and accretion map, river morphological and tidal flat maps of the study area, raster base GIS as well as ArcGIS based analysis have been applied. Finally the study reveals that 87255 ha area have been reclaimed (land accretion) in study area during 1973-2012.

INTRODUCTION

The Bay of Bengal (BoB), the marine area of Bangladesh, is characterized by a semi-enclosed tropical basin. The coastline of the country comprises about 710 km extending from the tip of Teknaf in the south-east to the south-west coast of Satkhira. An area about 166000 km2 along more than hundreds of off-shore Islands (OSI) of BoB, Bangladesh have been exists. Natural resources in these islands have been used for multiple purposes and have strongly influenced socio-economic development. The OSI in the BoB are known as chars, which means “children of the land”, created by silt which floods down the rivers from the Himalayas to the BoB, the chars build up over time and also eroded according to the rivers flow. Most of the erosion was caused by migration of channels and it might be considered as compensatory because erosion and accretion almost simultaneously occur. Flat with limited forestation and less than one meter above sea level, the chars are extremely vulnerable to cyclones, storms and tidal surges.

Most of OSI have an earth embankment to help combat ordinary tidal surges, and the better off build their houses on a raised earth platform. Life is precarious-but river erosion and population pressure elsewhere has brought thousands of poor people to the chars to seek new livelihoods. Poor people are more likely to live in marginal, low-lying areas most prone to flooding or even on the embankment itself. They are least likely to live near a cyclone shelter or a safe path, and most reluctant to leave their homes and possessions.

LANDSAT thematic mapper (TM) imagery have been extensively used for coastal zone appraisals, agricultural evaluation, water resource estimates, forest management inventories, geological surveys, and a host of other applications.

To overcome the study the following activities have been taken (i) to generate coastal morphological digital data sets for the year 1973, 1989 and 2010, (ii) to study coastal morphological changes over 37 years (1973-2010), (iii) to study the behavior of the process (Erosion and Accretion) of some selected OSI & River/Channel of the study area for the above period and generate maps under different time period.

Specifically, the generated digital data base of this study will be helpful for better planning, policy formulation, and decision-making in national development.

STUDY AREA

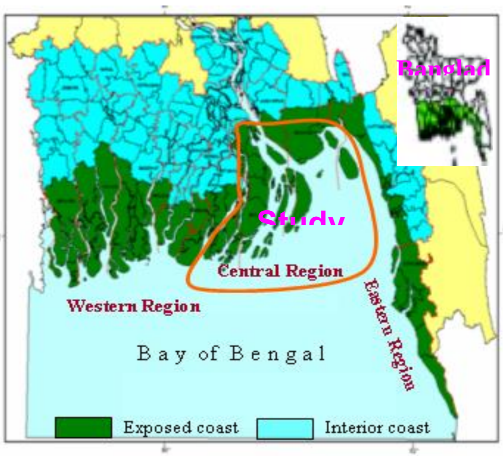

Figure 1: Study area, the central coast of Bangladesh

Our coast is divided into three regions western, central and eastern region according to characteristics. Heavy sediment load and one of the most complex tropical estuarine ecosystems of the world characterize the central coast. The coastline is most irregular, and consists of a series of islands, where the rivers are continuously changing their courses; the funnel shaped apex of the Bay of Bengal is relatively shallow, surrounded by numerous islands and estuarine channels. The area is dominated by semi-diurnal tidal currents, the maximum tidal range of 5 meters occurs in the upper estuary which gradually decreases southeastwards. Since the last two hundred years the estuary went through intensive morphological changes with migration and the growth of islands in the southern direction. This region is also subject to the impact of cyclone and storm surges causing an innumerable loss of life and property.

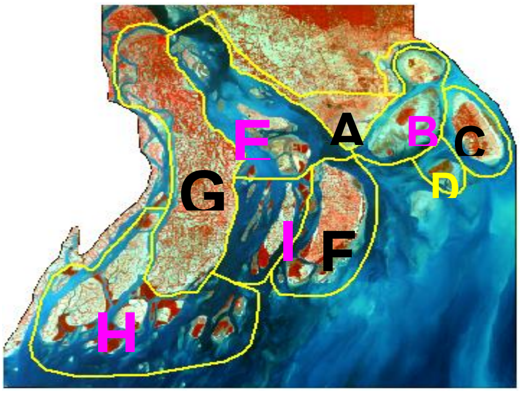

Figure 2: Nine sub-division of central coast

The study area (central region of coast) shows in figure1. It has also divided into eight sub-divisions due to different characteristics of islands. Figure 2 shows the study area in nine (A to I) different sub groups.

DATA AND SOFTWARE USED

Remote sensing data and Tide data

Sensor	Year	Date	Time	Frame	T. Gauge Location	Tidal Condition* Time	Tidal Condition* Ht (m)	Remarks
MSS	1973	02021973	0942	147/44				Tidal data not available
		02021973	0941	147/45				
		27011973	0941	146/44				
		27011973	0940	146/45				
TM	1989	28011989	0942	137/44	Char Ramdaspur	0416	0.72	For avoiding low tide data, a large number of data sets have been downloaded /collected for selection of high tide data
						0842	2.09	
						1732	0..51	
						2223	1.98	
		12011989	0941	137/45	Char Changa Shabagpur R	0306	1.00	
						0928	2.09	
						1533	0..90	
						2224	2.55	
					Galachipa (Lohalia R)	0251	0.81	
						0817	1.85	
						1529	0.53	
						2203	2.01	
		05011989	0942	136/44	Sandwip (SatalKhal)	0510	1.43	
		05011989	0941	136/45		1048	4.10	
						1717	1..32	
						2414	4.80	
	2010	30012010	0940	137/44	Char Ramdaspur	0646	0.87	
						1040	1.58	
						1914	0.73	
						2411	1.19	
		30012010	0939	137/45	Char Changa Shabagpur R	0016	2.73	
						0701	0.66	
						1244	2.26	
						1901	0.69	
					Galachipa (Lohalia R)	0558	0.63	
						1107	1.91	
						1748	0.36	
						2343	2.36	
		23012010	0942	136/44	Sandwip (SatalKhal)	0416	1.52	
		23012010	0941	136/45		0956	3.93	
		20032010	10:35	0213		1639	1..38	
						2229	4.65	

* Estimated Tidal Data

Table 1: Remote sensing and tide data sets

Selection of data is very important for delineation of coast line due to tidal effect. For avoiding low tide data a large number of data sets have been collected for selection of high tide data. Because our study have been conducted on high tide data.

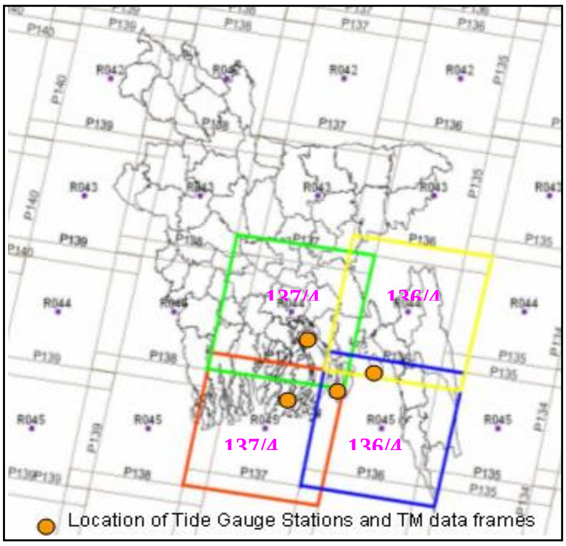

Figure 3: Location of tide gauge stations and TM frames of study

Landsat data

Landsat MSS data of 80 meter resolution of 1973, Landsat TM data of 30 meter resolution of 1989 and 2010 have been used in the study. Data sets for one season has four frames. The TM frames are 137/44, 137/45, 136/44 and 136/45. Table 1 show the Landsat MSS/TM frame numbers and dates of study data and figure 3 shows the location of four frames of 1973, 1989 and 2010 of study area. At least twelve frames need to cover the whole Bangladesh. All the data are IMG format. ERDAS and ArcGIS for image processing and analysis

Tide data

Most of the Landsat data during study period were found low and medium tide condition. Only two data received during study period almost in high tide condition in one station out of four stations.

APPROACH

The ultimate objective of this study is to generate the coastal morphological data sets. In the context of Bangladesh, generation of coastal morphological data is difficult due to tidal effect as well as frequent erosion and accretion process due to high current from upstream and tidal effect. Section 4.1 describes these difficulties and section 4.2 describes the approach undertaken in this study to overcome the problems.

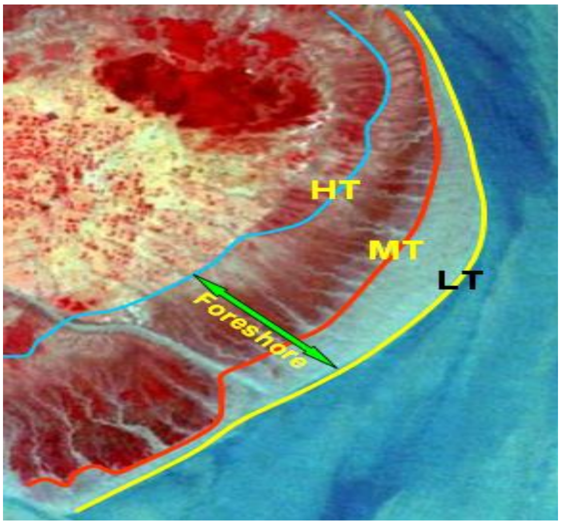

Figure 4: Foreshore Intersection delineate from spectral signature

Nature of problems

Conventionally a coastline is properly a line on a map indicating the disposition of a coast. In other word a coastline is the line of contact between land and a sea. It is easy to define but difficult to say which one is the real coastline (HT, MT and LT line), since the water level is always changing due to tidal process. Figure 4 shows the high tide (HT), medium tide (MT) and low tide (LT) condition of a coast line. To capture the contact line, people use the *tide-coordinated* coastline, which is the coastline extracted from a specific tide water level. This example is for a stable coastal island or main land. But most of islands have erosion and accretion and most of the Landsat data during study period were found low and medium tide condition already mentioned in chapter 4. 1.2.

Delineation of coast line: Solution from multi–temporal images

As it is difficult to separate the tidal flat condition of coastal island, multi-temporal remote sensing (high and moderate resolution) data have been used to overcome the tidal flat delineation problem.

Spectral signature on remotely sensed data provides information on different parts of the tidal flat i.e. foreshore intersection. Figure 4 shows the foreshore intersection of coastal island. Low tide

(LT) water line is not visible on all the images. Visibility of LT water line depends on the tide

condition at the time and date of acquisition. Legally, a low tide water line is selected as coastline. Medium tide (MT) water line is also not visible on all the images. High tide (HT) water line is visible on all the images irrespective of the time and date of acquisition. So, the HT water line is selected as coastline in this study.

PROCEDURE OF DATA GENERATION

Generation of coastal morphological data sets involves remote sensing (RS) data collection, pre-processing, data/layer generation, data analysis, finally extraction of coastal morphological data sets i.e. output of study. Procedures are shown in figure 00.

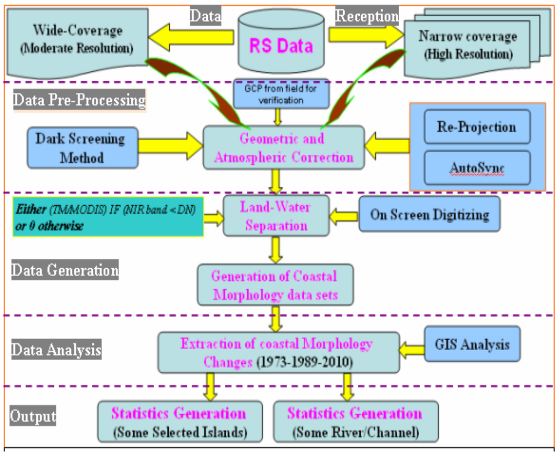

Figure 5: Procedure of data pre-processing, analysis and

Generation of Coastal Morphological data sets

Coastal morphological changes of Bangladesh have been generated from Landsat MSS/TM data of 1973, 1989 and 2010. To generate Landsat MSS/TM images from 1973-2010, some pre-processing steps are involved those are describe bellow:

Reception Landsat-MSS/TM data

In Bangladesh, there is no ground station to receive LANDSAT data. For research work we have downloaded Landsat-MSS/TM data from the website http://glovis.usgs.gov during the dry period of 1973, 1989 and 2010. Total numbers of downloaded data sets are shown in table-1. The data we have downloaded are frame wise. Figure-6 shows the sample of down loaded frames of one season including atmospheric corrected and geo-referenced.

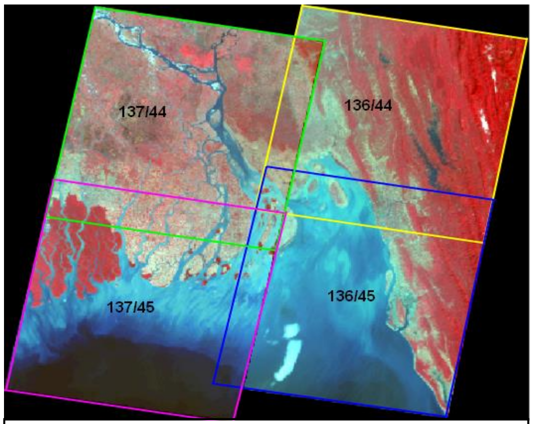

***Figure 6**: Landsat TM geo-referenced images of one season.*

Pre-processing of Landsat-MSS/TM data

a) Atmospheric correction

Many atmospheric correction methods have been proposed for use with multi-spectral satellite imagery. The dark-object atmospheric correction method, (Hadjimitsis et al., 2010), was probably the most widely used approach for atmospherically correcting different remotely sensed imagery. The scheme is based on identification of dark cluster of pixels of water having near-zero percent reflectance which is considered to be free from intervention of the parameters like turbidity and chlorophyll concentration. To fulfill the above mentioned requirement, the clusters of pixels were selected in the deeper part of the Bay of Bengal, where the intervention of the above mentioned parameters was minimum. A seed cluster of water having the lowest data values was selected from a number of 12 TM images. Based on the mean value of the seed cluster, the images used in the study were corrected. Figure 6 shows the atmospheric corrected images.

b) Geo-referencing

Many geo-referencing methods have been used to geo-reference multi-spectral satellite imagery. One is the method is collection of Ground Control Point (GCP) from study area using Global Positioning System (GPS)/Differential GPS. In this method GCP collected from study area and transformed this coordinate to input image (same area images) by using geometric model of ERDAS imagine software. At first our frames/images of 2010 were geometrically corrected and were projected to

Bangladesh Transverse Mercator (BTM) system by selecting 10 GCPs per image. Second order polynomial and then re-sampled with bilinear algorithm have been used during the re-sampling method. All the ten selected GCP's were easily identifiable and permanent in nature for measuring accurate results. A Root Mean Square (RMS) error of 0.30 (less than one pixel, 30m) was accepted for the correction process. The parameters of the BTM projection system are shown in table 4. The images/frames of other two seasons (1989 and 1973) were corrected from the geo-referenced images of 2010 as referenced images. Figure 6 shows the geo- referenced images of one season.

Land-water Classification based on Algorithm

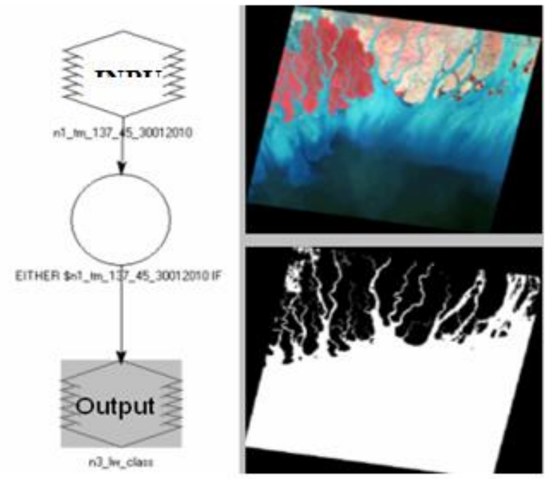

Figure 7: The land-water classification of frame 137/45 of 2010

A simple algorithm was used to land-water classification. For land and water separation band 4 (0.76 to 0.90 µm) NIR have been used because band 4 of Landat-TM is suitable for land and water separation. In this case DN values of water have been collected carefully from the histogram of the selected image and found DN value 40. This value applied in the equation 1. An algorithm also needs to use for mask the cloud cover areas. If the clouds are not masked in the images, it will reflect the wrong value in processing. Luckily I have found the cloud free images, so no need to mask out the cloud. Figure 7 shows the land-water classification of frame 137/45 of 2010. Similarly all the images have been classified in similar way.

Either (Landsat-5 TM) IF (Band 4<41) or 0 otherwise ---- (1)

Generation of Coastal Morphology data sets

Costal morphological data sets of 1973, 1989 and 2010 have been generated from Landsat MSS/TM mages using land-water classification. Tidal flat areas have been masked carefully by using spectral signature of TM band4. Figure 8 shows the coastal morphological digital data sets of 1973, 1989 and 2010 respectively at high tide condition.

Field data collection, verification and incorporation

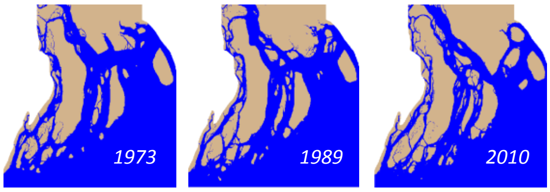

Figure 8: Coastal morphological digital data sets of 1973,

Field visit was conducted in three times during study period. Firstly ground control point (GCP) was collected using GPS for geo-referencing of satellite images. Secondly, generated geo-referenced data was verified by field using GPS at laboratory. Lastly, field survey has been conducted to verify the land-water (LW) classified images of study period 1973, 1989 and 2010. During field visit information aimed to collect the accuracy of LW classified images and also migration of islands. Classified images as well as raw images along with GPS and digital camera have been carried during field visit. Collection of tidal information was also very important. After the fieldwork, field data have been incorporated into LW classified time series images and for final analysis these were brought into raster based modeler as well as ArcGIS environments.

Generation of coastal morphological changes

For generation of coastal morphological changes during 1973 – 2010, the base layers of 1973, 1989 and 2010 generated by algorithm (equation 1) have been used as an input of raster based GIS as well as ArcGIS environments. Figure 9 shows the morphological changes of central coast of Bangladesh.

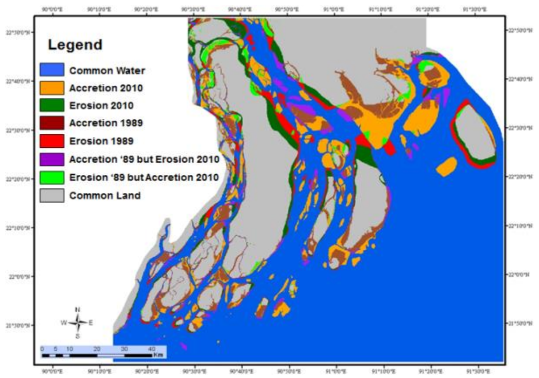

Figure 9: Morphological changes of central coast of

RESULT AND DISCUSSIONS

Visual Interpretation of Raw Images.

The objective of the visual interpretation is to identify the tone, texture, shape and color of the images in different time period that will helpful for GIS analysis. Figure 6 shows the mosaicked RGB (4, 3, 2) of landsat TM image of 2010. In this image the red color shows settlement and mangrove, blue color shows the water area and magenta color shows bare land. Mosaicked images of 1973 and 1989 also similar tone and texture were observed. But settlement areas have been found increasing tendency in 1989 in compare to 1973 and dense settlement shows in 2010 compare to 1973 & 1989. Some of the islands found different shapes in different seasons due to erosion or accretion.

GIS analysis

GIS analysis shows the morphological changes of central coast during past 37 years (1973-2010) in figure 9. Table 2 shows the statistics of some important islands.

It is clearly seen from the bar diagram of figure 10 that in site 'A' of study area shows more accretion tendency during 1973 to 1989 and 1989 to 2010. But accretion is more during 1989 – 2010 compare to 1973-1989. This may happen due to shifting of estuary towards south-west.

Table 2: Statistics of study area

Name of Island	Period	Accretion Area (h)	Erosion Area (h)	Loss	Gain	Loss/ Gain	Reclaim 1973-2010
Main land (A)	1973-1989	18124.4	3059.8		15064	30390.8	87254.6 (hector)
	1989-2010	20742.7	5416.5		15326		
Urir Char (B)	1973-1989	4684.5	555.1		4129	18472.6	
Maulavir Char	1989-2010	14849.6	506.4		14343		
Sandwip (C)	1973-1989	461.8	5023	4561.2		-7167.7	
	1989-2010	915.5	3522.1	2606.5			
(D)	1973-1989					3358.7 Newly generated	
	1989-2010	3358.7			3358		
Hatia (F)	1973-1989	6948.6	3630.2		3318	2081.6	
	1989-2010	4602.8	5839.6	1236.8			
Monpura (I)	1973-1989	2756.2	1143	342.6		1270.6	
	1989-2010	1162.9	1505.6		1613		
Bhola (G)	1973-1989	5352.2	8959.1	3606.8		-10285	
	1989-2010	6951.3	13629.8	6678.4			
(H)	1973-1989	18799.9	2636.7		16163	25387.1	
	1989-2010	12746.7	3522.6		9224		

Analysis shows the morphological changes of Site "B" (Urir char) during 37 years (1973-2010) in figure 9. It is clearly seen from the figure that Urir Char was very small char in 1973. But in 2010 it has been expanded with big shape about 7 times larger than 1973. Accretion is more during the period 1989-2010 compare to 1973-1989. Erosion shows less compare to accretion both the time period. There are many reasons (i) less water flow due to shrinking of upstream river and (ii) change of water flow of Meghna River to the south-west direction. Migrations of island

activities both the time period are also noticeable. Bar diagram of figure 10 show the difference at a glance.

In site "C" (Sandwip Island) has been eroded in three sides except right side during 1973 to 1989. But during 1989 to 2010 it was eroded in bottom and left side. Top of the image have been acceded during 1989 to 2010 those was eroded during 1973-2010. The right sides of the island have been accreted both the period. It also clearly seen from the figure 0 that during 1973 to 1989 the top part of the Island was eroded but it was accreted during 1989 to 2010. Bar diagram of figure 10 shows that the area of site 'C' is gradually decreasing during the study period 1973 to 2010. But decreasing tendency during 1973 – 1989 was more compare to 1989 – 2010. Because erosion was more during 1973-1989 compare to 1989-2010

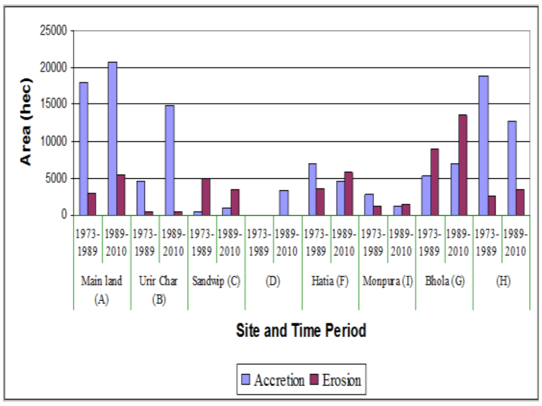

Figure 10: Bar diagram of different site if study area (A-I)

Site "D" has found newly accreted island during 1989 to 2010. Morphological changes of site "F" (Hatia Island) during 37 years (1973-2010) in figure 9. It is clearly seen from the figure that Hatia Island has been eroded in Top both the time periods 1973 to 1989 and 1989 to 2010. But during 1973 to 1989 it was eroded in left side also but not severe like top of the image. The right and bottom of the island have been accreted both the periods due to mangrove plantation. But mangrove plantation activities were more during 1973-1989 compare to 1989-2010. There are many hydro-dynamics factors for erosion and accretion but erosion is more prominent in upper part both the time periods 1973 to 1989 and 1989 to 2010 may high speed of water flow from big three rivers Ganges-Meghna-Bramaputra (GMB). Accretion activities have been developed in lower portion due to mangrove plantation. Heavy sediment load coming from GMB and high tidal flow resist the sediment to go directly to the Bay of Bengal may another factor for accretion. The study reveals that about 3320 ha area have been reclaimed during 1973 to 1989 and about 1236 ha area have been losses during 1989 to 2010. The twin actions of erosion and accretion in the Hatia Island have been resulted that about 2080 ha have been reclaimed during 37 years (1973-2010). Bar diagram of figure 10 site 'F' shows that the area of Hatia Island is gradually increasing during 1973-1989 but it is decreasing during the period 1989 to 2010.

Analysis shows the morphological changes of Site 'I' (Manpura Island) in figure 9. It is clearly seen from Top of the figure that Manpura Island has been accreted both the time periods 1973 to 1989 and 1989 to 2010. But during 1989 to 2010 it was eroded more compare to 1973 to 1989. Left half also shows similar erosion pattern. There were prominent navigation channel in 1973 that was acceded in 1989 and 2010. But accretion is more in 1989 compare to 2010. The bottom of the island has been accreted both the periods due to mangrove plantation. But mangrove plantation activities were more during 1973-1989 compare to 1989-2010. Bar diagram of Site 'I' (figure 10) shows that the area of Monpura Island is increasing during 1973-1989 but it is decreasing during the period 1989 to 2010. Erosion is more prominent in upper and upper left part both the time periods 1973 to 1989 and 1989 to 2010 may high speed of water flow from GMB. Accretion activities have been developed in lower portion due to mangrove plantation. Heavy sediment load coming from GMB and high tidal flow resist the sediment to go directly to the Bay of Bengal may one of the main factor to fill up the water channel of image 1973 in images of 1989 and 2010. The study reveals that about 1613 ha area has been reclaimed during 37 years (1973-2010).

Analysis shows the morphological changes of site 'G' (Bhola Island) in figure 9. It is clearly seen from the figure that Bhola Island has been eroded on right side in both the time periods 1973 to 1989 and 1989 to 2010. But erosion is more during 1973 to 1989 compare to 1989 to 2010. Accretions have been found very less both the periods. Erosion is more prominent in upper right part both the time periods 1973 to 1989 and 1989 to 2010 may high speed of water flow from GMB. The study reveals that about 10285 ha was eroded during 37 years and has been disappeared in to the sea. Bar diagram of site 'G' (figure 10) shows that the area of Bhola Island is gradually decreasing during 1973-1989 and also 1989 to 2010.

Analysis shows the morphological changes of study area 'H'. It is clearly seen from the figure 09 that study area 'H' has been accreted in both the time periods 1973 to 1989 and 1989 to 2010. But during 1973 to 1989 it was accreted more compare to 1989 to 2010. Mangrove plantation activities observed more during 1973-1989 compare to 1989-2010. Accretion activities have been developed due to mangrove plantation. Heavy sediment load coming from GMB and high tidal flow resist the sediment to go directly to the Bay of Bengal may one of the main factor to fill up the water channel of image 1973 in images of 1989 and 2010. Bar diagram of figure 10 of site 'H' shows that the area is gradually increasing during 1973-2010 but it is increasing during the period 1973 to 1989 is more compare to 1989 to 2010.

CONCLUSIONS AND RECOMENDATIONS

An intensive morphological change of the Meghna estuary was occurred through migration of channels and formation of new islands. Accretion is dominating phenomenon compare to erosion which may be due to heavy sediment load coming from GMB. Raising mangrove plantation is an important reason for land stability. Hydro dynamic interaction of river and ocean water may another factor for morphological changes. Study reveals that about 87254 ha area (table 2) of land has been reclaimed during the last 37 years (1973-2010). For future analysis hydro-dynamic data like speed of water flow, depth of water, etc will be added to improve the accuracy of our study. Study was carried out using Landsat MSS/TM images of various dates.

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