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RESEARCH PAPER

A Geomatics Approach to Evaluate the Land Erosion and Accretion in Coastal Bangladesh: A Case Study at Kalapara Upazila of Patuakhali District

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ABSTRACT

The main objective of the present study is to determine the erosion-accretion rate in the coastal Bangladesh. Multispectral remote sensing sources from Landsat MSS, Landsat TM, Landsat ETM and Landsat OLI, were used to extract the land area. Both Remote Sensing and Geographic Information system were used to extract the land area from satellite imageries to develop a Geomatics approach. The study was conducted in ten years interval from 1978 to 2018. It reveals that accretion rate is about 21.76 hectares/year and erosion in about 32.31 hectares /year which indicates the dynamics nature of coastal area. According to the analysis, about 1156.59 hectares of land was lost between the years 1978 to 2008 but there is an indication of accretion in next ten years as the net gain of land was 312.53 hectares from 2008 to 2018.

Key words: Coastal Dynamics, Erosion-Accretion, Satellite Imageries and Geomatics

Introduction

Coast is the interface between land and water (Rasheed 2008). It is one of the dynamic features in the coastal world (Mahapatra et al. 2014). Changes in the coast are influenced by both natural and anthropogenic factors (Chen et al. 2005). In coastal zone management, coastal erosion monitoring is considered as important subject matters (Ari et al. 2006). Moreover, International Geographic Data Committee declared coastlines as the most important environmental heritages on the earth's surface (Kurt et al. 2010). Understanding the coastline's dynamics is important to predict its future development (Hoffmann and Lampe 2007). Therefore, coastal zone monitoring is very convenient process for sustainable coastal management and environmental protection (Alesheikh et al. 2007).

The coastlines in Bangladesh are most dynamic in nature due to continuous erosion and accretion processes. The coastal land zone expands over 32% of the country and includes 147 Upazilas under 19 districts with 26% population of entire country. It covers an area of 47,150 sq. km accommodating a population of 38.5 million (BBS 2011) resulting in an average population density of 817 persons per sq. km. Bangladesh is highly vulnerable to sea level rise, as it is a densely populated coastal country of smooth relief comprising of broad and narrow ridges and depressions (Brammer 2014). World Bank (2000) indicated in a report 10 cm, 25 cm and 1 m rise in sea level by 2020, 2050 and 2100; affecting 2%, 4% and 17.5% of total land mass respectively (Milliman et al. 1989; cited in Frihy 2003). In the context of Bangladesh, estimates show that a 40-45 cm rise of sea level along the Bay of Bengal coast would submerge about 11 percent of the country's area, and will displace about five percent of the national population (Rasheed 2008). Remote sensing data integrated with Geographic Information System (GIS) technique provide a geomatics approach for identifying, monitoring, and mapping coastal features, evaluating temporal changes, and commenting on their environmental importance (Bhaskaran et al. 2010, Kennedy et al. 2009, Maiti and Bhattacharya, 2009).

The Kalapara Upazila has got economic significance as Kuakata Sea Beach and Paiyra Seaport are situated in this part of Bangladesh. Like many other coastal area of the world the Kalapara Upazila also face relentless pressures from urban expansion, recreational development and sea level rise due to climatic change. It has both eco-environmental and socio-economic importance and demands very intensive study to understand the natural functions and human intervention that affects coastal management and environmental conservation.

Therefore, this paper aims at analyzing the erosion and accretion scenario in Kalapara Upazila by using Geomatics technique and also determines the rates of erosion and accretion on temporal basis. There are lots of studies regarding coastal erosion and accretion mostly at the south eastern part of coastal region of Bangladesh. But there are few studies regarding middle part of Bangladesh coast. In this current study, remote sensing imageries have been used as a source of information and geospatial techniques have been used to assess the dynamics of coast by determining the rates of erosion and accretion processes.

Materials and Methods

Study area

Kalapara Upazila is the southern upazila under Patuakhali District of Bangladesh. Geologically this area is a part of Ganges Tidal Floodplain area (Rasheed 2008). It is bounded by Amtali Upazila of Barguna District on the north and west, the Bay of Bengal on south, Rabnabad Channel and Galachipa Upazila on the east. At present there are 9 (nine) Unions. The study area for this analysis is confined mainly in the southern part of the upazila that consists of 06 (six) union - Nilganj, Mithaganj, Lalua, Khaprabhanga, Latachapli (Kuakata) and Dhulasar. The area extend from 21°48'0"N to 21°59'30"N latitudes and 90°5'0"E to 90°18'15"E longitudes where Figure 1 shows the location of study area.

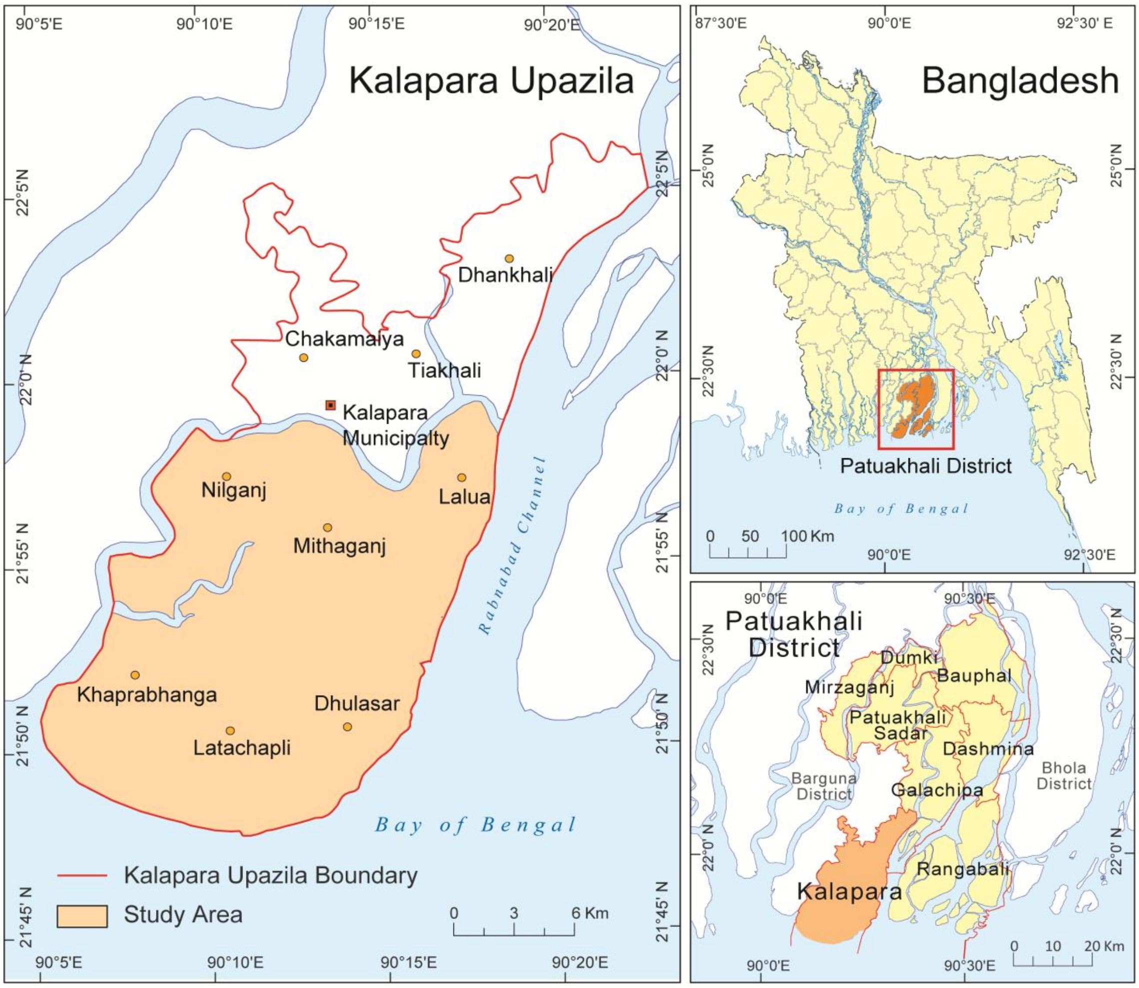

Figure 1: Location of the study area- Kalapara Upazila

Satellite Data Collection

In this study, remotely sensed data have been used to calculate the erosion and accretion along the part of Kalapara upazila. Landsat MSS (Multispectral Scanner System), Landsat TM (Thematic Mapper) and Landsat OLI (Operational Land Imager) images were downloaded from USGS Glovis and Earth Explorer website with multi dated. In addition, the images were selected as less than 5% cloud cover and good visibility of scene with L1 Tiff format with respectively year of 1978, 1988, 1998, 2008 and 2018.

Dry season (December to April) images were selected for the analysis for better visibility of shoreline and avoiding seasonal effect. The spectral information for Landsat-1 MSS and Landsat-4/5 TM sensor is 8-bit Digital Number (DN) value (Markham et al. 2006) and Landsat-8 OLI is 16 bit DN with 12-bit radiometric resolution (Roy and Mahmood 2016) in the L1 Tiff products. The downloaded images were low tidal period for its accessibility for mapping shoreline (Nayak 2002). More detail of images data area presented in Table 1.

Table 1: Details of the imagery used in the present study

Satellite Imagery	WRS: P/R	Acquisition date	Spatial Resolution (m)	Source
Landsat MSS	147/ 045	2/21/1978	30m	USGS Glovis
Landsat TM	137/ 045	2/19/1988	30m	USGS Glovis
Landsat TM	137/ 045	1/13/1998	30m	USGS Glovis
Landsat TM	137/ 045	12/10/2008	30m	USGS Glovis
Landsat OLI/TIRS	137/ 045	2/21/2018	30m	USGS Glovis

Source: USGS Image *(https://ers.cr.usgs.gov)*

Image Preprocessing

After stacking of band producing a composite image, the area of interest (AOI) were selected by subset tool in Erdas Imagine v14 environment. Universe Transverse Mercator (UTM) projection was used with 46N zone. Due to sun angle, haze, cloud, water content, sensor failure, sensor velocity, altitude, platform motion both radiometric and geometric errors may appear in satellite images (Lillesand et al. 2014). Thus it required rectification and restoration for better visualization as well as analysis. In this study, satellite image of 1978 was taken as basemap while 1988, 1998, 2008 and 2018 have been registered using third order polynomial model with basemap accepting Root Mean Square (RMS) error less than 0.5 of a single pixel by applying Imagine Auto Sync workstation with Automatic Point Matching (APM) algorithm, Erdas Imagine v.14 environment. The radiometric correction including Dark Object Subtraction (DOS) and linear enhancement were operated by ENVI v 5.3 and Erdas Imagine v 14 respectively in this present study. This provide atmospherically corrected surface reflectance image.

Shoreline Extraction

Several methods i.e. band ratio method such as NDWI (Modified Normalized Difference Water Index), MNDWI (Modified Normalized Difference Water Index) (McFeeters 1996, Xu 2006), fixed scale digitizing (Dewan et al. 2017) with single operator and image classification technique provides a best output for land water boundary demarcation while band ratio method NDWI (McFeeters 1996) gives best response for MSS and MNDWI (Xu 2006) for TM and OLI sensors (Li et al. 2013). Basically, these water indices are developed on the basis of spectral reflectance response of specific bands namely Green, Red, NIR, MIR, and SWIR.

The equation for NDWI (McFeeters 1996) for MSS image and MNDWI (Xu 2006) for TM, ETM+ and OLI images are as follows:

$$\text{NDWI (MSS)} = \frac{p^{\text{Green}} - p^{\text{NIR}}}{p^{\text{Green}} + p^{\text{NIR}}} \quad (1)$$

$$\text{MNDWI (TM)} = \frac{p^{\text{Green}} - p^{\text{MIR}}}{p^{\text{Green}} + p^{\text{MIR}}} \quad (2)$$

$$\text{MNDWI (OLI)} = \frac{p^{\text{Green}} - p^{\text{SWIR}}}{p^{\text{Green}} + p^{\text{SWIR}}} \quad (3)$$

While, $p^{\text{Green,}}$ p^{NIR}, p^{SWIR} are the surface reflectance of green, Near Infrared, Short and Mid-Near Infrared bands respectively. In this study, the shoreline was extracted by digitizing in a fixed zoom scale (1:2000) in ArcGIS v 10.2.2 in vector format and cross check was performed with MNDWI (Xu 2006) value which basically convert into vector format from raster using raster calculator in ArcGIS v 10.2.2. Some areas were further manually edited based on MNDWI value where discrepancies were found. During digitization, tidal flat of muddy coast was not considered but the coast along mangrove, the edge of mangrove onward sea coast is considered in this study. In this context, the low tidal data was selected for this study. Moreover, for better visual enhancement of the boundary between land and water, different band combinations were applied i.e. RGB- 7-5-1 band composite for TM/ETM+, RGB- 7-5-3 band composite for OLI during digitizing period. For digitizing low tide level satellite data have been interpreted and dune crest, embankment, saltpans, beaches and seaward side of mangrove were considered.

Results and Discussion

Like other coastal area of Bangladesh, Kalapara Upazila shows a dynamic nature due to active erosion and accretion process. In the current study five images were used which were; 1978, 1988, 1998, 2008 and 2018. Erosion and accretion were calculated for 1978-1988, 1988-1998, 1998-2008 and 2008-2018 and finally 1978-2018 time period. The result showed that the area of the study area was about 30,406 hectares (Table 2) in the year of 1978 which reduced to 29,984 hectares (Table 2) in 2018. At the first time period i.e. 1978-1988, the area lost about 455 hectares of land due to erosion process and gained about 206 hectares (Table 3) of land due to accretion process. In next span 1988-1998, erosion process was most dominant than the accretion, where accretion was found about 214 hectares and erosion was about 383 hectares of land (Table 3). From year 1998 to 2008, the area experienced highest erosion and lowest accretion in the entire study period. The area lost about 492 hectares of land due to erosion process and gained about 174 hectares in the third time span. At the last time period i.e. 2008-2018, accretion was much dominant than the erosion where accretion was found about 554 hectares and erosion about 241 hectares (Table 3). In the last 40 years from 1978 to 2018, the study area's net loss of about 422 hectares of land because of the dominance of the erosion process.

Table 2: Areal dynamics of study area in temporal scale ((in Hectares)

Year	1978	1988	1998	2008	2018
Area (in hectares)	30406.46	30158.22	29989.84	29671.76	29984.28

Source: Developed from Landsat Images 1978, 1988, 1998, 2008 & 2018.

From temporal analysis between the year of 1978 and 1988, it is found that erosion process was observed active in the eastern (south of Lalua Union) and south western part (mainly the Kuakata beach area) of the study area (Figure 2). At the same time accretion process

Table 3: Erosion and accretion of study area in temporal scale (in Hectares)

Period	Erosion	Accretion	Unchanged	Net Gain/Loss
1978-1988	454.72	206.48	29951.74	-248.24
1988-1998	382.88	214.50	29775.33	-168.38
1998-2008	492.76	174.68	29497.08	-318.08
2008-2018	241.52	554.04	29430.24	312.53

Source: Developed from Landsat Images 1978, 1988, 1998, 2008 & 2018.

was not dominant along the eastern part of the area. Between the years 1978- 1988, erosion was much higher than the accretion process which resulted net loss of about 248.24 hectares of land (Table 3). Erosion (about 382.88 hectares) was more dominant than accretion (about 214.50 hectares) during the period of 1988 to 1998 along the eastern border (Lalua Union) of the area and the net loss was 168.38 hectares but the erosion was not higher than year 1978-1988 and there was some similarity in the rate of accretion. Erosion process rapidly increased along the eastern part (Lalua Union) of the area from the year 1998 to 2008 with an amount of 492.76 hectares which was more active than accretion (174.68 hectares) at the same time span and the net loss was 318.08 hectares. From year 1978 to 2008 times span the analysis found erosion based dynamics in the study area but there was a drastic change between years 2008 to 2018. The erosion

reduced to 241.52 hectares from 492.76 hectares (1998 – 2008) and accretion processes was dominant in amount of 554.04 hectares which was 174.68 hectares in 1998-2008.the accretion processes mainly seen over the entire boundary of the area but a sharp deposition was occurred in the south eastern part of the area (Lal kakrar dwip, Latachapli Union) (Figure 2) and resulted 312.53 hectares net gain (Table 3).

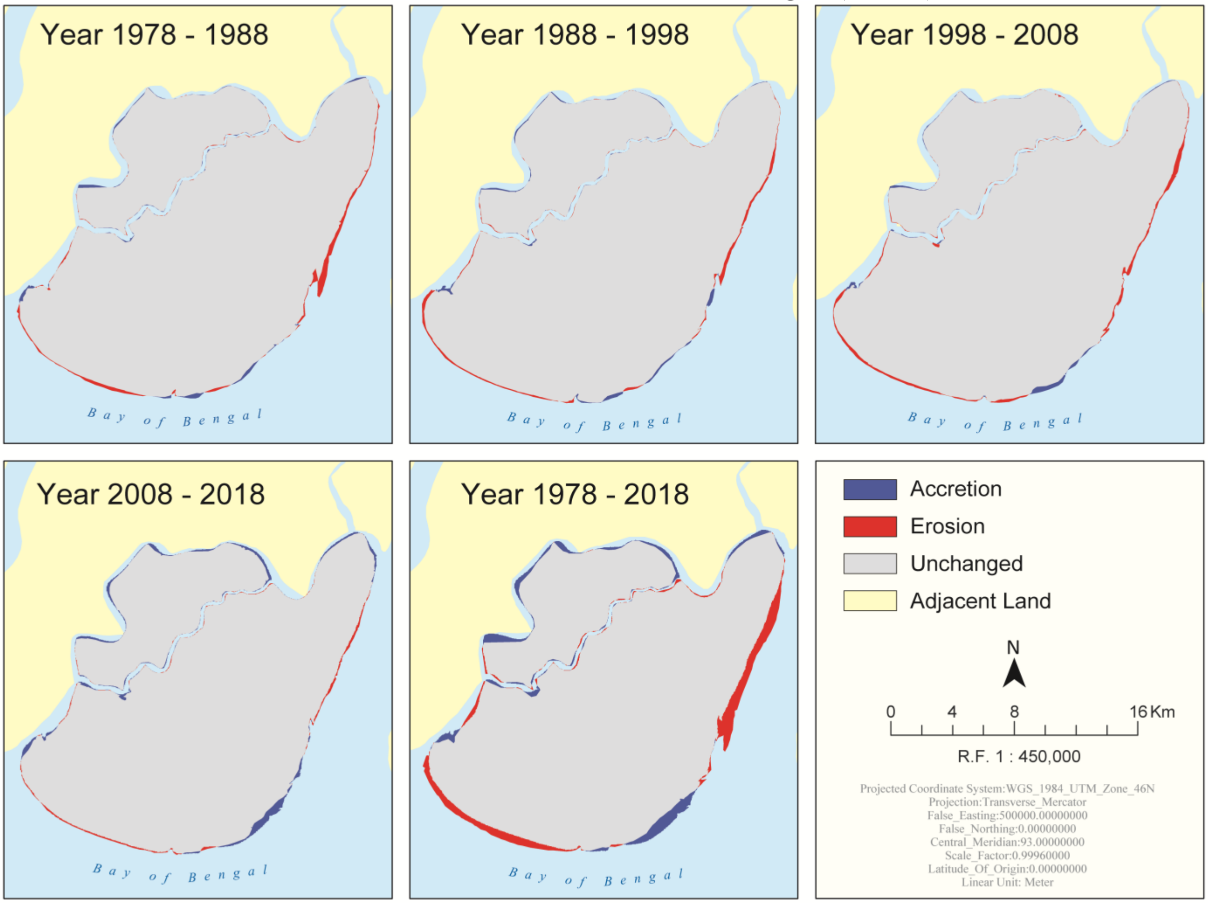

Figure 2: Erosion-Accretion map of Study area

Source: Developed from Landsat Images 1978, 1988, 1998. 2008 & 2018.

Finally, the analysis about land area change summarized that from 1978 to 2018, erosion process was more dominant along the eastern and most of the south western part of the area. In contrast, the accretion was effective along the north and south eastern part of the area. From 1978 to 2018, the area lost about 1292.58 hectares of land area with rate of 32.31 hectares /year. At the same time period, the area gained about 870.41 hectares land with rate of 21.76 hectares /year which was slower than erosion process (32.31 hectares /year.). The maximum erosion occurred in the transition period of 1998-2008 about 492.76 hectares while the minimum erosion occurred during the transition year 2008-2018 (241.52 hectares). The net loss rate of land area in this island was 10.55 hectares /year during this time span (Figure 3).

Conclusion

The nature of coastal area is very dynamic in the context of time and space. The southern part of Kalapara Upazila is one of dynamic coastal areas where erosion and accretion simultaneously happen like other coastal area

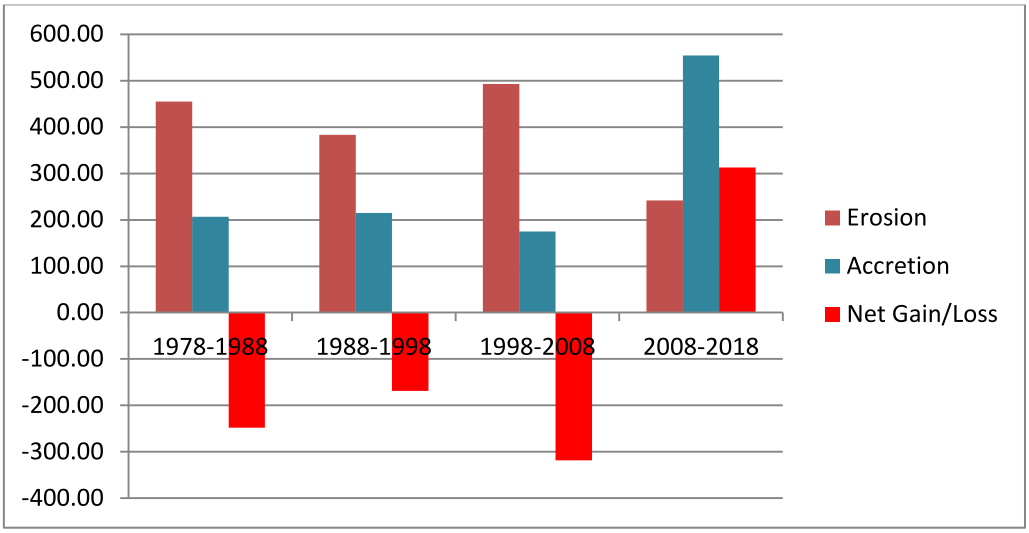

Figure 3: Annual change of Erosion and Accretion in ten years interval (in hectares)
Source: Developed from Landsat Images 1978, 1988, 1998. 2008 & 2018.

situated in the Ganges Tidal floodplain. The data acquired from satellite imagery suggest that erosion process take place in much higher than accretion in the study area from 1978 to 2008 although accretion rate was higher than erosion in last 10 years. At the scale of the entire study area although there is land erosion occurred but accretion processes also took place. Both erosion and accretion process are active at the open sea. The main factors for the erosion process are tidal water pressure, loose bank materials and shoreline configuration. The deposition of the sediment carried by the Rabnabad Channel result in the accretion of the area. Kalapara Upazila is a part of the potential zone for land reclaimation under the strategy of Bangladesh Delta plan 2100. For such strategy and planning it is very crucial to evaluate the erosion-accretion process for reclaiming new land in the coastal zone. Further analysis can be more explanatory which relates the dynamics of coast with hydro-metrological data and sea level data.

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