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APPLICATION OF LANDSAT IMAGERY AND VEGETATION INDEX PROPERTY TO ASSESS THE SHORELINE CHANGES ALONG COX'S BAZAR–TEKNAF COAST

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ABSTRACT

Bangladesh is located at the head of the Bay of Bengal. The coast of Bangladesh is known as a zone of vulnerabilities as well as opportunities which involves coast and island boundaries. The eastern coastal zone consists of sandy beaches and hilly areas and is morphologically very dynamic. This shoreline is an important zone which facilitates tourism opportunity, fishing industry, natural resources and regional highway. Cox's Bazar-Teknaf shoreline has been experiencing severe erosion at a number of places due to wave action. Wave and wind induced motion results in sediment distribution and shaping of nearshore morphology. The study has been performed by using Remote Sensing and GIS techniques. The shoreline shifting analysis has been performed by the process of open source Landsat images from 1980 to 2017. Satellite derived band algebra; Normalized Difference Vegetation Index has been utilized to identify the vegetation cover. The satellite images of an object carry a unique index property. In this study the index property of vegetation cover has been used to delineate more stable shorelines. At different locations, the average change in shoreline goes up to 120 m in erosion and 100 m in deposition. Based on the coastline shifting the erosion behaviour and the vulnerable areas are identified.

Keywords: *Geographic Information System; Landsat Imagery; NDVI;* Remote Sensing; Shoreline.

1. INTRODUCTION

Coastal zones are interfaces of land and ocean adjusting geosphere, climate and biosphere (Enmark, 2007) and these dynamic areas comprise the natural boundary between land and ocean (Lazin, 2016). The coastal zone is composed of the coastal plain, continental shelf and water that covers the shelf. It also includes other major features such as large bays, lagoons, coastal dune fields, river estuaries and deltas (Inman *et al*., 1973; Crossland *et al*., 2005; Fedra *et al*., 1988).

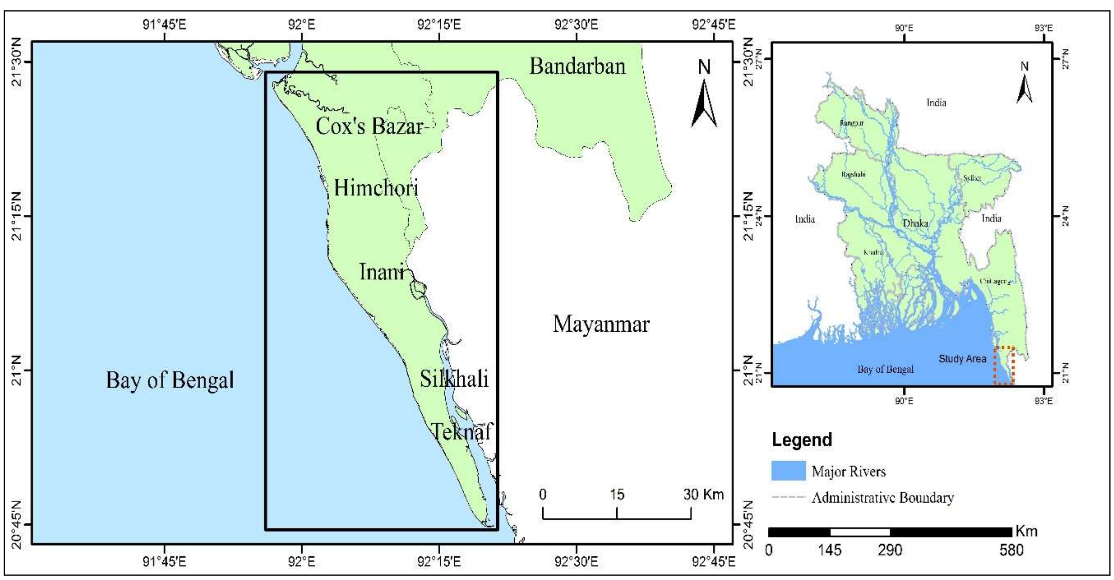

Figure 1: Location map of the study area

An area of 47,201 Km^2 is covered by the coastal Zone of Bangladesh (WARPO, 2006). This coastal area has abundance of resources and has been developed for a wide variety of purposes including settlement, agriculture, fisheries, tourism and communication (Alam *et al*., 1999). Approximately 46 million people lives in the coastal

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zones and it comprises 2.85 million hectares of cultivable land (Bala and Hossain, 2010). This coastal zone provides 20% of the rice production (Begum and Fleming, 1997). The coastal zone of Bangladesh is different from the rest of the country due to its unique geo-physical characteristics. These zones are vulnerable due to several natural disasters like erosion, deposition, cyclone, storm surges, sea level rise, settlement and also various forms of pollution (Akter, 2015).

The impact of growing population and development along the shoreline have been greatly discussed in the literature such as in Cendrero (1989), Turner *et al*. (1996) and UN (2003). Understanding coastal processes and beach morpho-dynamics to evaluate the shoreline changes is a scientific goal as well as a requirement to support coastal management plans (Galgano & Leatherman, 1991; Honeycutt *et al*., 2001; Pajak & Leatherman, 2002). It is important to understand the shoreline changes in different time scales (short and long) to identify the priority areas (such as erosion prone areas) for coastal management (Esteves, 2004). The shoreline changes has been calculated in this study in two different ways, (i) short term changes represents the changes in the same point between two nearest years (1980-1989, 1989-1993, 1993-1996, 1996-2000, 2000-2004, 2004-2006, 2006-2010, 2010-2013 and 2013-2017), and (ii) long term shoreline changes has been computed in the same point based on a base year which is 1980 with all the mentioned different years (1989, 1993, 1996, 2000, 2004, 2006, 2010, 2013 and 2017).

The study area consists 85 km of sandy beach line from Cox's Bazar to Teknaf (Figure 1). The image analysis has been carried out by using Landsat images and the erosion or deposition has been detected in every 500 m interval throughout this 85 km Shoreline.

2. DATA AND METHODOLOGY

The spatial and temporal changes in shoreline of coastal areas can be evaluated qualitatively and quantitatively by using historic maps, aerial photographs, remote sensing and GIS technique, beach profiles, topographic and bathymetric surveys. These datasets might provide a variety of means to analyse the rate of changes of shoreline position. Remote Sensing and Geographic Information System (GIS) can quantify the coastal processes, erosion and accretion especially in the last decades and this is well documented now (Durduran, 2010; Sener *et al.,* 2010). Different methods for coastline extraction from optical imagery have been developed (Bosworth *et al.,* 2003; Di *et al.,* 2003; Foody *et al.,* 2005; Dewidar and Frihy, 2008). It has become critical to assess the amount of erosion and accretion for the management of coastal zone and socio-economic developments in the coastal areas. Shoreline delineation is a complex and time-consuming task. Shoreline variability as well as trend analysis depends largely on the accuracy of shoreline delineation. However, during the demarcation of shoreline, temporal and spatial dimensionality must be taken care of (Islam *et al*., 2014).

Table 1: Satellite images used for this study

Satellite	Sensor	Band Composite	Spatial Resolution of Band Composite (m)	Year
Landsat	MSS	2, 3, 4	60	19 February 1980
	TM	3, 4, 5	30	22 February 1989 25 February 1993 18 February 1996 29 February 2000 8 February 2004 13 February 2006 8 February 2010
	OLI	4, 5, 6	30	21 April 2013 11 February 2017

The objective of the present study is to measure the spatial and temporal shifting of shoreline by using multi temporal satellite data. This study will also find the dynamic nature of the Cox's Bazar-Teknaf shoreline and will identify the vulnerable zones along the shoreline. In this context, geospatial techniques i.e., the Remote Sensing and Geographic Information System (GIS) have been used. Multi-temporal Landsat satellite images of the study area have been acquired by optical sensors during the dry season (February-April) from 1980 to 2017 (Table **1**) were downloaded from Earth Explorer. Dry period satellite images were chosen because vegetation cover and other ground conditions, particularly the water level, are relatively consistent during the dry season, which is essential for assessing the inter-year change of erosion and accretion (Hossain *et al*., 2013).

2.1 Satellite Images Analysis

The remotely sensed satellite images have been analysed by using Geographic Information System (GIS). All satellite images were projected onto the Bangladesh Transverse Mercator (BTM) projection system, whose specifications are: (1) Ellipsoid = Everest 1830, (2) Projection = Transverse Mercator, (3) Central meridian = 90° E, (4) False easting = 500,000 m and (5) False northing = 2,000,000 m (ISPAN, 1992). The analysis of the images started with the digitization of the shorelines from all satellite images. All selected satellite images have been carefully analysed for shorelines and vegetation covers using the ArcView GIS software.

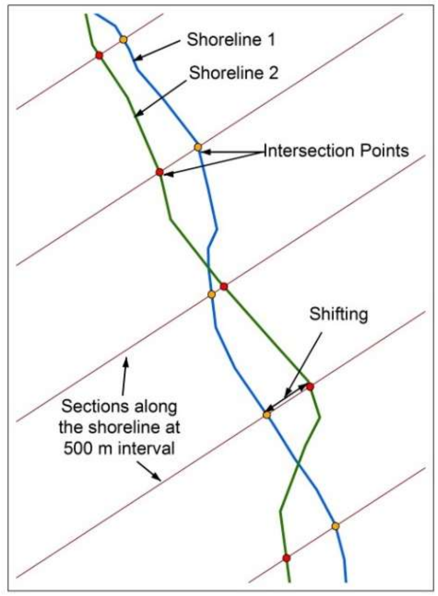

Figure 2: Schematic diagram of shoreline movement

Figure 2 describes the Schematic diagram of shoreline movement from 1980-2017 and similar method was used by Hossain *et al*. (2013). To quantify the changes in shoreline at different locations a total of 166 transects at 500 m intervals along the 85 km study reach have been digitized and coordinate points between the shoreline and transects have been determined.

2.2 Shoreline Shifting

Shoreline is the interface between the land and the sea. It is dynamic and it's spatial position changes over many time scales (Moore, 2000). Shoreline changes depict the way of shoreline movement, movement direction and rate. The shoreline may move landwards through the process of erosion; or seawards by sediment accretion (Boak and Turner, 2005). Shoreline changes can be estimated over different time scales ranging from geological to diurnal (WIOMSA, 2015). It is a highly challenging task to identify the cause of shoreline changes without field measurement, but Remote Sensing and GIS technique provides an opportunity to quantify the shoreline changes by image analysis.

2.3 NDVI calculation

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum to observe green vegetation. NDVI was first used in 1973 by Rouse *et al.* from the Remote Sensing Centre of Texas A&M University. Generally, healthy vegetation will absorb most of the visible light that falls on it, and reflects a large portion of the near-infrared light. Unhealthy or scattered vegetation reflects more visible light and less near-infrared light on the other hand, uncovered soils reflect moderately in both the red and infrared segment of the electromagnetic spectrum (Holme *et al*., 1987). The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands.

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \quad (1)$$

Theoretically, calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); in practice extreme negative values represent water, values around zero represent bare soil and close to +1 (0.8 - 0.9) indicates the highest possible density of vegetation (Weier and David, 2000).

3. RESULTS AND DISCUSSION

The shifting of the Cox's Bazar-Teknaf shoreline with respect to transects has been calculated. Table **2** and Table **3** show the average value within the specified time and the maximum values indicate the highest value within the same time period for the total study reach. The positive value indicates deposition and negative value denotes the amount of erosion.

Table 2: Short term shoreline shifting due to deposition and erosion

	Deposition (m)		Erosion (m)	
Year	Average	Maximum	Average	Maximum
1980-1989	60.69	174.93	-102.13	-380.56
1989-1993	72.29	405.10	-20.92	-57.75
1993-1996	35.03	141.43	-55.64	-219.50
1996-2000	82.92	309.10	-36.85	-110.43
2000-2004	50.08	218.87	-81.32	-352.82
2004-2006	23.72	121.45	-32.57	-149.80
2006-2010	111.92	322.71	-50.82	-141.01
2010-2013	37.35	277.94	-59.68	-245.74
2013-2017	28.65	89.72	-57.41	-380.40

Table 3: Long term shoreline shifting due to deposition and erosion

	Deposition (m)		Erosion (m)	
Year	Average	Maximum	Average	Maximum
1980-1989	60.69	174.93	-102.13	-380.56
1980-1993	68.37	269.39	-64.21	-174.76
1980-1996	88.04	250.79	-97.96	-276.75
1980-2000	57.59	363.20	-94.80	-253.12
1980-2004	80.26	184.95	-100.64	-411.95
1980-2006	87.54	378.11	-114.79	-311.71
1980-2010	72.71	529.64	-79.55	-344.32
1980-2013	56.55	263.99	-73.47	-431.88
1980-2017	97.20	420.45	-96.77	-326.62

Table 2 depicts the short term changes in the shore line which has been calculated beweeen two consecutive taken year. The highest deposition occured during the period 1989-1993 where as the maximum erosion happened in between 1980 to 1989. Table 3 illustrates the longterm chenges which has been calculatd based on the year 1980 for this study. In both erosion and deposition cases the maximum rate does not follow any specific pattern.

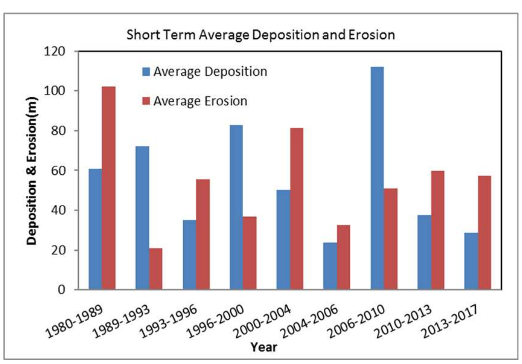

Figure 3: Changes in short time deposition and Erosion

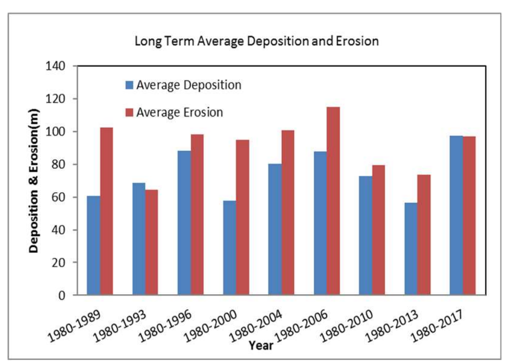

Figure 4: Changes in long time deposition and Erosion

FIGURE 3 and FIGURE 4 describe the short and long-term average deposition and erosion amount through the 85 km long shoreline. From Figure 3 it has been found that there is dramatic change in the amount of erosion and deposition. The total area of deposition and erosion dominates alternatively till the year of 2010 and after the year

2010 the value of erosion has increased whereas the amount of deposition has decreased. This indicates a net increasing in erosion for last 7 years.

Figure 5 illustrates the changes in deposition and erosion along the shoreline between Cox's bazar and Teknaf. It has been found that Himchari area which is about 12 km from Cox's Bazar, is the most vulnerable area where the maximum amount of erosion occurs during the selected period of analysis.

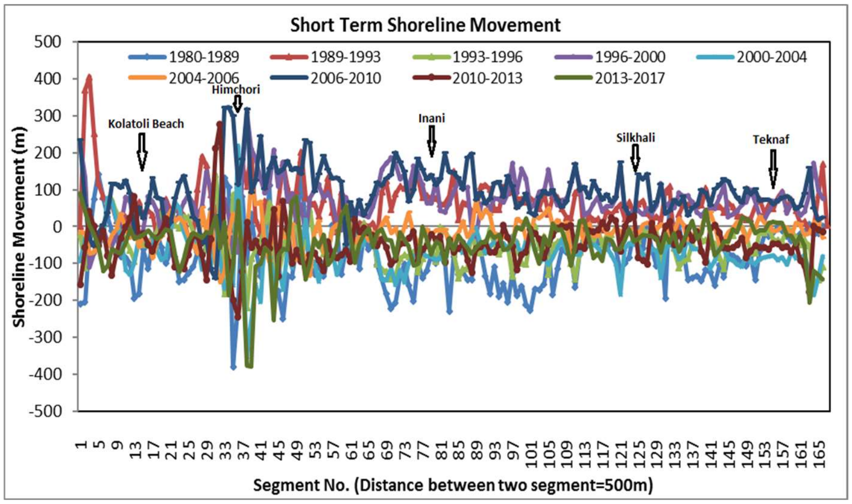

Figure 5: Changes in shoreline between Cox's bazar and Teknaf

The total length of the study area has been divided into three sub-sections to identify the shoreline changes clearly which are shown in Figure 6 and this figure also presents the shoreline changes for last 37 years. Figure 7, Figure 8 and Figure 9 depict the short time shoreline changes in different years and it has been found that the highest erosion occurred in between section *A-A* and *B-B*. The shoreline during the year 2004-2006 shows minimum average deposition (23 m) and the maximum deposition occurs during the year 2006-2010 which is around 112 m. The maximum erosion 102 m occurred during the period 1982-1989 and the minimum erosion 20 m occurred during 1989-1993.

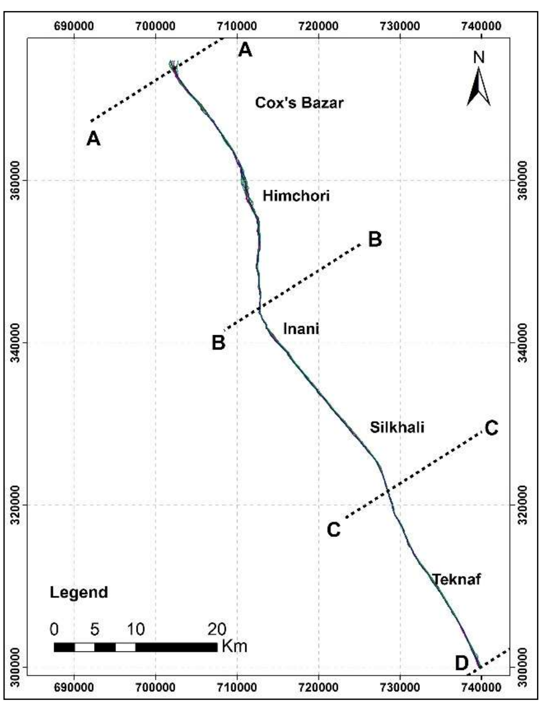

Figure 6: Shorelines of different years between Cox's bazar and Teknaf

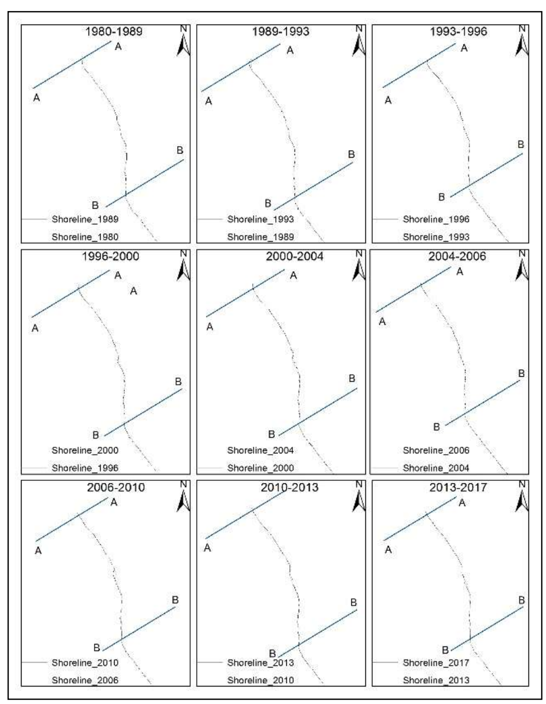

Figure 7: Short term shoreline shifting within section A-A and B-B

Figure 10 illustrates the NDVI values for the respective years considered and it can be clearly visible from the figures that areas having lower NDVI values (less vegetation) are more susceptible to shoreline changes, which indicates that the areas are more dynamic in nature. The areas with high NDVI values (high vegetation coverage) are more stable in the study area.

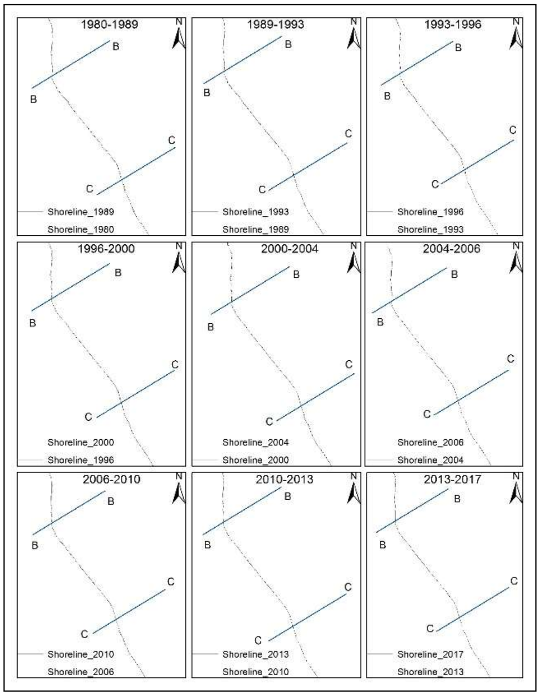

Figure 8: Short term shoreline shifting within section B-B and C-C

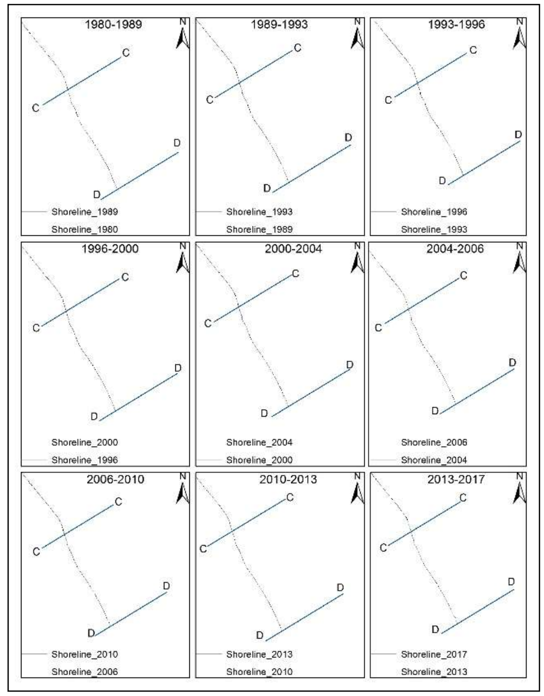

Figure 9: Short term shoreline shifting within section C-C and D-D

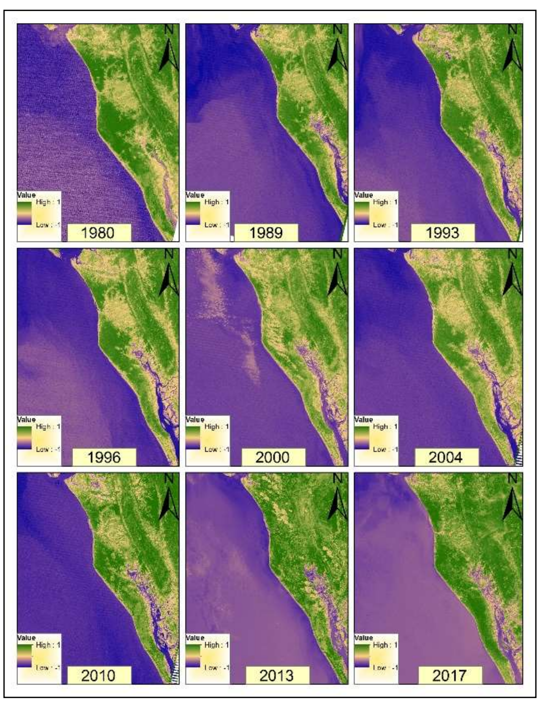

Figure 10: NDVI values within the study reach

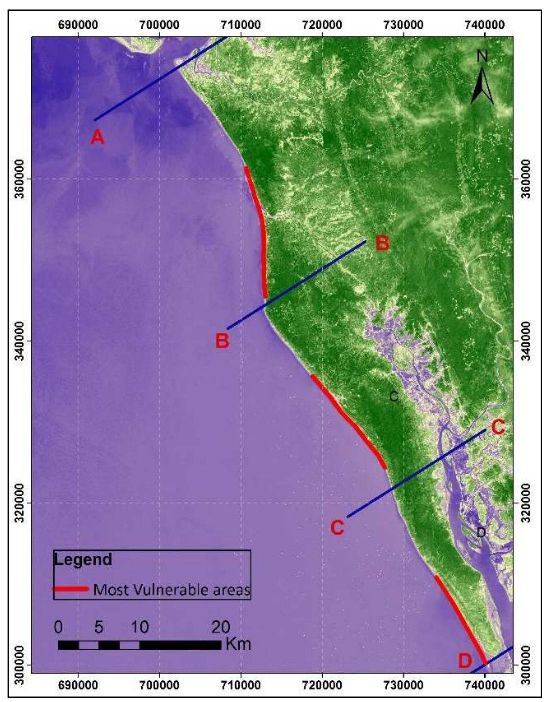

Figure 11: Most vulnerable areas within the study reach

Figure 11 highlights the most dynamic and vulnerable locations along the Cox's Bazar-Teknaf shoreline. From this figure it can be said that there is considerable shifting almost in every sections. Maximum erosion and deposition has been found near Himchori area. The Inani region is also very dynamic in nature.

4. CONCLUSION

The Cox's Bazar-Teknaf shoreline is found to be very dynamic in nature. From the time series analysis of Landsat imagery from 1980 to 2017, it has been found that the shoreline shifting occurs with respect to every transect lines. For the different 3 segments, the shoreline shifting rate is found to be higher in the section A-A and B-B during last 37 years. Based on the results of this study it can be said that special shore protection measures need to be taken for the current and future planning and management of Cox's Bazar-Teknaf shoreline. All the concerning protection works or defensive mechanism for any development project should be taken without disturbing the natural coastal processes that has been going on from time immoral.

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