Spatio - Temporal Change Detection of Shoreline outside of the Coastal Embankment of Bangladesh: The Case Study on Barguna Sadar Upazila, Barguna District

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Abstract

The main aim of this study is to delineate the shoreline change outside of the coastal embankment of Bangladesh. To fulfill this purpose, choose Barguna Sadar Upazila as a study area due to its unique position. This site is located at such a place where west and east side situated near the bank of the Bishkhali and Payra river, and in the south, the Bay of Bengal and these two rivers formed an estuary, which is the breeding place for erosion and accretion. To analyze the changing pattern of shoreline, followed geospatial techniques. First, NDWI method used to delineate the land and water from the satellite images. Then, DSAS version 4.4 tool is used to detect the pattern of shoreline from the year 1980 to 2017. From the analysis, it is obtained that the study area gained almost 449.10 hectares of land (1980 - 2017) as well as the length of shoreline is increased (1.05 km). The whole study area is divided into 113 segments. Amongst them, 92 shows positive movements, and the remaining shows negative movement. The highest movement is observed in the middle part of the study area (in the estuary, the movement value is 680 m), wherein the lowest is observed in the east side (-170 m). It is obtained from the analysis that the movement is seaward and the changing rate is -4.0 to 18 m per year. From this observation, it might be concluded that the study area is dominated by the accretion process rather than erosion. Due to this reason, the vulnerability level based on shoreline change is low.

Keywords: Shoreline, Outside of the Coastal Embankment, NDWI, DSAS.

Abbreviation: NDWI - Normalized Difference Water Index;
DSAS - Digital Shoreline Analysis System;
TOA - Top of Atmosphere
DN - Digital Number
NSM - Net Shoreline Movement EPR - End Point Rate
USGS - United States Geological Survey

1. Introduction

The shoreline is the boundary between land and sea that continuously changed by natural processes or man- made activities. Natural processes include wave characteristics, circulation of water near the seashore, geomorphological formation, characteristics of sediments, etc. Anthropogenic activities included sand mining, resource extraction in the coastal belt, etc. The area of the shoreline is changed by the erosion and accretion processes.

The coastal area of Bangladesh isn't stable because of its unique geographical position. This country regularly faced extreme natural events, viz. cyclone, storm surge, erosion, sea level rise, salinity intrusion, etc. Due to that reason the lives of the coastal people are always at risk.

From the index base study, it was found out that Meghna river estuary area was the most vulnerable area which included Manpura and Hatiya Islands, banks of the Meghna River, and the shoreline of Bhola coastal zone. Amongst these areas, Hatiya was less vulnerable because of the high accretion rate at the southern part. The western coast which included the Sundarban area, and parts of Barguna, Patuakhali, and Mongla coastal zone, Amongst these areas, Hatiya was less vulnerable because of the high accretion rate at the southern part. The western coast which included the Sundarban area, and parts of Barguna, Patuakhali, and Mongla coastal zone, was highly vulnerable. But the presence of mangrove forest in this part reduced the vulnerability level less than Meghna River estuary area. It was revealed from this study that the vulnerability level was moderate to low in the Noakhali Feni coastal zone, the Chittagong coastal zone, and the Cox's Bazar coastal zone which also added Kutubdia and Maheskhali islands. This result was found because of the sea level rise and tidal range variables were low (1). A recent study revealed that 57.9 km coastline of Ganges delta in Bangladesh faced a very highly vulnerable situation wherein 50 km were highly vulnerable. This scenario was found because of the presence of intertidal and supratidal flats which elevation was very low from the sea level as well as moderate erosion rate at the coastline and high susceptible tendency during the period of storm surge. All of those characteristics made the Sundarban, Kuakata Upazila, and isolated islands of Patuakhali districts highly vulnerable. On the other hand, almost 61 km coastline was moderately vulnerable since the slope was moderate along with supratidal flats in those areas and the erosion rate was moderate. Amongst 286.2 km of shoreline, only 117 km were fallen into a lower spectrum in the regards of vulnerable scale. These areas were found in the southeast coast of Bhola Island, west coast of Barabagi, and Dublar Char, Katka, and Kochikhali. (2)

The area which is situated outside of the coastal embankment is more vulnerable than inside. To reduce the risk, it is one of the most important tasks to analyze the shifting pattern of shoreline as well as the level of vulnerability due to this shifting which help the policymakers to take various constructive activities to cope with current and near future situation.

2. Methods

2.1. Selection of the Study Area

Barguna Sadar Upazila is situated in such a place, where Bishkhali and Payra (Burishwar) river flow from both sides (west and east side), and at the in front of the Upazila (south side), Bay of Bengal meet with these two rivers and make an estuary (Figure 1). Because of its geographical position, erosion and accretion both are active. The road in the study area is used for multi - purposes. To protect people from the tide as well as storm surge, this is used as embankment, on the other hand, it is used for communication. So, this site is chosen to conduct this study.

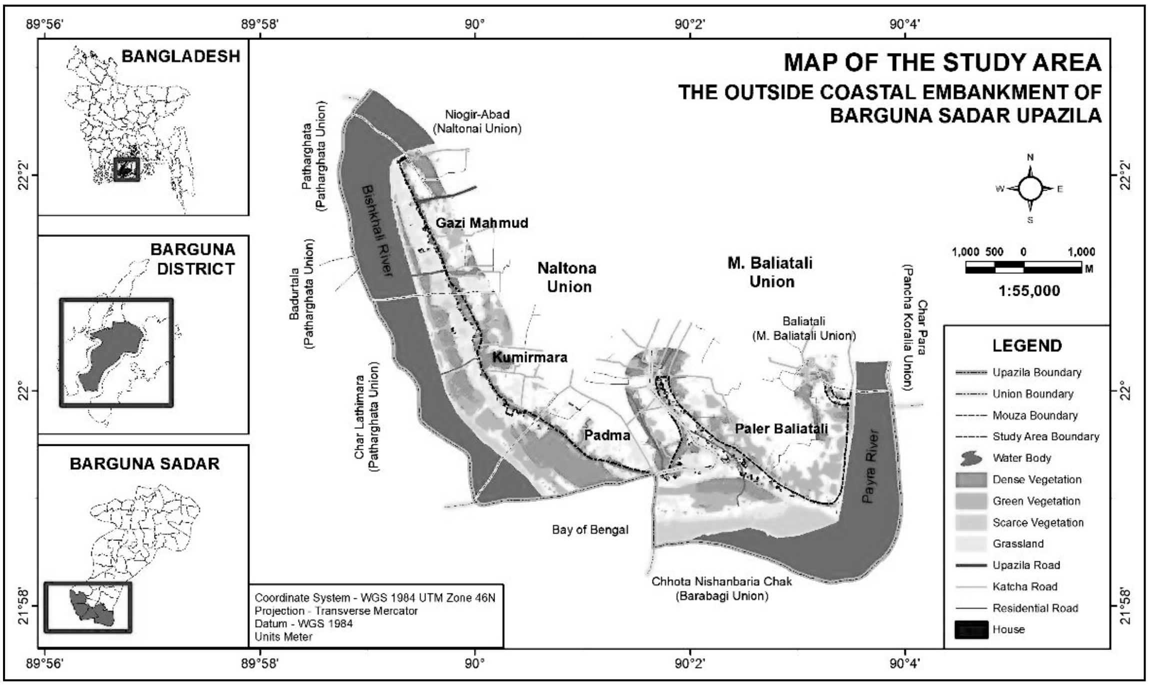


Figure 1 - Map of the Study Area

Table 1 - The Imagery which Used to Study the Shoreline Change

Satellite	Sensor Type	Path / Rows	Acquisition Date	Resolution	Data Type
Landsat 8	OLI/TIRS	137/45	01/17/2017	30 m	Level 1
Landsat 7	ETM +	137/45	01/17/2012	30 m	Level 1
Landsat 7	ETM +	137/45	02/23/2007	30 m	Level 1
Landsat 7	ETM +	137/45	02/17/2002	30 m	Level 1
Landsat 5	TM	137/45	01/26/1997	30 m	Level 1
Landsat 5	TM	137/45	02/04/1992	30 m	Level 1
Landsat 5	TM	137/45	02/19/1988	30 m	Level 1
Landsat 5	TM	137/45	01/15/1980	30 m	Level 1

2.2. Analysis Techniques

To analyze shoreline change, followed these methods step by step (Figure 2).

2.2.1. Collection of Landsat Images

The first step is to collect Landsat images within distinct intervals. The collected years of Landsat image were 1980, 1988, 1992, 1997, 2002, 2007, 2012, and 2017 (Table 1). There are no images in the period between 1982 and 1987, due to that reason images are collected at 8 years interval. From 1990, data is available for every year. Hence, images collected at 5 years interval.

2.2.2. Pre-Processing of Satellite Image

It is necessary to prepare satellite images before analysis. Selected images have radiance value which should be converted into TOA planetary reflectance values (3). For that reason, it is needed to use reflectance coefficient values which are available in the metadata file of the image. To convert radiance value to TOA, there are few steps, which needed to follow.

2.2.2.1. Conversion of DN into TOA Reflectance Values

Equation 1 is followed to convert DN into TOA reflectance (3).

$$\rho\lambda = M\rho \times Q\ cal + A\rho \quad (1)$$

Here,

ρ = TOA planetary reflectance (without correction)
$M\rho$ = Band − Specific Multiplicative Rescaling Factor
$Q\ cal$ = Pixel Value (DN)
$A\rho$ = Band − specific additative rescaling factor

2.2.2.2. Correction the Reflectance Value with the Sun Angle

The following equation is used to correct resulted reflectance values with sun angle (3).

$$\rho\lambda\ corrected = \rho\lambda \div \sin\theta SE \quad (2)$$

Here,

$\rho\lambda$ corrected = Reflectance values after sun angle correction
$\rho\lambda$ = TOA planetary reflectance
θSE = Local sun elevation angle (sun angle)

2.2.3. Normalized Difference Water Index

Then followed the NDWI formula to extract the shoreline of the study area (4).

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR} \quad (3)$$

Where,
GREEN = Green Band
NIR = Near Infrared Band

The range of NDWI is - 1 to + 1, and positive values represent water body whereas negative value shows the land. After extracted NDWI images, classified those into two categories likely land and water based on a positive and negative value. Then classified, used 'raster to polygon' tool to convert raster image into a polygon shapefile. With the help of 'erase' and 'intersect' tool, determine the erosion, accretion, and unchanged area throughout the study year. On the other hand, polygon shapefiles converted into polyline by the help of 'polygon to polyline' tool.

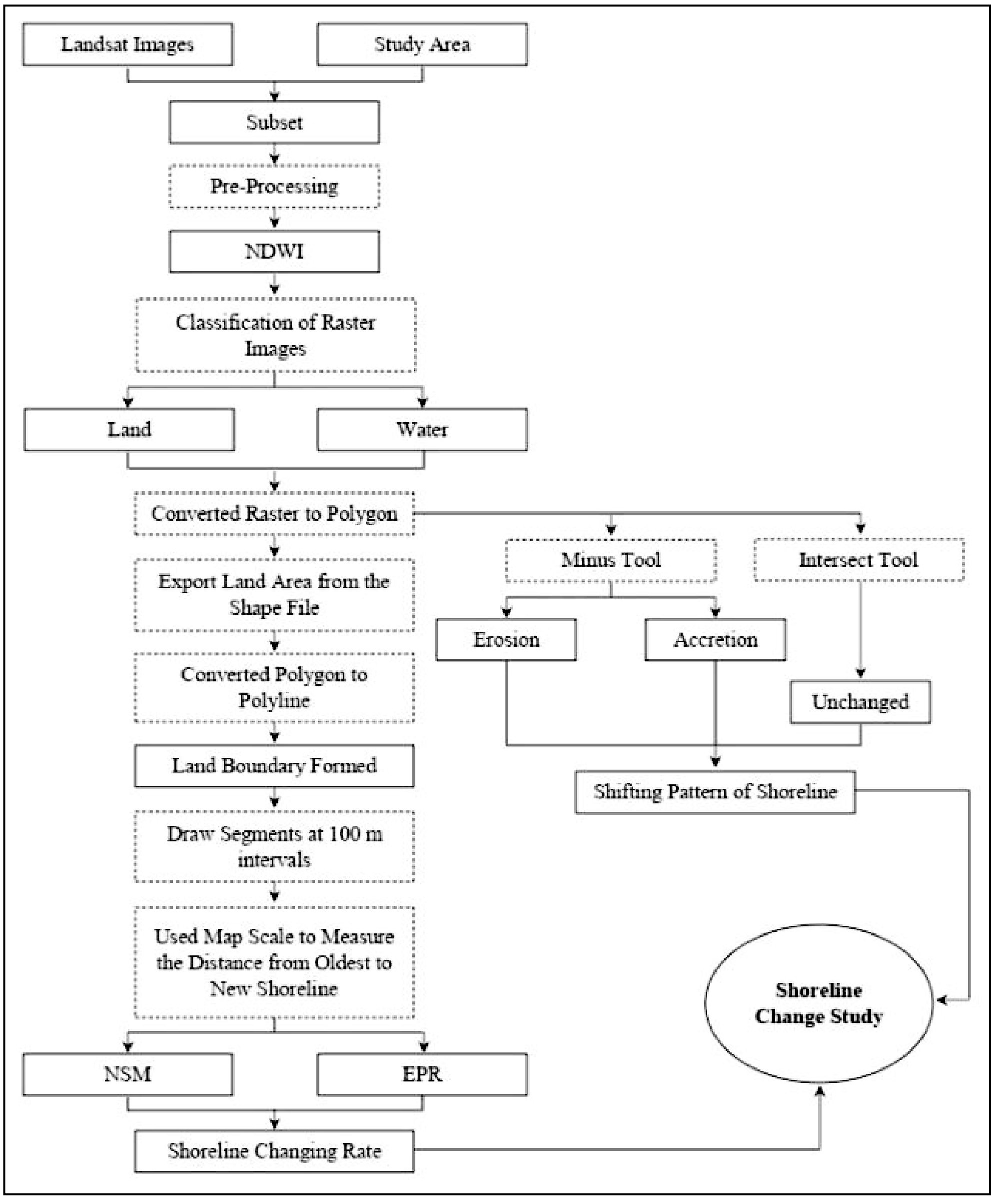


Figure 2 - Flow Chart Diagram for Shoreline Change Study

To detect the shoreline change, used DSAS version 4.4 (Thieler, et. al., 2017). With the help of this software, first, shorelines of the study area are divided into 113 segments with 100 m intervals. Then, figure out the length of shorelines.

After that calculated net shoreline movement by following this formula (5).

$$\textbf{Net Shoreline Movement} = \textbf{Distance between oldest and youngest shoreline} \quad (4)$$

To find out the changing rate, the calculated end point rate (EPR) (5).

$$\textbf{End Point Rate} = \frac{\textbf{Distance in meters}}{\textbf{Time between oldest and most recent shoreline}} \quad (5)$$

2.2.4. Vulnerability Level Detection

The vulnerability level of the study area due to its shoreline change is determined through standard values. The standard scores which is followed is given below (Table 2).

3. Results

3.1. Length of Shoreline

The analysis shows that the total length of the shoreline of study area was 14.60 km in 1980 that increased to about 15.64 km in 2017 (Table 3). It is noticed that the sum of mouza wise shoreline length isn't equal to the overall length as there are areas which is still undefined (Figure 3).

The shoreline length at Gazi Mahmud area was 2.52 km in 1980, which decreased after 1997 (0.61 km). After the period of 2002, the length is increased (0.57 km). In the year 2017, the length was 1.49 km. It is found from the analysis that the length of shoreline at Kumirmara area was 2.37 km in 1980. The highest length was observed in 1992 (3.75 km). After that, shoreline length is continuously decreased, and 2.81 km was obtained in 2017.

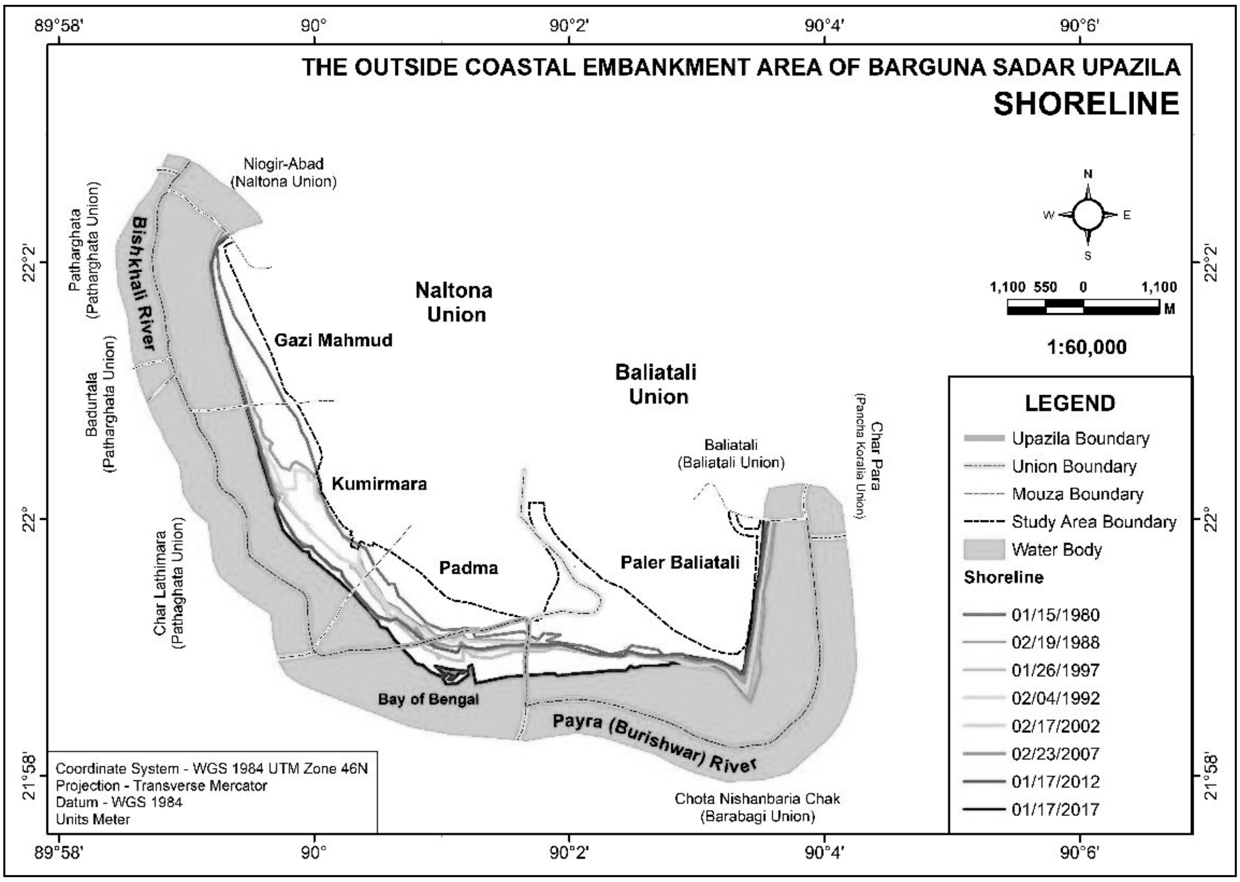
Table 2 - Criteria and Ranking for Measure the Vulnerability Level

Criteria	0	0.25	0.50	0.75	1	Unit
	Very Low	Low	Moderate	High	Very High	
Shoreline Erosion/ Accretion	> 10	10.0 - 2.0	2.0 - -2.0	-2.0 - -10.0	< -10.00	meter/year

[Data Source - Pramanik, et. al, 2015 (6)]

Table 3 - Length of Shoreline (km)

Area	1980	1988	1992	1997	2002	2007	2012	2017
Gazi Mahmud	2.52	1.75	2.00	0.61	0.57	1.35	1.95	1.49
Kumirmara	2.37	3.15	3.75	3.15	3.08	3.22	3.18	2.81
Padma	1.77	1.49	1.37	1.21	1.53	1.61	1.30	1.04
Paler Baliatali	3.43	2.95	3.06	2.91	3.03	3.62	4.92	5.06
Study Area	14.60	14.51	14.98	14.47	14.45	14.62	13.86	15.64



[Data Source - NASA LP DAAC, 1980, 1988, 1992, 1997, 2002, 2007, 2012, 2017]
[Prepared By - Author]

Figure 3 - Shoreline of the Study Area at Various Period

Table 3 shows that 1.77 km was found in 1980 at Padma area. After that, the length shows a decreasing trend. The shoreline length is increased at the Paler Baliatali area. In 1980, the length was about 3.43 km. It is identified that the length was
5.06 km in 2017 at that area.
3.2 Area of the Study Area

It is observed from the analysis that the area of the outside coastal embankment was 414.47 hectares in 1980 that increased with time to about 863.57 hectares in 2017 (Table 4).
Though shoreline found in the decreased pattern, the area is increased at Gazi Mahmud, Kumirmara, and Padma area. The highest area is acquired by Kumirmara. In 1980, the area was 22.48 hectares which had increased to about 211.75 hectares in 2017.

This analysis shows that, with an increase of 1.05 km shoreline, the study area has gained about
449.10 hectares of land. That result is found because of the deposition of silt near the bank of the river.
It is estimated from the analysis that erosion and accretion rate are very high in the study area. Table 5 shows that in the year of 1980 to 1988, accretion occurred about 158.51 hectares and erosion occurred at about 15.41 hectares, whereas the unchanged area remains about 399.07 hectares. From 1988 to 1992, the accretion rate was much slower while only 26.66 hectares land was raised, and the unchanged area remains about 546.11 hectares. The amount of eroded land was 11.46 hectares that period.
n the next five years (1992 to 1997), the accretion rate was very much high (118.57 hectares), and about 549.45 Ihectares of land found unchanged. The eroded rate was insignificant (3.32 hectares). In the period between 1997 and 2002, erosion rate was much higher (39.66 hectares) then accretion (only 1.47 hectares) and about 648.36 hectares of land found unchanged. From the year 2002 to 2007, it is found that accretion rate again gains speed and the amount was 48.78 hectares. About 634.73 hectares of land remain unchanged. Almost 15.10 hectares of land were subject to erosion in that period.

From the period between 2007 to 2012, accretion was 6.96 hectares and erosion was 17.06 hectares, whereas the unchanged area remains about 666.45 hectares (Table 4). In the last five years (2012 to 2017), the accretion rate was very much high (190.16 hectares) and about 680.45 hectares area

were found in an unchanged condition. The eroded rate was very much lower than the previous five years (7.04 hectares).

From Table 4, it is found that in the period between 1980 and 1988, gained almost 143.10 hectares of land and that process continued till the year 1997. After that, this area lost 38.20 hectares of land in the year between 1997 and 2002. In the next five years (2002 to 2007), the study area again gained
33.68 hectares of land. Between 2007 and 2012, erosion rate was much higher than accretion, so that time the amount of loss was 10.10 hectares of land. The deposition rate was higher in the year between 2012 and 2017. Due to that reason, this area gained about 183.12 hectares of land.
Mouza based land area changed are given below as a Table 6.

Table 4 - Area (hectares) of the Study Area

Area	1980	1988	1992	1997	2002	2007	2012	2017
Gazi Mahmud	43.27	98.16	99.23	103.09	103.07	102.47	101.51	103.79
Kumirmara	22.48	76.62	92.92	152.30	148.76	181.65	183.93	211.75
Padma	110.79	131.38	134.88	149.61	142.32	156.55	156.36	176.78
Paler Baliatali	191.53	208.49	206.11	216.32	209.56	203.69	193.83	351.25
Study Area	414.47	557.57	572.77	688.03	649.83	683.51	673.42	863.57

Table 5 - Land Area Changed of the Study Area

Parameter	1980-88	1988-92	1992-97	1997-2002	2002-07	2007-12	2012-17
Accretion (Hectare)	158.51	26.66	118.57	1.47	48.78	6.96	190.16
Erosion (Hectare)	15.41	11.46	3.32	39.66	15.10	17.06	7.04
Unchanged (Hectare)	399.07	546.11	569.45	648.36	634.73	666.45	680.45
Gain/Loss (Hectare)	143.10	15.20	115.26	-38.20	33.68	-10.10	183.12
Shoreline Change (km)	-0.09	0.47	-0.51	-0.03	0.17	-0.76	1.78

Table 6 - Land Area Changed (Mouza Based) of the Study Area

Gazi Mahmud							
Parameter	**1980-88**	**1988-92**	**1992-97**	**1997-2002**	**2002-07**	**2007-12**	**2012-17**
Accretion (Hectare)	54.88	1.62	3.86	0.05	0.00	0.01	2.44
Erosion (Hectare)	0	0.55	0	0.07	0.61	0.97	0.16
Unchanged (Hectare)	43.27	97.60	99.23	103.02	102.47	101.50	101.35
Gain/Loss (Hectare)	54.88	1.07	3.86	-0.02	-0.60	-0.96	2.28
Kumirmara							
Accretion (Hectare)	54.20	17.46	59.38	0.35	33.45	2.84	27.82
Erosion (Hectare)	0.07	1.15	0	3.89	0.56	0.56	0.00
Unchanged (Hectare)	22.42	75.46	92.92	148.41	148.20	181.09	183.93
Gain/Loss (Hectare)	54.13	16.30	59.38	-3.54	32.89	2.28	27.82
Padma							
Accretion (Hectare)	20.59	3.50	14.73	0.20	14.48	1.05	20.42
Erosion (Hectare)	0	0.0001	0	7.49	0.25	1.24	0.00
Unchanged (Hectare)	110.79	131.38	134.88	142.12	142.07	155.31	156.36
Gain/Loss (Hectare)	20.59	3.50	14.73	-7.30	14.24	-0.19	20.42
Paler Baliatali							
Accretion (Hectare)	17.15	0.49	10.31	0.72	0.08	0.04	163.54
Erosion (Hectare)	0.20	2.87	0.10	7.48	5.95	9.90	6.11
Unchanged (Hectare)	191.34	205.62	206.01	208.84	203.61	193.79	187.72
Gain/Loss (Hectare)	16.96	-2.38	10.21	-6.76	-5.88	-9.86	157.42

3.3. NSM and EPR

To find out the trend of shoreline shifting, calculated NSM and EPR. Through NSM, figured out the movement of shoreline and EPR helped to find out the movement direction (either towards the sea or inland). Positives value indicated the movement towards the sea and negative indicates the movement towards the land. The highest movement is 680 m and the lowest is minus (-) 170 meters. The highest movement found in the Kumirmara area. And the lowest is obtained at Paler Baliatali (Figure 4). For this study, used

113 segments at 100 meters interval. From those segments, 92 shows positive shifting, and 21 shows negative shifting (Figure 5). Figure 6 revealed that the movement towards the sea is low at Gazi Mahmud (73.92 meters to 500 meters). After that movement

towards sea increased up to the Padma (516.3 m to 680 m) and then it again started to fall near the western side of Paler Baliatali (598.01 m to -170 m).

From this analysis, it is found that shoreline shifting is positively high in the middle part of the study area (Figure 4).

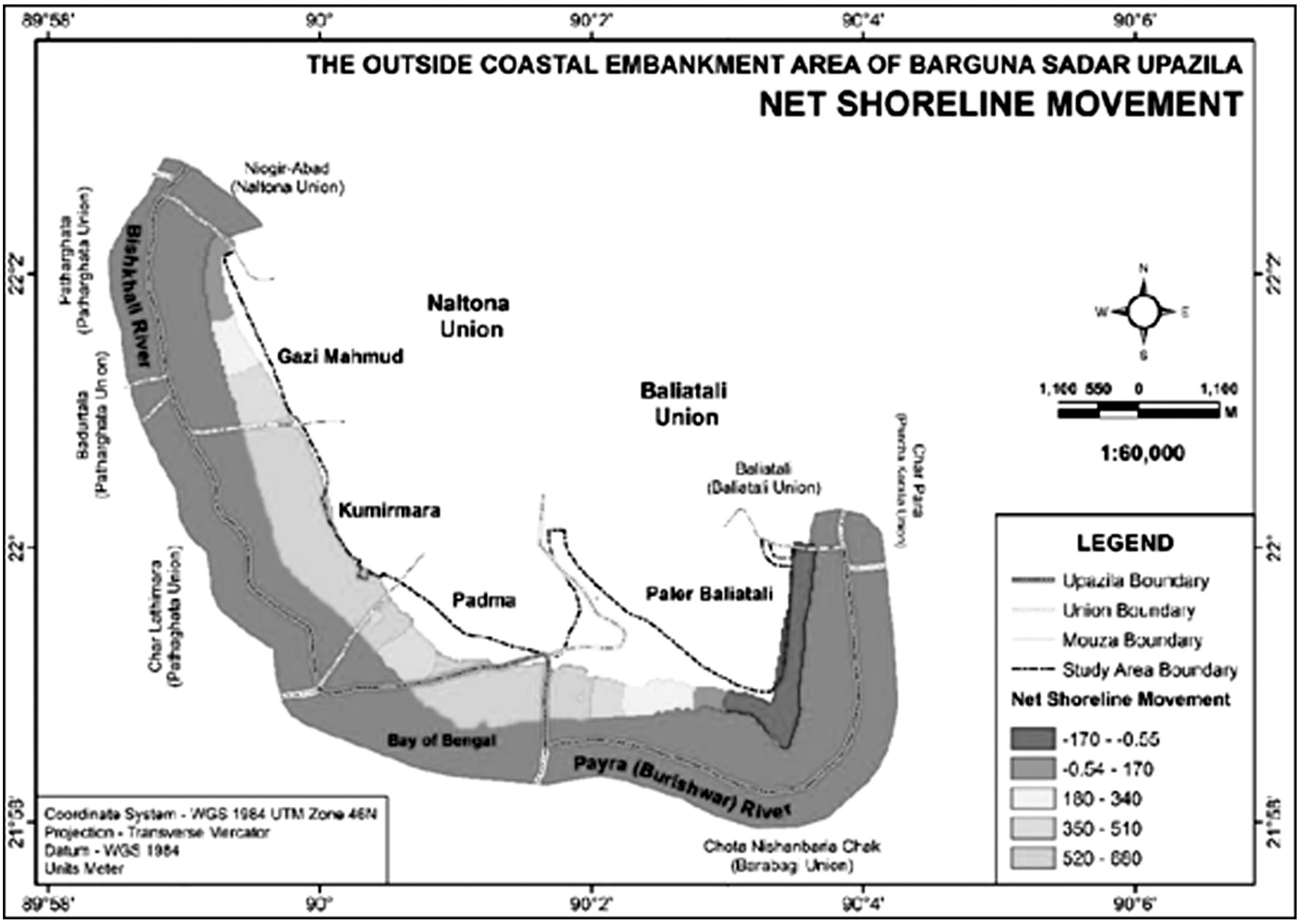


Figure 4 - Net Shoreline Movement of the Study Area

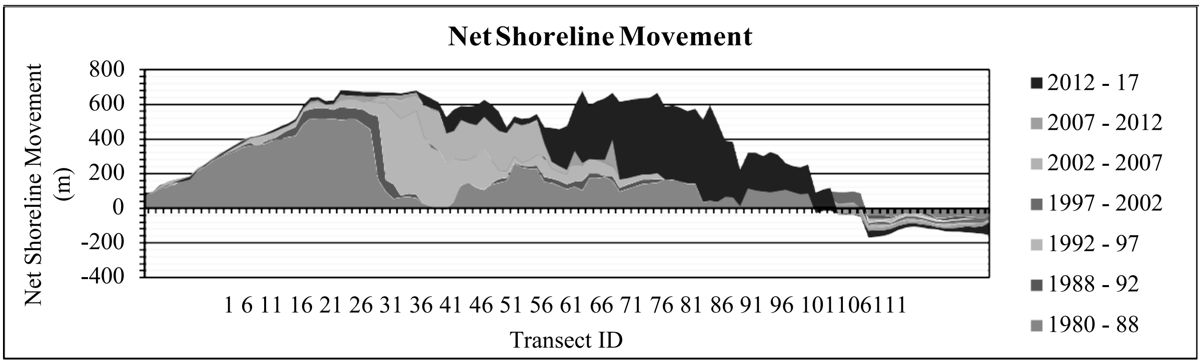


Figure 5 - Net Shoreline Movement in the Five Years Difference

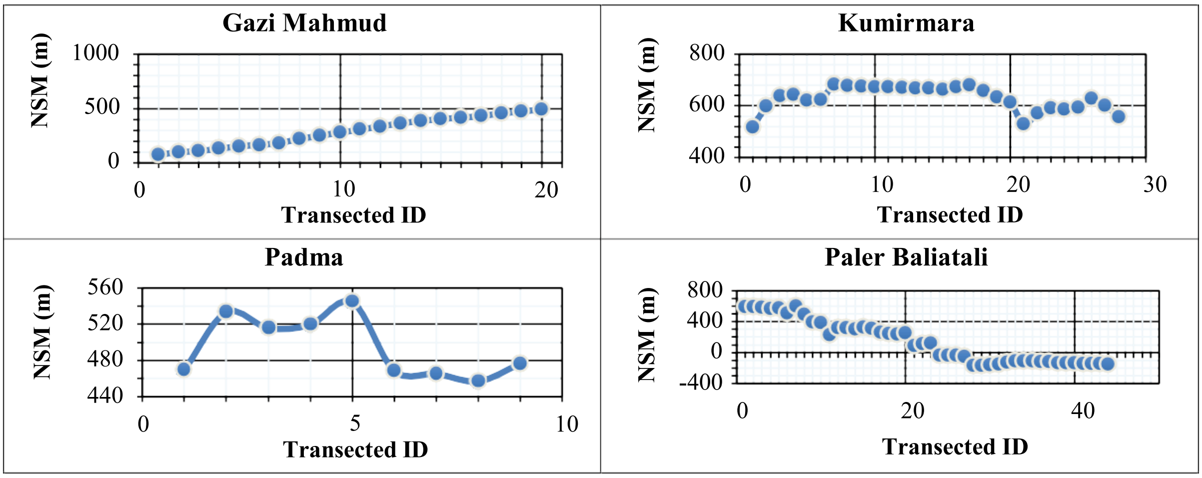


Figure 6 - Area wise NSM

Through the estimation of end point rate, the rate of shoreline shifting has been computed (Figure 7). From the Figure 8, it has been found that the shifting rate at Gazi Mahmud is positive and the range is 2 m to 13.26 m per year. At Kumirmara and Padma, the shifting rates are also positive, and the ranges are varying from 13.96 m to 18.36 m per year and 12.35 m to 14.72 m per year respectively.

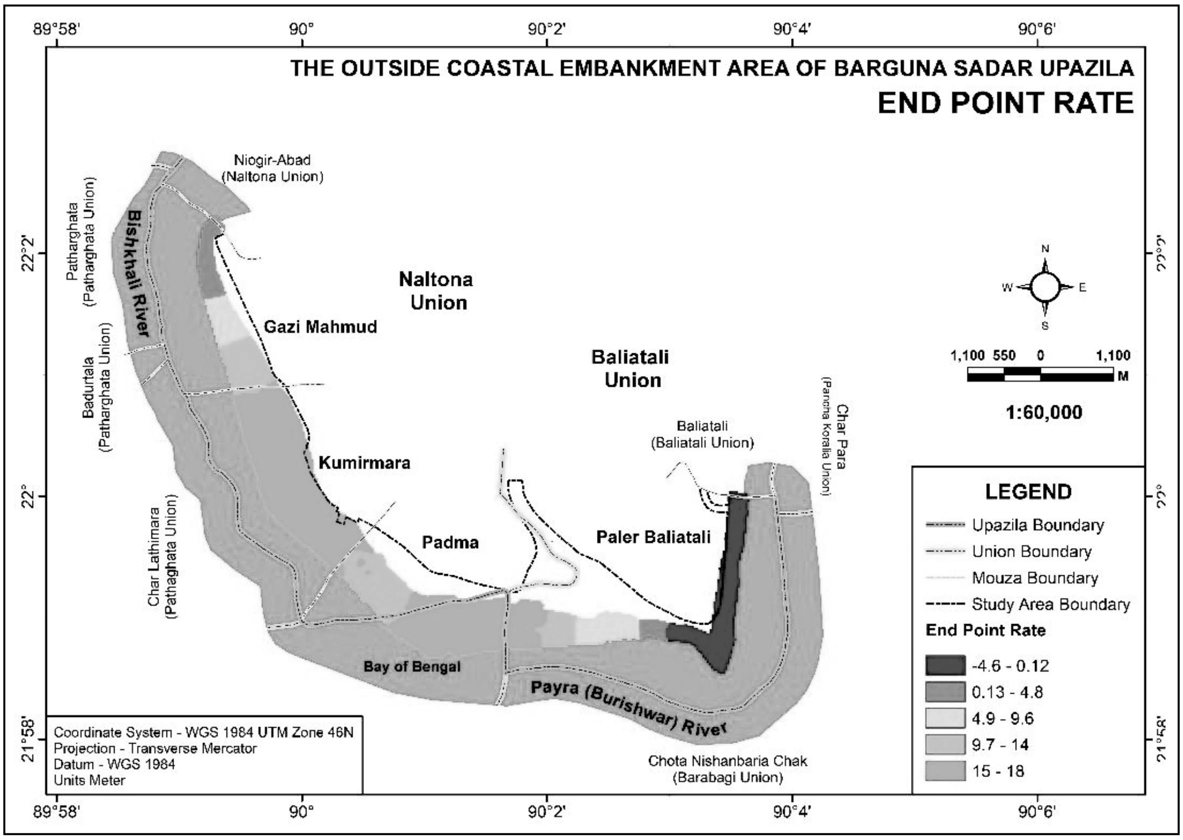


Figure 7 - End Point Rate of the Study Area

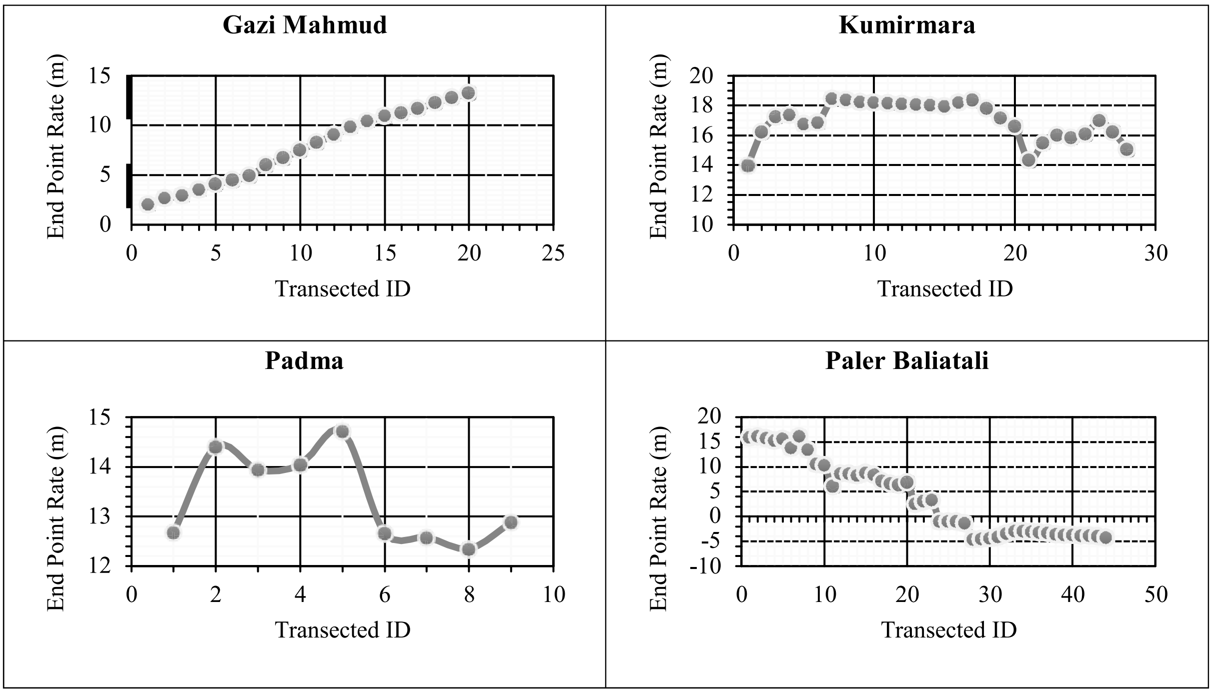


Figure 8 - Area wise EPR

3.4. Shifting Pattern of Shoreline

From the analysis of the shifting pattern of the study area, it is found that the deposition rate was higher at Gazi Mahmud area (54.88 hectares) in the period between 1980 and 1988. But that pattern was shifted towards Kumirmara in the next four years (1988 to 1992). During that period, this area gained 16.30 hectares of land and the processes of accretion continued till 1997. After that period, erosion and accretion were equally active in the study area. Then, in the last five years (2012 to 2017), the accretion rate was found much higher in the estuary of Bishkhali River, Bay of Bengal, and Payra (Burishwar) river (Figure 9).

So, this analysis suggested that land extended towards the south-east in the year between 1980 and 1988, whereas this pattern slowly shifted to the south-west in the last five years.

3.5. Vulnerability Level based on Shoreline Change

Based on the rate of shoreline changing rate, it is found that Kumirmara and Padma are free from the risk of shoreline shifting as the movement is positive (Figure 10). About 37.64% and 62.36% are fallen into the very low and low vulnerability categories at Gazi Mahmud area. The high vulnerability category found on the western side of Paler Baliatali (30.89%). The very low, low, and moderate categories are found in about 34%, 28.19%, and 6.92% area respectively.

Overall, it is identified through spatial analysis that about 64.85% area is fallen into the very low vulnerability category, whereas 19.41%, 2.88%, and 12.86% represented low, moderate, and high categories respectively (Table 7).

4. Discussion

The shoreline length is increased from the period of 1980 to 2017 along with study area gains new land. It is observed that the highest accretion has occurred between 2012 to 2017 period (190.16 hectares) and the highest erosion is observed between 1997 to 2002 (39.66 hectares). The area is 414.47, 557.57, 572.77, 688.03, 649.83, 683.51, 673.42, and 863.57 hectares in the period of 1980, 1988, 1992, 1997, 2002, 2007, 2012, and 2017. This indicated that the land mass is increased in study area. The net shoreline movement of the study area is seaward.

Figure 8 shows that the movement is high in the south and south-eastern part of the study area. In the eastern part, the movement is towards the inland. It is estimated that the rate of shoreline change is - 4.6 m to 19 m per year. The highest positive changing rate is found at Kumirmara area (13.96 m to 18.36 m per year). Based on the changing rate, it is observed that the vulnerability level is very low at Kumirmara and Padma area, whereas the vulnerability level is low at Gazi Mahmud area. At Paler Baliatali, the south-western part is fallen into a very low category, and the eastern part falls into the high category (Figure 10).

SHIFTING PATTERN OF SHORELINE

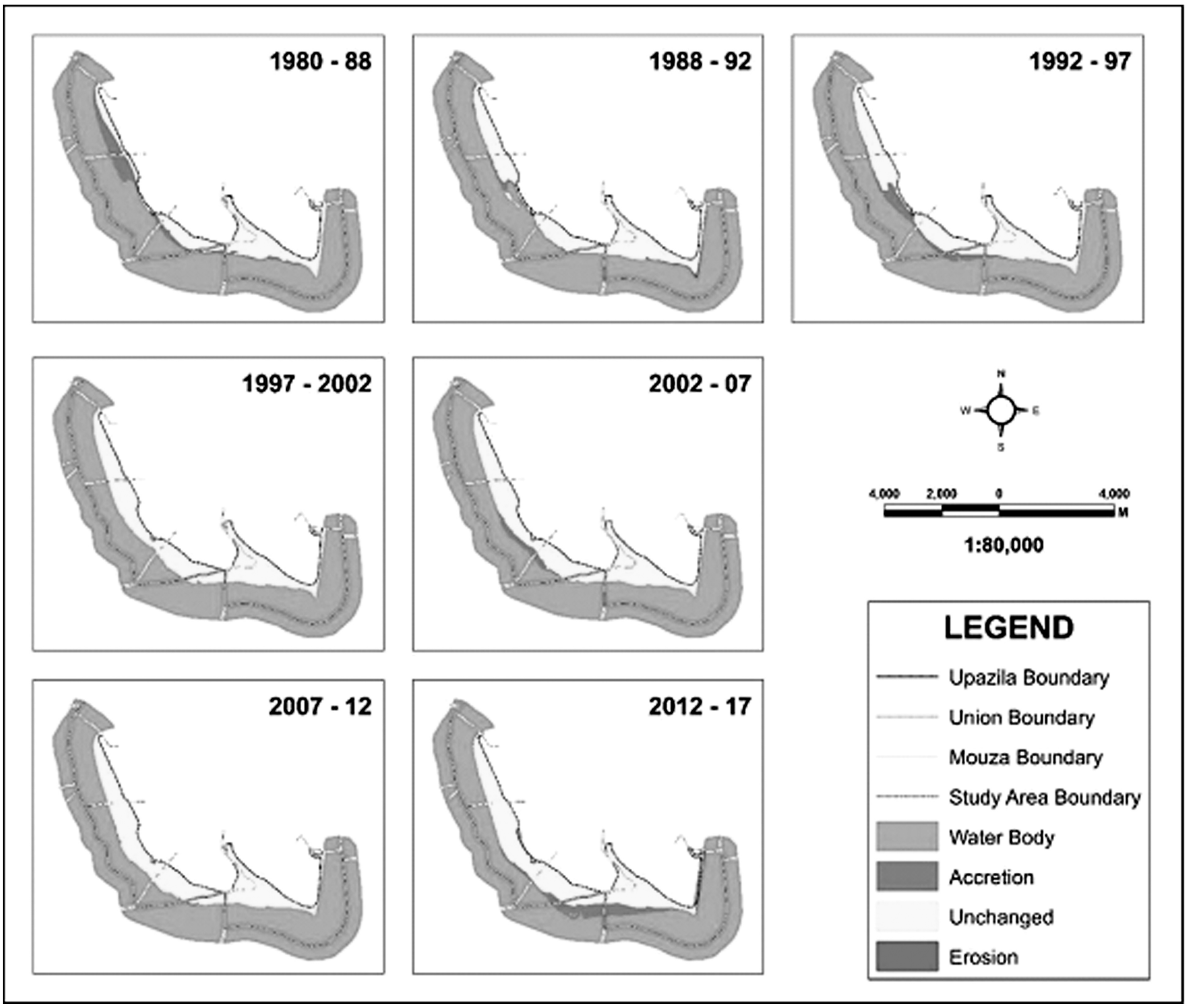


Figure 9 - Erosion Accretion in the Study Area

Table 7 - Vulnerable Area (hectares) based on Shoreline Change

Level of Vulnerability	Gazi Mahmud	Kumirmara	Padma	Paler Baliatali	Total
Very Low	39.06	211.75	176.78	119.43	547.03
Low	64.72	0	0	99.00	163.73
Moderate	0	0	0	24.32	24.32
High	0	0	0	108.50	108.50
Very High	0	0	0	0	0

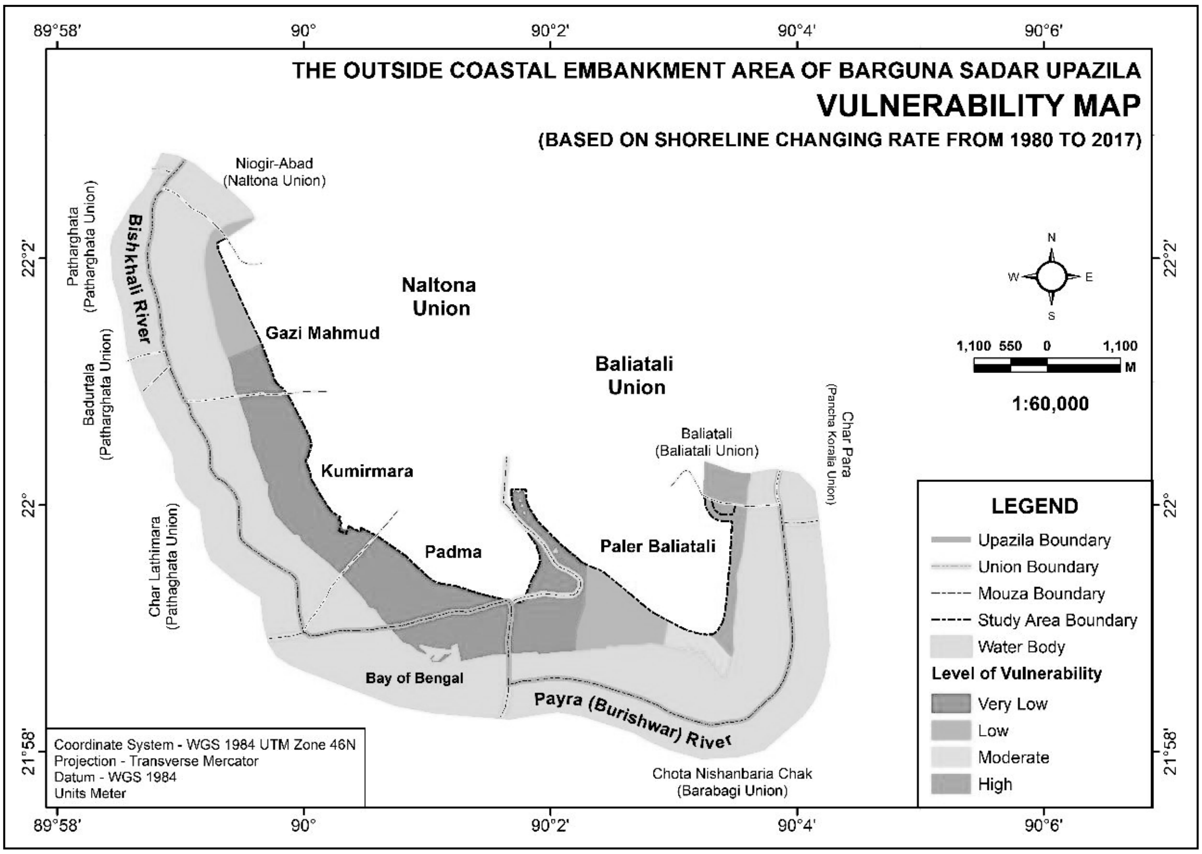


Figure 10 -Vulnerability Map based on Shoreline Changing Rate

5. Conclusion

This study is conducted to delineate the shoreline change outside of the coastal embankment Barguna Sadar Upazila, Bangladesh. The geospatial technique, NDWI, was followed to identify the land and water of the study area from the Landsat images of 1990 to 2017. It is found that the study area gained almost 449.1 hectares of land wherein the length of the shoreline is also increased (1.05 km). The analysis revealed that accretion process is highly active rather than erosion, due to that reason the vulnerability level based on shoreline change is low.

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