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Inventorying the Dynamics of Shoreline Changes of the Maheshkhali Island, Cox's Bazar, Bangladesh

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Abstract: This study mainly focused on the exploration of spatial and temporal dynamics of the shoreline change of the Maheshkhaki Island. Besides this, what is the scenario of erosion and accretional processes along the shorelines that has been illustrated. Shoreline is generally defined as the confluence place of landmass and waterbodies is considered to be one of the most dynamic processes in the coastal zone. Maheshkhali is an offshore Island of the Bay of Bengal and it is a unique island due to its geophysical locations. The Eastern and North-eastern part of the island is separated from mainland by a narrow channel and western part of the Island is open to the see. So, Strong wave actions as well as wind movement is prevalent in the western part. Remote sensing tools and techniques are the significant platform for processing the satellite imageries for identifying the shoreline changes. Landsat Multi-spectral Scanner (MSS) imageries have used for 1972, near infrared band (NIR, Band-4) is effective for shoreline detection. Landsat TM imagery of 1996 and Landsat OLI imagery of 2020 have been used for image data, near infrared (NIR, band 5) is effective for shoreline detection. 20 cross-sections have been taken and the width distance of each cross section has been measured for analysing the shoreline shifting direction and pattern. The total erosion and accretion from 1972 to 2020 are 1633.28 hectares and 2254.62 hectares respectively. The percentage of variation between erosion and accretion is (+) 38.04%, which indicates overall the accretion level is higher than the erosion level. The substantial shoreline shifting has been occurred in cross-section (XS)-9 due to erosion and accretion where the amount of shifting is (-) 4.38 kms from the sea to land and (+) 3.21 kms from interior land to the sea respectively. Overall, for all cross-sections, most of the shifting tendency has been observed in the western part of the Island.

Keywords: Shoreline shifting, change detection, erosion and accretion, cross-sections

Introduction

Shoreline is generally defined as the confluence place of landmass and waterbodies (Dolan et al. 1980 and Horikawa 1988), is considered to be one of the most dynamic processes in the coastal zone. Remote sensing provides a way for swift identification of the coastlines at comparatively low cost. Frequent observations over the years support a complete quantification of shoreline changes (Patel and Bhandari, 2018). Shoreline is dependent on frequent changes due to natural reason and anthropogenic interference in coastal areas. Identifying the region susceptible to erosion and quantifying its extent is necessary for

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coastal zone management. Shorelines are always vulnerable to changes due to coastal processes, which are influenced by wave action, sediment characteristics, beach forms, etc. (Kumar et. al., 2010). Shoreline is subjected to continuous changes due to natural causes and anthropogenic interventions in coastal areas. Identifying the region vulnerable to erosion and quantifying its extent is essential for coastal zone management (Patel and Bhandari, 2018). Maheshkhali is an offshore island of the Bay of Bengal. It is the only hilly island of Bangladesh. The Eastern and North-eastern part of the island is separated from mainland by a narrow channel and western part of the Island is open to the sea. Strong wave actions as well as wind movement is prevalent in the western part. Few years ago, this island was connected to the mainland by bridge. Consequently, the coastal resources along the shoreline, such as, mangroves, hills and others have been more exposed to the people of surrounding places for the utilization. So, this part of the island is more dynamic than eastern part in terms of shoreline and other geomorphic changes. From the economic and environmental point of view, coastal management and development including shoreline monitoring are significant. Through this, it has been tried to explore the shoreline shifting and pattern of changes from 1972 to 2020 including the geomorphological changes along the shoreline of the Island.

Aims and Objectives

The main aim of this research project is to detect the shoreline changes, erosional and accretional features along the shoreline of the island. To fulfill this aim, the specific objectives are as follows.

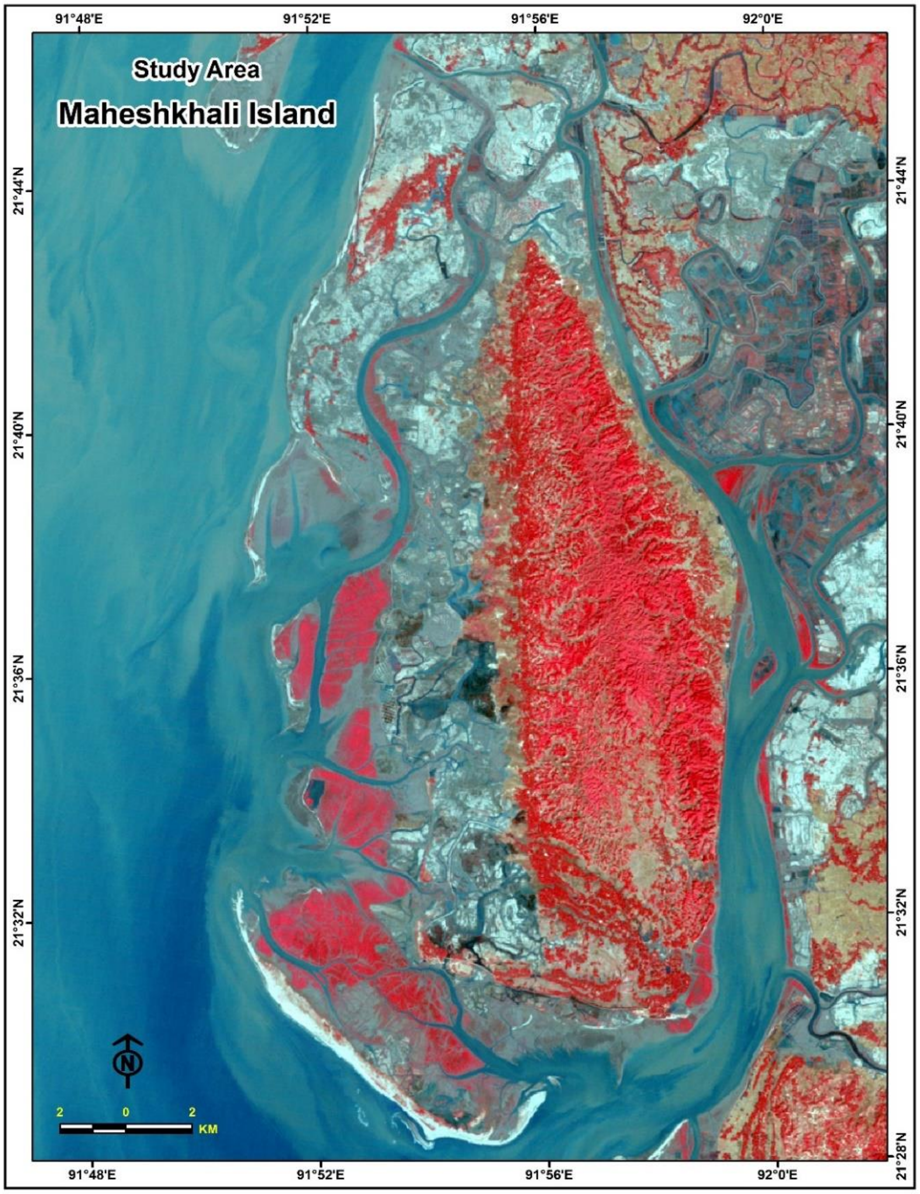
i. To demarcate the shoreline of the Island using satellite imageries for 1972, 1996, and 2020 and

ii. To identify and measure the erosional and accretional features illustrating the cross-sections across the shorelines for the mentioned period of time.

Study Area: Maheshkhali Island

The Maheshkhali Island lies within 21°20/ N - 21°50/N latitude and 91°45/E - 92°00 E longitude and bordered by Chakoria and Cox's Bazar in the north, north-eastern eastern and south-eastern part across the Maheshkhali channel. The Kutubdia channel splits Moheshkhali Island from Kutubdia in the north-western side and extreme western and south-western part is open to the Bay of Bengal.

Map 1: Study Area of the Maheshkhali Island



Source: Earthexplorer.usgs.gov; prepared by author using Erdas Imagine and ArcMap 10.5

The island is partitioned into four sections i.e., active coastal plain, young coastal plain, old coastal plain, and hills with piedmont plain. Two different depositional systems exist in the Moheshkhali Island- closed to semi closed system in the southern part and open to semi closed system in the northern part (Majlis et al., 2011).

Data and Methods

There are some technical approaches have been applied to investigate the dynamics of shoreline and its spatial change from 1972 to 2020. These approaches run sequentially step-by-step using several techniques and processes. Firstly, Landsat MSS, TM and OLI images have been collected from *earthexplorer.usgs.gov* website. Next, all layers of the images have been layer stacked using Eradas imagine 2014. Then, data has been altered into vector data set by using GIS tools (ArcMap 10.5). Satellite imageries of Landsat series at the same time for each time interval. For analyzing the data, same band combination has been utilized.

Table 1 Satellite images with their sensor, acquisition dates and spatial resolution (meter)

Date of acquisition	Sensor	Spatial resolution	Row	Path
18/12/2020	OLI/TIRS	30×30	45	136
16/12/1996	TM	30×30	45	136
27/12/1972	MSS	60×60	45	146

Landsat Multi-spectral Scanner (MSS) imageries have been used for 1972, near infrared band (NIR, Band-4) is effective for shoreline detection. Landsat TM imagery of 1996 and Landsat OLI imagery of 2020 have been used for image data, near infrared (NIR, band 5) is useful for shoreline recognition. Bangladesh Transverse Mercator (BTM) have been used as coordinate system for spatial analysis.

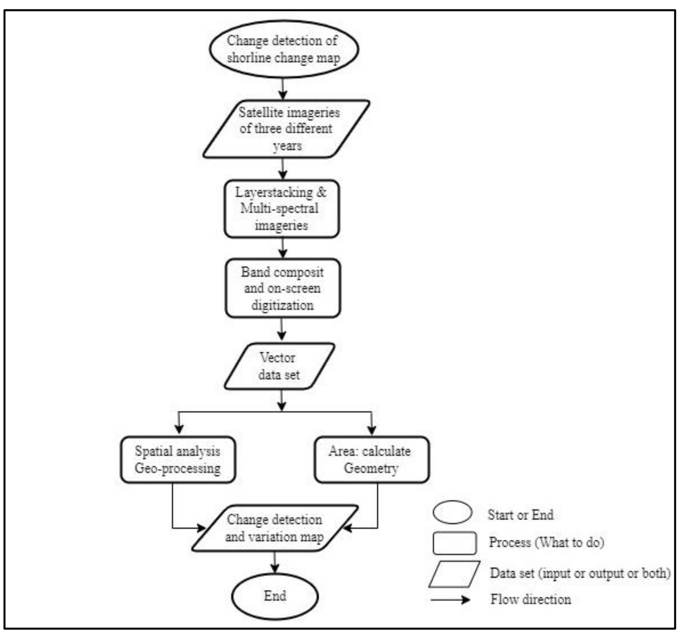
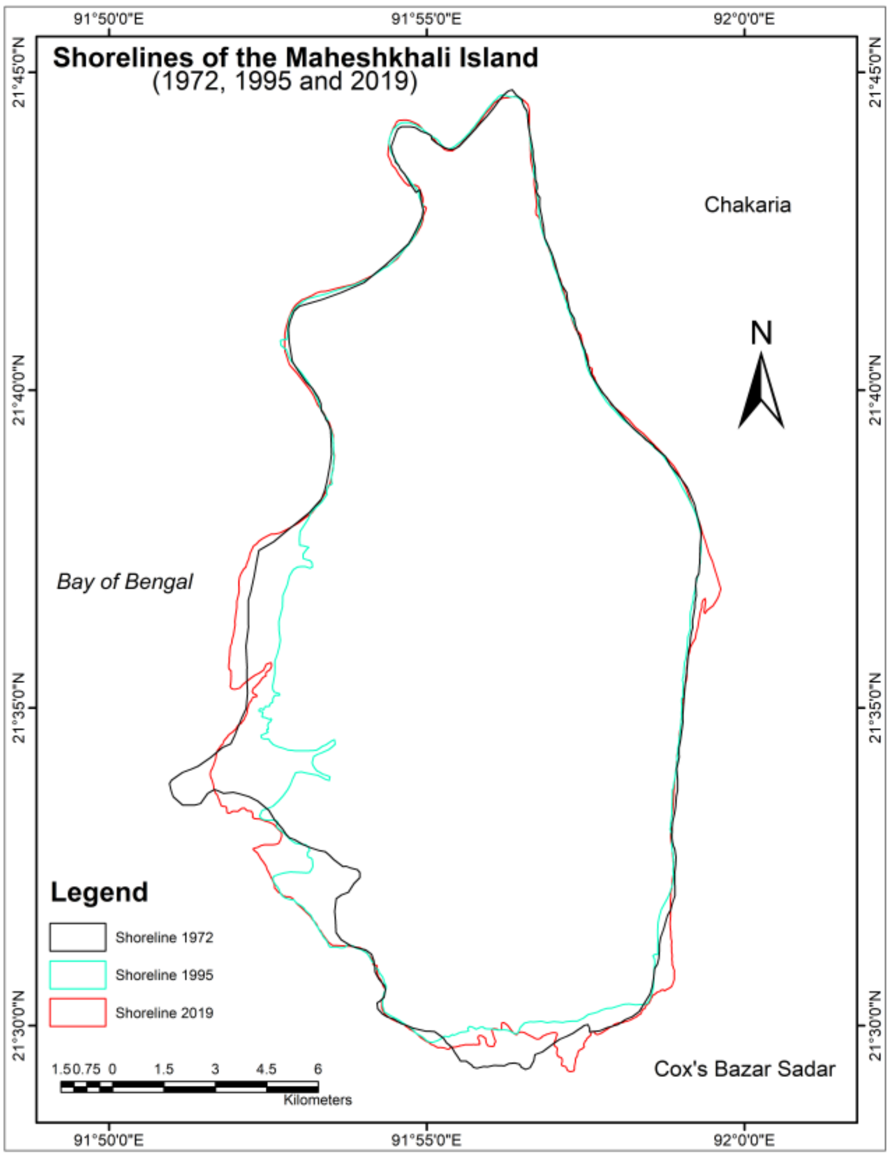


Figure 1: Flowchart of the data processing approaches, tools and techniques.

Results and Discussions

Demarcation of Shoreline of the Maheshkhali Island: The shoreline of the Maheshkhali Island has been demarcated (1972, 1996 and 2020) using the satellite imageries which has been illustrated in Map 2. Here, it is clear that the shorelines of the Island have been changed in three different landmark years. The changes of shorelines are more noticeable in the western and the southern part of the Island. In 1972, the total area of the interior of the island was 23,448 hectares, whereas in 2020, it was 24,071 hectares. Overall, the area of the island has been increased which has been shown in table 1.

Map 2: Shorelines of the Maheshkhali Island



Source: earthexplorer.usgs.gov; prepared by author using Erdas Imagine and ArcMap 10.5

Table 1: Areal extent of Maheshkhali Island (1972, 1996 and 2020).

Year	Maheshkhali Area (Hectare)
1972	23448
1996	22265
2020	24071

Source: Landsat Imageries prepared by author using Erdas Imagine and ArcMap 10.5

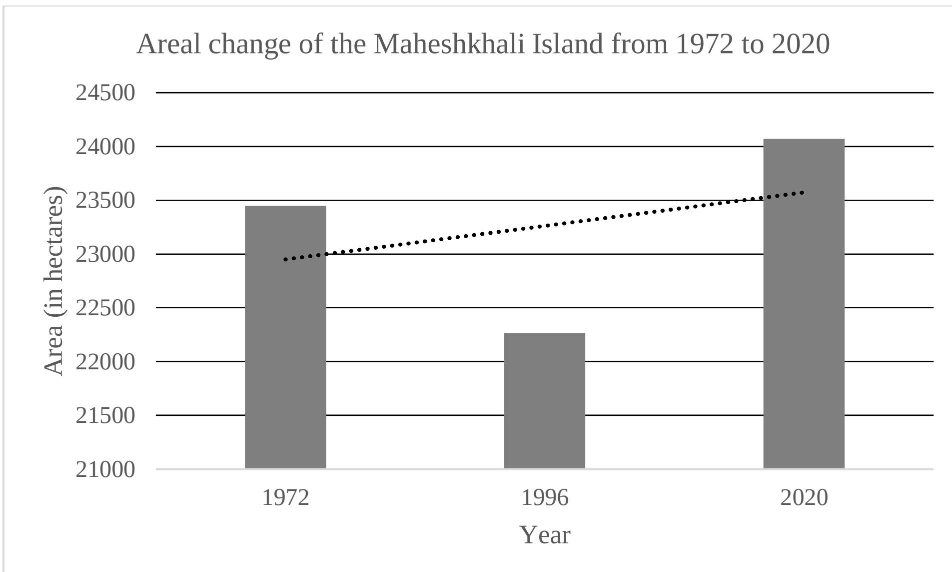
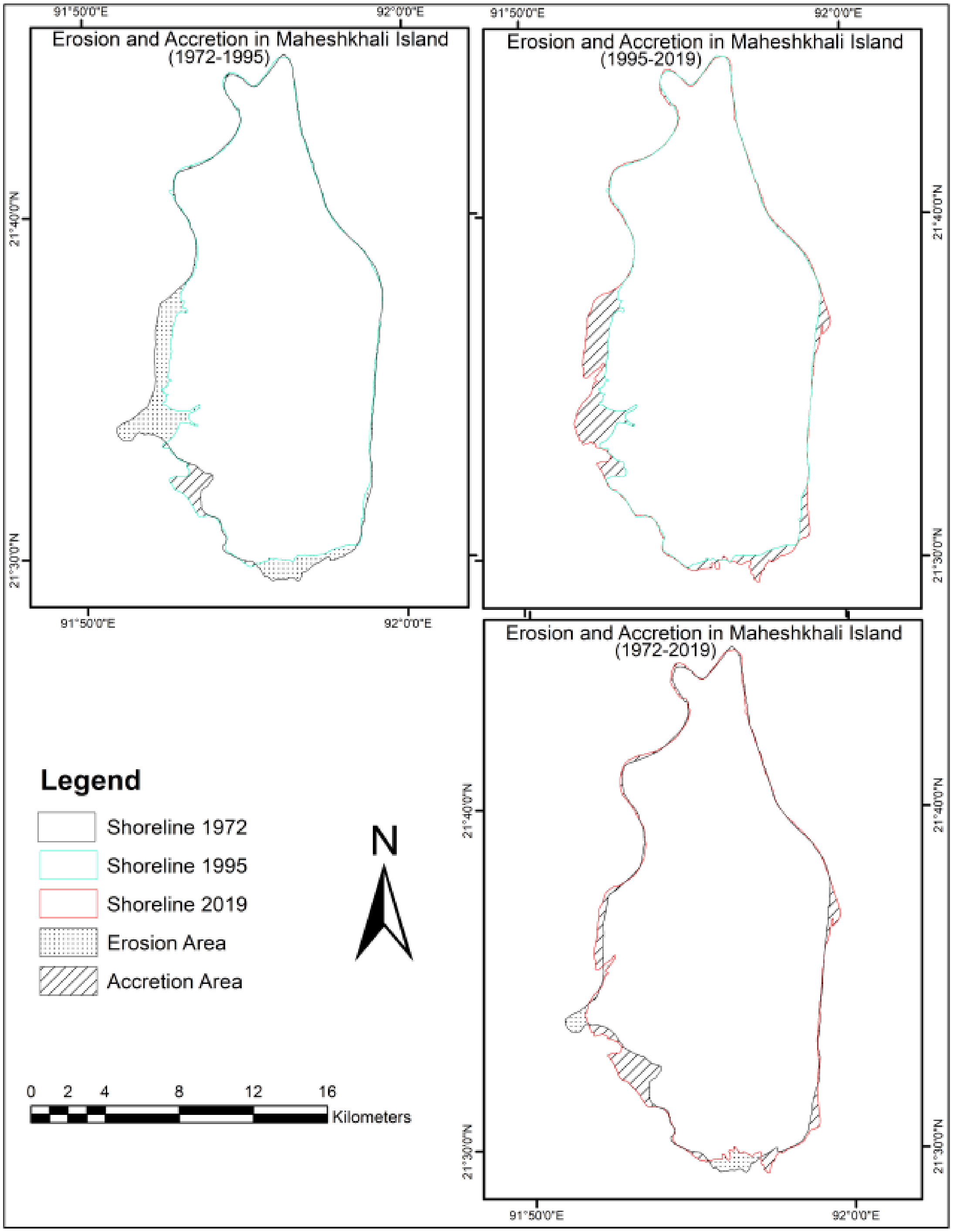


Figure: Areal extent of Maheshkhali Island (1972, 1996 and 2020); Source: Satellite Imageries using Erdas Imagine and ArcMap 10.5

Erosion and Accretion along the shoreline of the Maheshkhali Island (1972-1996, 1996-2020 and 1972-2020)

According to the map 3 and table 2, it is observed that most of the erosion ad accretion has been taken place in the western and the southern part of the Island. From 1972 to 1996, the erosion was dominant, and the total amount land erosion is 1585.21 hectares whereas the total accretion is 400.64 hectares. So, the variation between erosion and accretion is substantial. The variation of percentage between erosion and accretion is -74.73%. Besides, from 1996 to 2020, the accretion was dominant, and the amount of accretion is 1853.98 hectares whereas the amount of erosion is only 48.07 hectares. So, the percentage of variation is +3756.83% which indicates a remarkable geomorphic change regarding shoreline changes. Overall, from 1972 to 2020, the accretion is dominant along the shorelines of the Island.

Map 3: Erosion and Accretion along the shoreline of the Maheshkhali Island (1972-1996, 1996-2020 and 1972-2020)



Source: earthexplorer.usgs.gov; prepared by author using Erdas Imagine and ArcMap 10.5

Table 2: Erosion and Accretion along the shoreline of the Maheshkhali Island (1972-1996, 1996-2020 and 1972-2020)

Year	Area of Erosion and Accretion (hectare)		Variation (in hectare)	Variation (%)
	Erosion	Accretion		
1972-1996	-1585.21	+400.64	-1184.57	-74.73
1996-2020	-48.07	+1853.98	+1805.91	+3756.83
1972-2020	- 1633.28	+ 2254.62	+ 621.34	+ 38.04

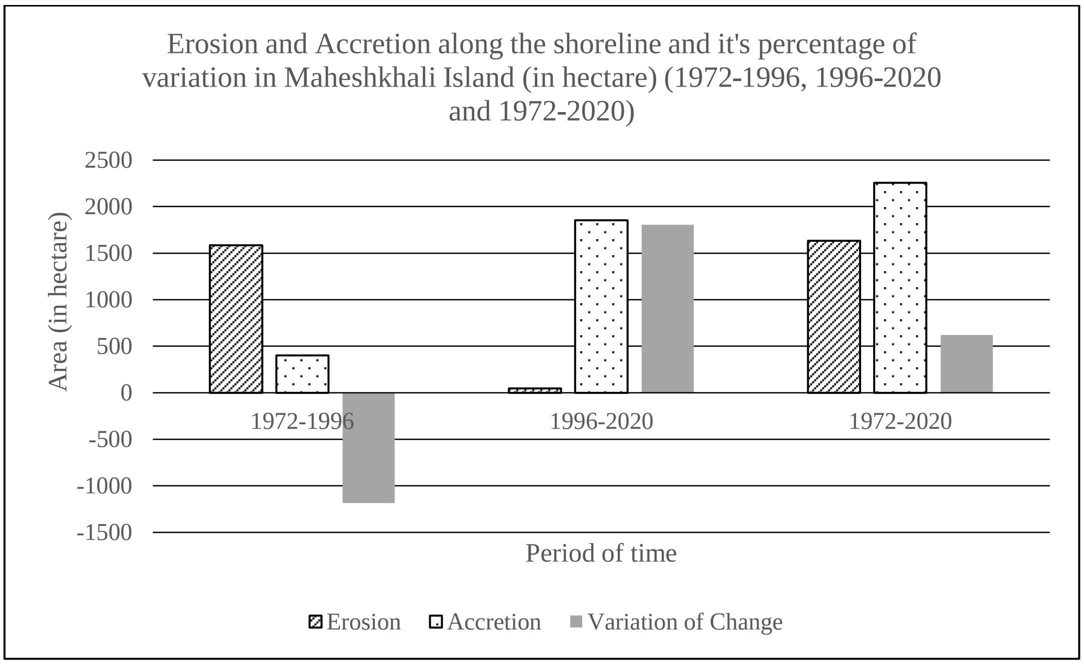


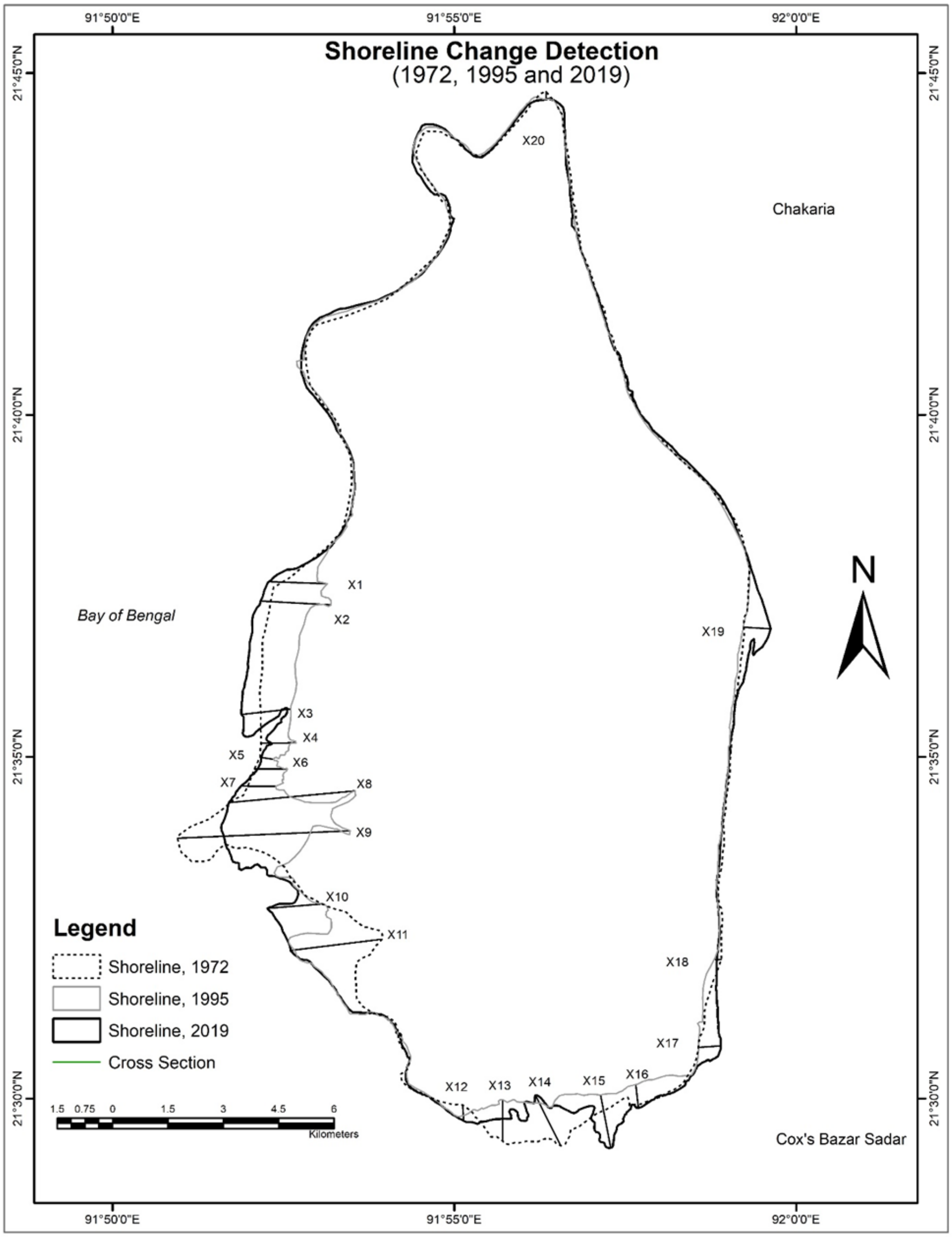
Figure 3: Erosion and Accretion along the shoreline of the Maheshkhali Island (1972-1996, 1996-2020 and 1972-2020)

Source: Satellite Imageries using Erdas Imagine and ArcMap 10.5

Shoreline change detection from 1972 to 2020

It is depicted by the Map 4 and Table 3, there are 20 cross-sections has been taken along the shorelines of the island. Mainly, these cross-sections have been taken considering locations where substantial changes occurred for identifying the directions of shoreline changes. From 1972 to 1996, Within the 20 cross-sections, 18 cross-sections are dominant for erosion. On the contrary, all cross-sections are accretion dominant except two.

Map 4: Shoreline Change Detection (1972, 1996 and 2020)



Source: earthexplorer.usgs.gov; prepared by author using Erdas Imagine and ArcMap 10.5

Table 3: Cross-sections and its changing values (km) from land to sea (+) or sea to land (-)

Cross Section	1972-1996	1996-2020	1972-2020
XS-1	-1.14	1.47	0.33
XS-2	-1.53	**1.79**	0.26
XS-3	-0.77	1.26	0.49
XS-4	-0.88	0.63	-0.25
XS-5	-0.35	0.31	-0.04
XS-6	-0.83	0.75	-0.08
XS-7	-0.71	0.88	0.17
XS-8	-3.16	3.19	0.03
XS-9	-4.36	3.21	-1.15
XS-10	-0.05	1.42	1.37
XS-11	2.25	0.09	2.34
XS-12	0.29	0.15	0.44
XS-13	-1.11	0.51	-0.60
XS-14	-1.26	-0.23	-1.49
XS-15	-0.44	1.45	1.01
XS-16	0.01	0.57	0.58
XS-17	-0.54	0.63	0.09
XS-18	-0.17	0.07	-0.10
XS-19	-0.01	0.69	0.68
XS-20	-0.20	-0.01	-0.21

Source: Satellite Imageries using Erdas Imagine and ArcMap 10.5

It is depicted by the figure 4 and table 3, in 1972 to 1996, the accretion is occurred in XS-11 and it is the largest, such as-2.25 kms and the smallest accretion is occurred in XS-12 and the amount is 0.29 kms. Therefore, the shoreline has been changed in these two cross-sections from interior land to seaward. Again, the highest and the lowest erosion has been taken place in XS-9 and XS-19 respectively. So, here, the shoreline has been changed 4.36 kms and 0.01 km from seaward to interior landward.

From 1996 to 2020, the highest accretion is occurred in XS-9 and the lowest accretion is occurred in XS-18. The amounts are 3.21 kms and 0.07 km respectively and the shoreline has been changed from interior land to seaward. On the contrary, the only erosion occurred in XS-14, where the amount is 0.23 km from the sea to interior landward.

Overall, from 1972 to 2020, among the 20 cross-sections, 12 XS are dominant for accretion and the remaining 8 XS are dominant for erosion. In this period, the highest accretion has been taken place in XS-11 and the lowest accretion has been taken place in XS-8. The amount of these two cross-section points is 2.34 kms and 0.03 km respectively where the shoreline is changed from interior land to seaward. For this period, the highest erosion occurred in XS-14 where the shoreline has been changed 1.49 kms from the sea to landward and the lowest erosion occurred in XS-5 where the shoreline has been shifted 0.04 km from the sea to interior land of the Island.

It has been depicted by the map 4 that all the cross-sections (xs-1, xs-2, xs-3, xs-4, xs-5, xs-6, xs-7, xs-8, xs-9, xs-10, xs-11, xs-12, xs-13, xs-14, xs-15, xs-16, xs-17, xs-18) are taken from the western and the southern part of the Island except two (xs-19 and xs-20) cross-sections which are located the north and eastern side of the Island. In addition, major shoreline changes are also occurred in the western and southern part. It has been happened due to the geo-physical location of the Island. As the western and southern part of the Island is open to the sea, so strong wind and wave actions are active in these parts. Consequently, these parts of the Island are geomorphologically dynamic and unstable. The pattern of coastline in these sides is meander due to the effect of different geomorphic processes.

Besides, the island is gradually lower elevated from the east to south and from north to south. Most of the mangrove forests is developed in the western and southern part of the island along the shorelines. So, all the eroded sediments (matter) transported from the eastern higher elevated area (Hilly area) are in the lower elevated western and southern part of the Island. The mangrove forest located in these sides is very significant for sediments deposition in these sides. Because mangroves protect the sediments from mixing with the sea water and settles down the transported sediments from the upper story of the hills.

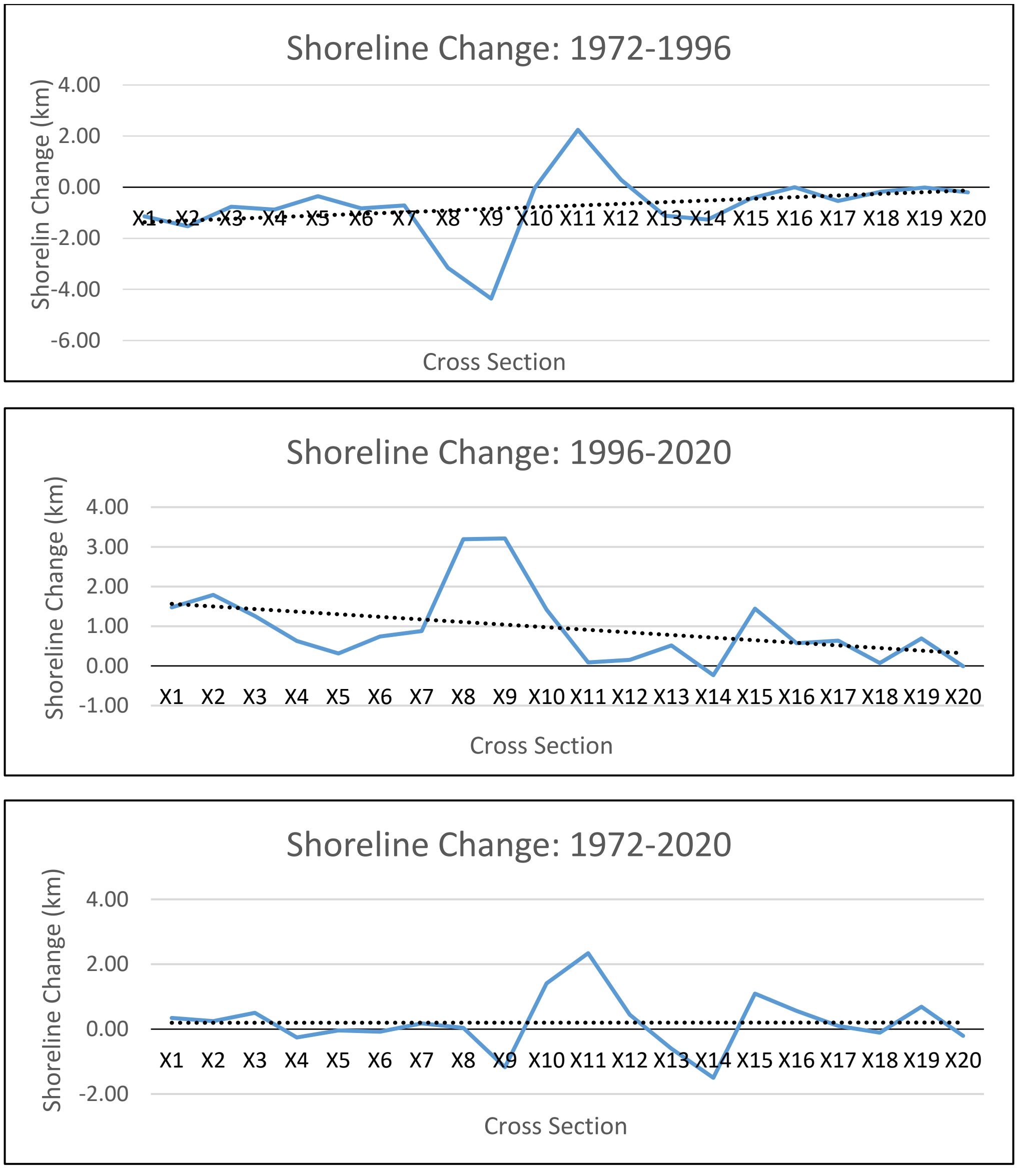


Figure 4: Shoreline Changes 1972-1996, 1996-2020 and 1972-2020; Source: Satellite Imageries using Erdas Imagine and ArcMap 10.5

From the table 4 and figure 5, it has been observed that for the period of 1972 to 1996, the total shifting of shoreline from the sea to interior land is 1.03 kms and shifting from land to sea 0.85 km. Therefore, in this period, total erosion is higher than the total accretion along the shoreline of the Island. From the period of 1996 to 2020, the total shifting of shoreline is 1.06 kms from land to the sea and shifting from the sea to land is only 0.12 km.

So, in this period, erosion is minimum and the accretion much higher than the erosion. In addition, within the whole period of 1972 to 2020, the total shifting of shoreline from land to the sea is due to accretion is 1.91 kms and shifting from the sea to land due to erosion is 1.15 kms. Therefore, within the whole period of 1972 to 2020, accretion is higher than erosion along the shoreline of the Island.

Table 4: Shoreline change detection from 1972 to 2020

Period	**Land to Sea (km) (Accretion)**	**Sea to Land (km) (Erosion)**
1972-1996	+ 0.85	- 1.03
1996-2020	+ 1.06	- 0.12
1972-2020	+ 1.91	- 1.15

Source: Satellite Imageries using Erdas Imagine and ArcMap 10.5

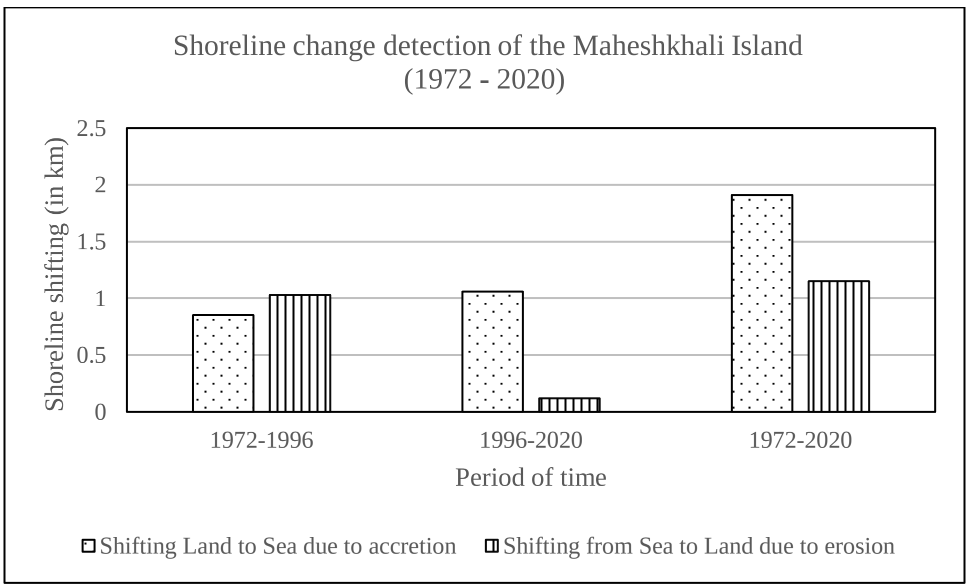


Figure 5: Maheshkhali Shoreline change detection (1972 - 2020); Source: Satellite Imageries using Erdas Imagine and ArcMap 10.5

Findings

The specific findings are:

The shorelines of the Maheshkhali Island for the years 1972, 1996 and 2020 have been demarcated by satellite image interpretations using Erdas imagine and ArcMap 10.5. There is a substantial erosion and accretion has been identified along the shoreline. For the period of 1972 to 1996, the erosion (-), accretion (+) and percentage of variation (%) are 1585.21 hectares, 400.64 hectares, -74.73% respectively. For the period of 1996 to 2020, the erosion (-), accretion (+) and percentage of variation (%) are 48.07 hectares, 1853.98 hectares, and, 3756.83% respectively. Overall, for the period of 1972 to 2020, the erosion (-), accretion

(+) and percentage of variation (%) are 1633.28 hectares, 2254.62 hectares and +38.04 % respectively.

For most of the cross-sections, it has been observed that the western part of the island is more unstable than the eastern part. The highest change of shoreline has been observed in the period of 1996 to 2020 and it is +1.06 km from the land to sea. The overall change is from land to see 1.91 kms and see to land is 1.15 kms.

Conclusion

Maheshkhali is potential for its historical places and its natural scenic beauty. This island attracts many tourists from the different parts of the country. Due to its geo-physical location, this island has several unique characteristics, and its shoreline is gradually changing which is very precise. So, this paper would be a significant document for the authority who have the responsibility of monitoring shoreline changes for coastal development and management. As the dynamism of shoreline, over the years, several coastal lands have been emerged and submerged. But fact is that the total land of the island should be updated and preserve an archive which would be monitored by the local authority. There is a limitation for this sort of study that sometimes, the appropriate expected satellite imagery is not found in the different archives of the online platform. So, it would be better applying a suitable index for the identification of shoreline and its justification via any statistical coefficients.

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