AN APPLICATION OF GEOINFORMATICS INTEGRATED WITH DSAS FOR ANALYSIS OF COASTAL EROSION ALONG RUSHIKULYA RIVER MOUTH IN EASTERN COASTAL INDIA

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ABSTRACT

In the context of present world climate change scenario, coastal erosion is a serious matter of concern. The shoreline geometry is impacted by coastal processes and agents that include waves, tides, storms, tectonic and physical processes. The coastal erosion is caused by a combination of nature and human actions. In this context, the estuarine regions are vulnerable ones as they represent special ecosystems in terms of economic activities and ecological resources Geoinformatics has proved to be revolutionary tools for such monitoring and analysis of changes along coastal areas. Studies also reveal that Remote Sensing (multi temporal satellite images), GPS and GIS, integrated with DSAS has demonstrated to be very effective tools for analyzing shore line changes and coastal erosion. Present research has attempted to analyze the costal erosion patterns using remote sensing – multi temporal satellite images, GIS and DSAS for Rushikulya estuary lying in Odisha state along eastern coastal India. Rushikulya estuary is one of the major mass nesting sites of Olive Ridley sea turtles, which is now being impacted by landuse / landcover changes, extreme weather events and significant loss of nesting sites due to erosion. From the present study it has been observed that the coast along Rushikulya estuary area in Ganjam district of Odisha has undergone high erosion prior to 1999 and accretion is more prevalent during recent years.

Keywords: Geoinformatics, GIS, DSAS, Remote Sensing, Coastal Erosion, Shoreline Change.

INTRODUCTION

In the context of present world climate change scenario, Coastal erosion is a serious matter of concern. An estuary is defined as an area where rivers and streams bringing fresh water combine with saline water from the sea to make the estuarine region characterised by brackish water with its own special ecosystem. The nearby lands and estuaries are places of transformation from land to sea. Estuaries have important role in commercial and economical activities. It has vital role in transportation and shipping. In the vision of environmental protection, it also protects the sea from pollutants and sediments from land and due to estuary, land is being protected from storms and floods. Estuaries have been considered as economic centres of coastal communities as these areas are the better place for fishing and suitable for breeding grounds for fish and birds. In recent year studies it has been found that coastal regions are densely populated as coastal areas are rich in fisheries and sea food and highly vegetative. Presently almost about 40% of the total population in world living near to coast. From the past studies, it has been noticed that estuarine land has faced serious notable variations in the last few decades specifically due to substantial environmental change by human activity. The coastal processes like erosion, accretion, movement of sand dunes, longshore drift, tide, wave and storm surge affects the coastline and estuary morphology.

"Coastal shoreline is defined as the interface between land and sea. It changes variably due to various morphological, climatological or geological factors" (Oyedotum, 2014). The shoreline geometry is impacted by coastal processes and agents that include waves, tides, storms, tectonic and physical processes. The resultant erosion or accretion poses threat to coastal communities, infrastructure, resources and ecosystem (Oyedotum, 2014). "The coastal erosion is caused by a combination of nature and human actions" (Isha and Adib, 2020). In this context, the estuarine regions are vulnerable ones as they represent special ecosystems in terms of economic activities and ecological resources. So periodical monitoring of shoreline geometry is essential to identify coastal erosion, accretion and vulnerable locations.

In this context, the state of the art Geoinformatics has proved to be revolutionary tools for such monitoring and analysis of changes along coastal areas. The Geoinformatics or geospatial technology is a development of information technology application in geospatial sciences that enables the geospatial scientists to precisely locate and map the spatio-temporal phenomena and objects on earth so that their spatio-temporal change identification and monitoring can be done in an enhanced manner. Geoinformatics comprises of tools like Remote Sensing, Global Positioning System (GPS), Geographical Information System (GIS) and other geospatial technology/ tools. Remote Sensing and GPS help in earth surface data collection, precise location and mapping of various geospatial objects and phenomena. GIS helps in organizing, data, storage of geospatial data, its processing, analysis, simulating real world scenario and effective presentation of results in terms of dynamic digital maps. Several earlier studies have proved the tremendous efficiency of Geoinformatics in mapping and analyzing shore line geometry and coastal erosion.

Another development of Geoinformatics is tool developed by United States Geological Society, i.e. Digital Shoreline Analysis System (DSAS). “The DSAS is a GIS tool used for historical trend analysis (HTA) to study the changes in shoreline geometry” (Oyedotum, 2014). It has been developed, updated and upgraded to be used with ESRI GIS softwares (ArcView to ARCGIS). “The studies reveal that the GIS integrated with DSAS has been used in costal studies for historical record of coastline dynamics, shoreline variation, erosion, changes, gully development and evolution studies, cliff, retreat and erosion studies and shoreline cliff modelling studies” (Oyedotum, 2014). The several other studies also reveal that Remote Sensing (multi temporal satellite images), GPS and GIS, integrated with DSAS has demonstrated to be very effective tools for analyzing shore line changes and coastal erosion (Isha and Adib, 2020; Baig et al., 2020; Paul et al., 2024). So the present research has attempted to analyze the costal erosion patterns using remote sensing – multi temporal satellite images, GIS and DSAS for Rushikulya estuary lying in Odisha state along eastern coastal India.

STUDY AREA

The study area of present study is Rushikulya estuary, located in Ganjam district of Odisha state in eastern coastal India (Figure 1). The study area extends within longitude 84^{o} 50’ to 85^{o} 10’ east and latitude 19^{o} 20’ to 19^{o} 35’ north. The area is noted for its salt pans just north of the river mouth. The east coast railway line and national highway running from north to south divides the study area. Ganjam is the major town located within this area. Rushikulya River occurs as a transverse strip from east to North West in the central portion of the area. Its mouth opens to the Bay of Bengal at *Puruna Bandha* in Ganjam district. The

Baghua, the Dhanei, the Badanadi are the tributaries. The total area is roughly triangular in shape bordered by the Bay of Bengal on its hypotenuse side.

"Olive Ridley sea turtle is an endangered species due to anthropogenic threats and shrinking of suitable nesting sites" (Mishra et al., 2021). "Rushikulya estuary is one of the major mass nesting sites of Olive Ridley sea turtles, which is now being impacted by landuse / landcover changes, extreme weather events and significant loss of nesting sites due to erosion" (Mishra et al., 2021). The Rushikulya sea turtle rookery was recognized during 1994 by Wildlife Institute of India as the second-largest rookery in Odisha for Olive Ridley sea turtle nesting (Mishra et al., 2021). The Rushikulya river mouth has been experiencing severe changes in the mouth region every year and the study focused mainly on a detailed analysis of shoreline changes at the mouth area. The area has been affected several times by various natural phenomena like torpical cyclones, flood, tidal fluctuation, due to which human settlement, Economic activities and coastal ecosystem are highly affected due to shoreline change in the areas of the river mouth.

DATA AND METHOD

The baseline map was prepared using the Survey of India (SOI) toposheet no- 74E/3 on 1: 50,000 scale. The multi-temporal Landsat satellite images acquired for the period between 1976 and 2019 were used as primary data source for shoreline extraction. Different satellite images with different sensors and spatial resolutions have been used in this research study for analysis of shoreline position and details of images have been described in Table 1. The cropped images were geometrically corrected using ERDAS Imagine 9.1 software by applying the Universal Transverse Mercator (UTM)–The World Geodetic System (WGS) 84 projection and coordinate system. Shoreline positions for several dates, i.e. 17th Feb 1976, 11th Dec 1989, 7th Dec 1999, 10th Dec 2009, and 6th Dec 2019 have been digitized manually in ArcGIS. These shoreline positions were exported to ArcGIS with attribute fields that included object identity (ID), name, date, length and feature characteristics. These multi dated shape files of shorelines were overlaid together for the identification of shoreline changes (shift towards either offshore or onshore). Then, the intersection of shoreline geometry was converted into polygon geometry using the feature to polygon conversion tool in ArcGIS for the estimation of erosion and accretion. Various techniques for mapping shoreline change have been adopted.

Pre-processing of satellite imagery

Five satellite imageries of the years 1976, 1989, 1999, 2009 and 2019 have been utilized in this study. Landsat MSS, TM & ETM+ data sets have been downloaded from the USGS and GLCF website. All the datasets are projected in UTM projection with zone no 45N and WGS 84 datum. Satellite imagery of 1976 has been considered as base data and image of 1989, 1999, 2009 and 2019 have been geo-registered using polynomial model and the study area was masked before using the image through ArcGIS 10.1. The details of satellite images used in the study have been described in Table 1.

Detection of Shoreline

The year wise shoreline has been digitized from satellite imagery in line feature. Satellite imagery is very useful to identify the shoreline position and coastal change. The shoreline digitized from the satellite images has been validated with the collected Ground Control Points using GPS. After extraction of the shoreline, the rate of shifting in shoreline has been estimated.

Quantification of Erosion

The shoreline erosion has been estimated from multi temporal satellite data for the period of 1976-1989, 1989-1999, 1999-2009 and 2009-2020 using binary change detection. To extract the accurate erosion and accretion areas, it is needed to merge the satellite images of selected years. In this study the specific model Digital Shoreline Analysis System (DSAS) has been used for measurement of erosion and accretion in ARC GIS software. In this model the net shoreline movement (NSM), end point rate (EPR), linear regression rate (LRR) can be identified which helps in delineation of change in shoreline. It is an automated method. It is helpful to user to calculate the change from multiple historical shoreline position. For this study the transect layer has been created by considering 50 meters of spacing as fixed distance. In this method the uncertainty of results increases by high spacing of transects and massive data values occurs along low distance spacing. So here 50 m spacing has been taken for the study. In this work these results have been calculated for 1976 – 2019 using End Point Rate (EPR), Net Shoreline Movement (NSM) and Linear Regression Rate (LRR).

- End Point Rate is calculated by dividing the distance of shoreline movement by the time between the oldest and recent shoreline.

  EPR (m/yr) = distance/ (time between the oldest and recent shoreline)

- Net shoreline Movement is used to calculate the distance. It denotes the distance between oldest and recent shoreline.

  NSM (m) = distance between the oldest and recent shoreline

- Linear Regression Rate is determined by fitting a least squared regression line to all shoreline points for a particular transects. LRR is the slope of line.

RESULTS AND DISCUSSION

Shoreline change map near Rushikulya river mouth has been prepared at a temporal scale of 40 years and variation of river mouth in different periods has been shown in Figure 2. The above study reveals that the shoreline change has dynamic behaviour, which has been influenced by the occurrences of cyclonic storms and wave height. In Ganjam coast there is change in length of coastline in 40 years of period for the year from 1976 to 2019. In this study DSAS tool has been used for measurement of erosion and accretion. For this the transect layer has been created by considering 50 meters of spacing as fixed distance. In this work these results have been calculated for the year between 1976- 2019. Coast under study area shows different behaviour under different time period.

For comparative analysis purpose, the study area has been divided into two separate physiographic units, namely Zone I (northern part of study area) and Zone II (southern part of the study area). These two parts are separated by Rushikulya river flowing in the middle. The maximum, minimum and average EPR and NSM values along the coast of the study area for the Zone I and Zone II have been described in Table 2 and Table 3 respectively. The results indicate that in the Zone I, maximum erosion (NSM is '-319.9') has occurred during 1989 to 1999 and maximum accretion (384.36) has occurred during 1999 to 2009. Considering the average NSM in Zone I, the period from 1989 to 1999 has remained predominantly erosion prone, followed by period from 1976 to 1989. The recent years from 1999 to 2019 are characterised by lesser erosion and higher accretion in the Zone I. While analyzing the results for Zone II, it is observed that highest erosion has occurred during 1976 to1989 and the subsequent years are predominantly characterised by accretion in Zone II. A comparative study of both parts of the study area indicates that Zone I has experienced erosion prevalence whereas Zone II has experienced accretion prevalence. Further, since the year 1999, the accretion is more predominant in study area.

In this context maps have been prepared showing predominant erosion and accretion areas with indicating maximum NSM in those areas. Map (Figure 3) depicts that a maximum erosion of 142.7 m and an accretion of 97.2 m has been observed in Zone 1 (northern part of Rushikulya river mouth) during the period 1976 to 1989 at Rushikulya estuary. In the shoreline mapping for period 1989 to 1999 (Figure 4), it has been identified that the maximum erosion in zone 1 area is ranging from 313 m to 330.4 m and accretion of 117 m has been found in zone 2 (southern part of Rushikulya river mouth) area. The map of the year 1999 to 2009 (Figure 5) shows the maximum erosion of 137.7 m and maximum accretion of 333.2 m at zone 1 area. During the period form 2009 to 2019 (Figure 6) the maximum accretions of 192.5 m and 117.9 m has been identified in zone 1 and zone 2 areas respectively. So these years have been characterised by valuable accretion along the coast of Rushikulya estuary.

As a result of the present study, at Rushikulya coast an average erosion of 14 m per year has been observed in the period 1976 to 1989, which has increased during 1989 to 1999, i.e. around 31.5 m per year. Then in the period between1999 to 2009 average erosion has decreased to about 13.7 m per year, followed by further decrease to about 7.1 m during the period 2009 to 2019. The composite shoreline map of showing predominant erosion nd accretion areas during 1976 to 2019 (Figure 7) reveals that the maximum erosion is found in zone 1 of study area (north of Rushikulya river mouth) and ranges in between 133.7 m to 211.4 m. The prevalence of erosion along the coats in study area prior to 1999 is perhaps due to greater impacts of some of the very severe tropical cyclones. The Figure 8 describes the position of Rushikulya river mouth in these years and the Table 4 describes the details of shifting of this mouth. The major changes in the position and shifting of mouth of Rushikulya river may be attributed to the major tropical cyclones during 1999, 2019 etc.

CONCLUSION

From the present study it has been observed that the coast along Rushikulya estuary area in Ganjam district of Odisha has undergone high erosion prior to 1999 and accretion is more prevalent during recent years. The factors for erosion may be attributed to tropical cyclones and anthropogenic impacts. Further, it is observed that the northern part of Rushikulya River is more prone to erosion and accretion is more prevalent in southern part. The observation on Rushikulya mouth indicates that it has shifted in both northward as well as south ward. But the distance of northward shifting is more in comparison to southward positions. The coastal erosion is driven by both natural and anthropogenic factors. However, the coastal protection measures may support to great extent in this regard for lessening impacts on coastal habitats and ecosystem. The study also demonstrates the great efficacy of Geoinformatics integrated with DSAS for such shoreline and coastal erosion analysis studies.

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Table 1: Details of Satellite Image Used in the Study

Date and Year	Path/Row	Satellite ID	Sensor	Resolution (m)
17-02-1976	150/046	Landsat 2	MSS	80
11-12-1989	140/047	Landsat 5	TM	30
07-12-1999	140/047	Landsat 5	TM	30
10-12-2009	140/047	Landsat 7	ETM+	30
06-12-2019	140/047	Landsat 7	ETM+	30

Table 2: Summary of shoreline change analysis for Zone I (Northern part of Rushikulya Estuary)

Time Period	No. Of Transect	EPR in m min	EPR in m max	EPR in m Avg.	NSM in m min	NSM in m max	NSM in m Avg.
1976 - 1989	201	-18.88	7.51	-2.71	-245.83	97.75	-35.35
1989 – 1999	221	-32.18	6.01	-6.50	-319.9	59.78	-64.62
1999 - 2009	231	-25.6	38.33	-0.5	-256.72	384.36	-5.74
2009 - 2019	233	-9.45	18.28	-0.72	-95.02	183.77	-7.31

Table 3: Summary of shoreline change analysis for Zone II (Southern part of Rushikulya Estuary)

Time Period	No. Of Transect	EPR in m min	EPR in m max	EPR in m Avg.	NSM in m min	NSM in m max	NSM in m Avg.
1976 - 1989	115	-5.73	1.01	-2.23	-74.38	13.06	-28.98
1989 – 1999	118	-3.35	11.67	2.64	-33.57	116.83	26.47
1999 - 2009	116	-4.63	4.49	1.01	-46.07	44.7	10.09
2009 - 2019	163	-1.36	30.21	4.50	-13.64	303.73	45.32

Table 4: Details about decade wise shifting of Rushikulya mouth and location

Ref. No given in Map	Year	lattitude	longitude	width (m)	Direction of movement	Distance
1	1976	19.37290	85.07586	86		
2	1989	19.36901	85.06837	114	southward	900 m from that of 1976
3	1999	19.37073	85.07252	1021	northward	Became wide over 1km
4	2009	19.38351	85.08680	254	northward	2.06 km from that in 1999
5	2019	19.37767	85.08330	303	southward	380 m from that in 2009

Figure 1: Map Showing Location of Study area (Rushikulya River Estuary)

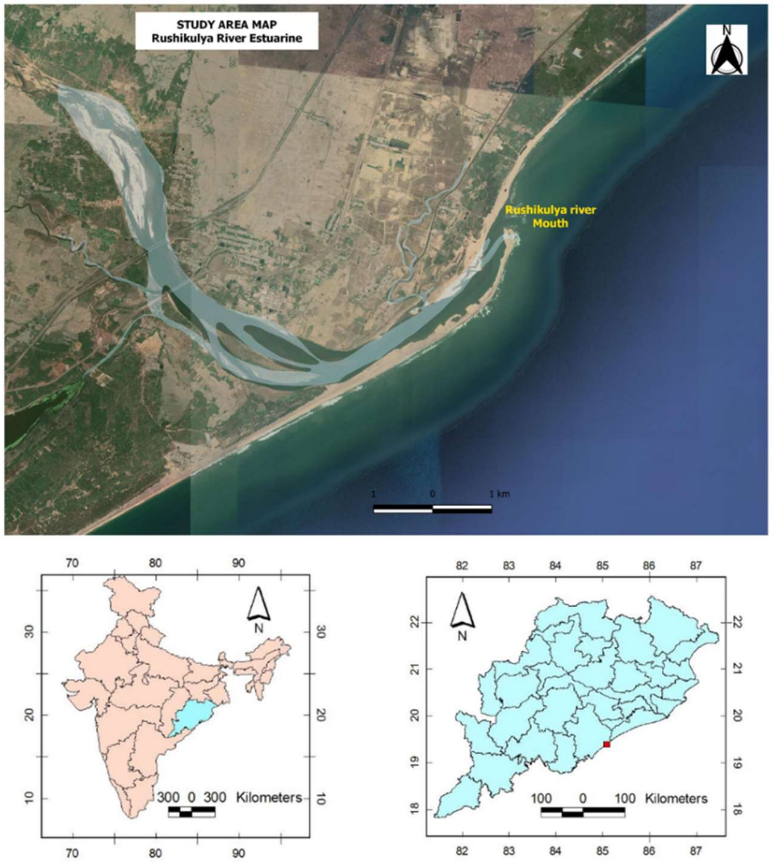

Figure 2: Shoreline map along Rushikulya coast during various Years from 1976 to 2019

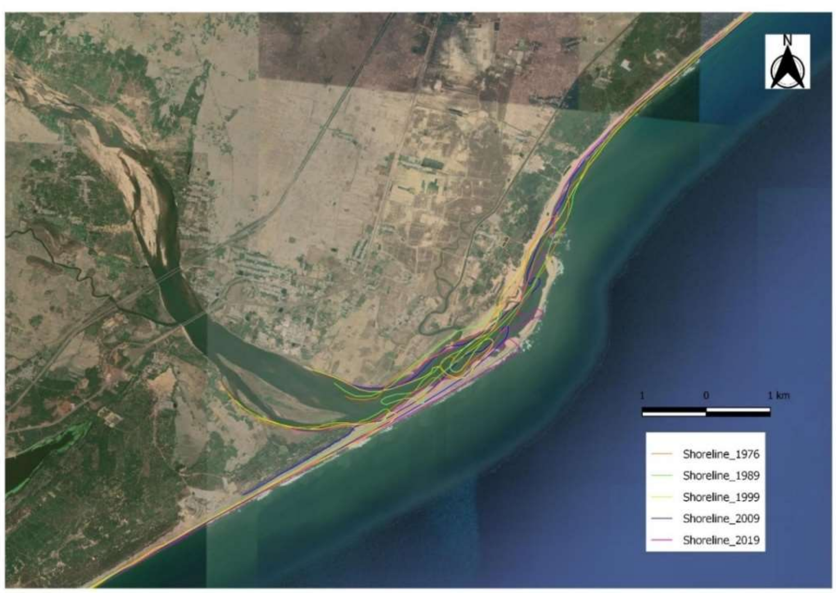

Figure 3: Map Showing Predominant Erosion and accretion areas in Study Area During 1976-1989

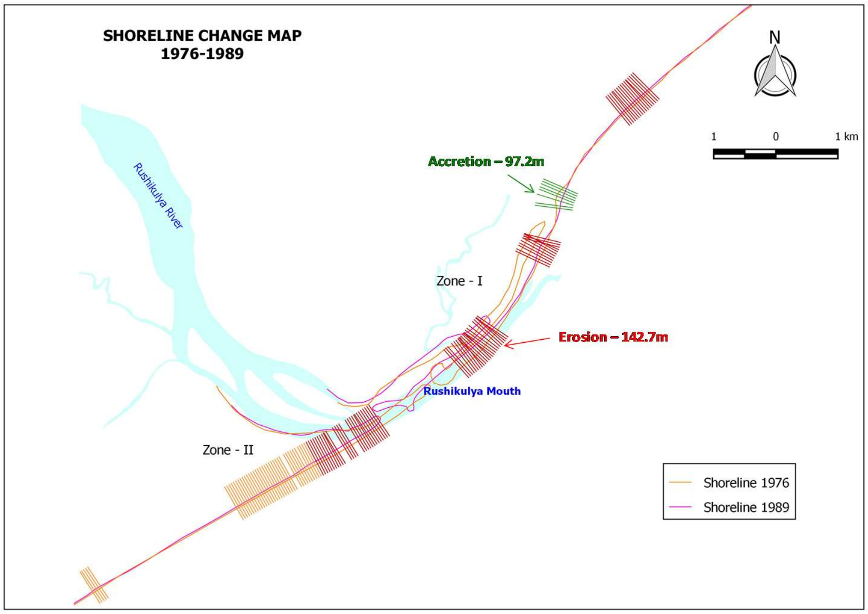

Figure 4: Map Showing Predominant Erosion and accretion areas in Study Area During 1989-1999

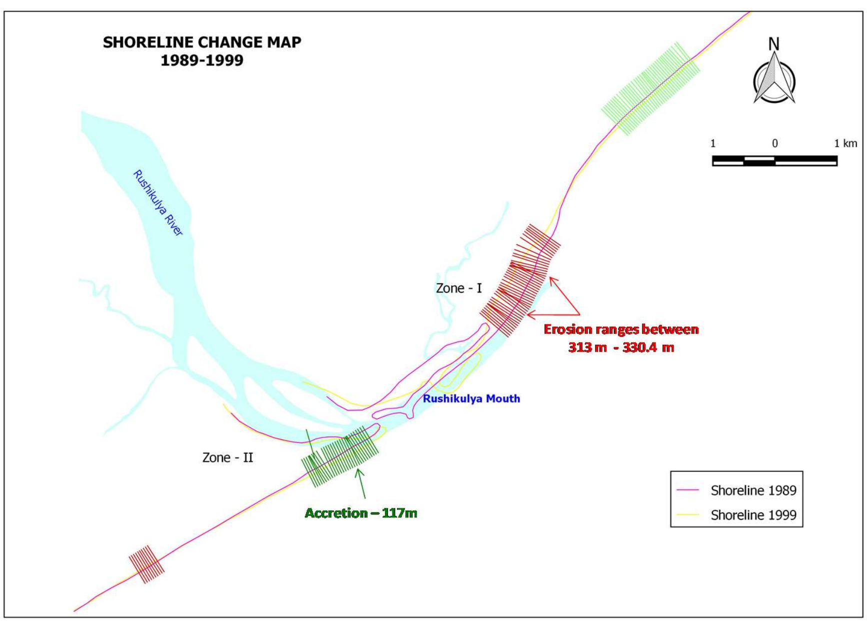

Figure 5: Map Showing Predominant Erosion and accretion areas in Study Area During 1999 -2009

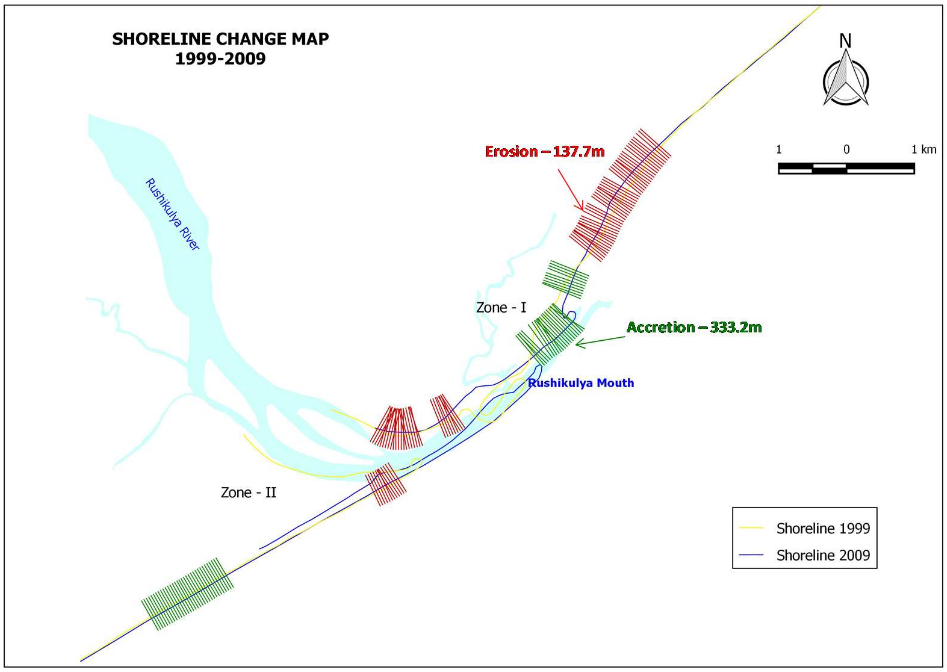

Figure 6: Map Showing Predominant Erosion and accretion areas in Study Area Durig 2009 - 2019

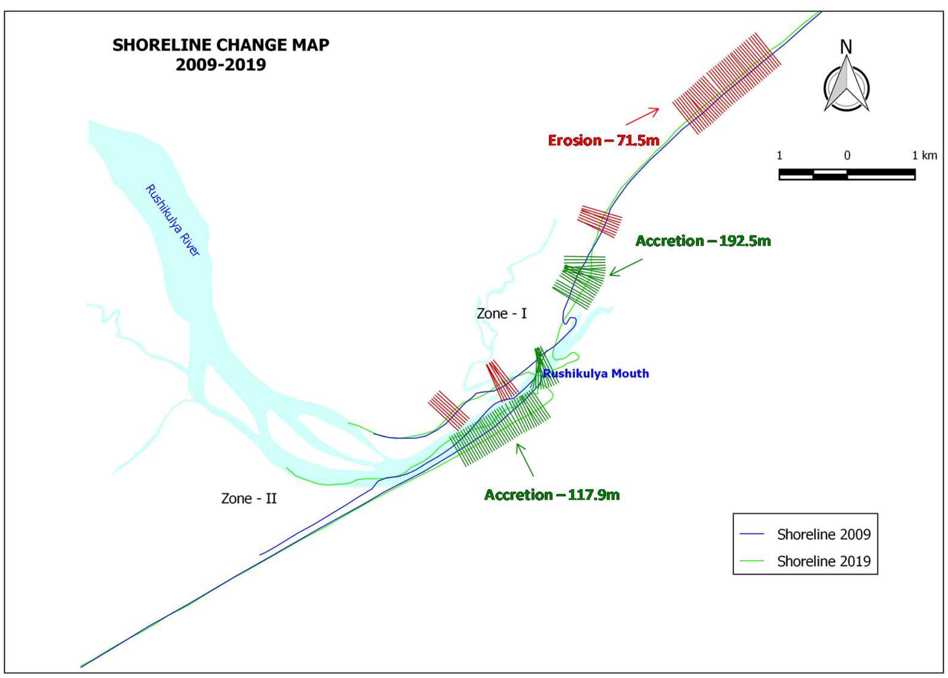

Figure 7: Composite Map Showing Predominant Erosion and accretion areas in Study Area Since 1976 to 2019

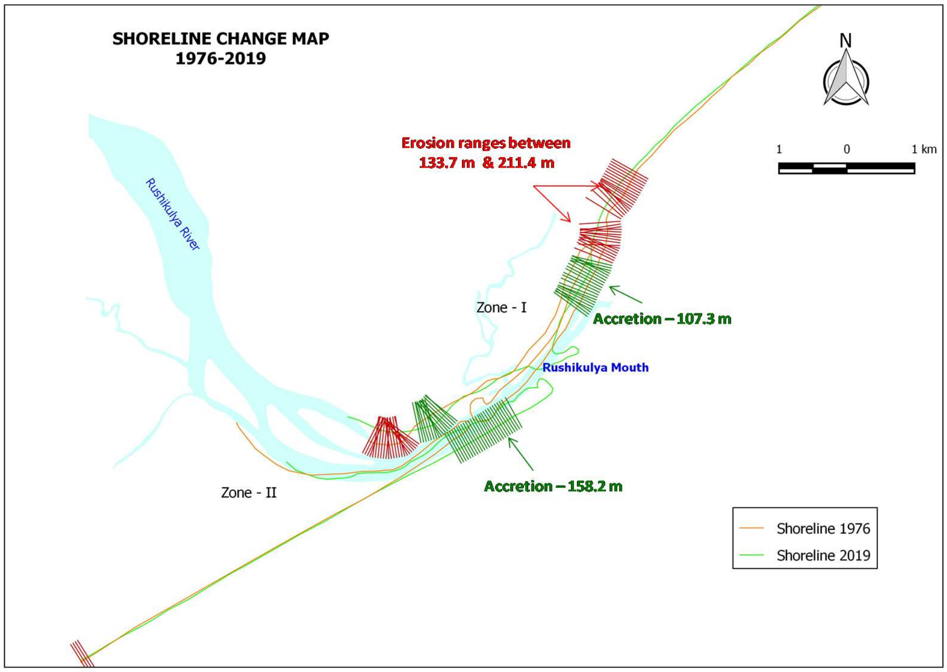

Figure 8: Position and Shifting of Rushikulya River mouth since 1976 to 2019