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Measuring shoreline erosion and accretion using digital shoreline assessment system: A case study of Puri to Ganjam, Odisha

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Abstract
The coastline is constantly changing due to tides, waves, sea-level rise and fall, storm surges, land erosion, accretion, etc. This type of erosion and accretion has an intense effect on coastal areas. The area from Puri to Ganjam on the Orissa coast is relatively densely populated. Chilika Lagoon is located in this area and plays an important role in controlling the economic and social life of the region. Shoreline erosion and deposition affect the livelihoods of the area around Chilika Lagoon. About 70 km long sand spit is protecting the Chilika Lagoon and its biota. Erosion and accretion in front of the Chilika lagoon spit are very important for the survival of the largest lagoon in Asia. Some parts of the study area are prone to erosion and some are prone to accretion. There are various methods to calculate coastal erosion and accretion rates. Various coastal mapping techniques have been developed during the last 50 years. This work uses the Digital Shoreline Analysis System (DSAS) to calculate the amount of erosion and deposition along the Odisha coast from Ganjam to Puri. Later, this study area was surveyed and the results of the DSAS software were verified with the actual situation.

Keywords: Landsat thematic mapper, DSAS, Chilika, shoreline, coastal erosion

Introduction
The coastline is a dynamic region where land and sea meet. It is constantly changing due to tides, waves, sea-level rise and fall, storm surges, land erosion, accretion, etc. The shoreline is constantly shifting through constant changes and episodic changes. As a result, new terrain is created somewhere and the land is submerged in the sea. This type of erosion and accretion has a profound effect on coastal areas. The presence of densely populated villages or towns in coastal areas is even more important.

Various geomorphologists have shown that most of the sandy coasts are erosion-prone (Letherman, 2001; Hinkel *et al*, 2013) [5, 3]. The study area from Puri to Ganjam on the Orissa coast is relatively densely populated. According to historians, this region was formerly very commercially active and large ports were developed in this region. Chilika Lagoon is located in this area and plays an important role in controlling the economic and social life of the region. Shoreline erosion and deposition affect the livelihoods of the area around Lagoon Chilika. Long-term observation has shown that this region is more prone to deposition. The Mahanadi fan is increasing gradually and it has helped in the formation of Chilika Lagoon. A 70 km long spit is protecting the Chilika Lagoon and its biota. Erosion and accretion in front of the Chilika lagoon spit are very important for the survival of the largest lagoon in Asia. In the short run, some of these areas are prone to erosion and some are prone to deposition.

There are various methods for calculating coastal erosion and accretion. Various coastal mapping techniques have been developed during the last 50 years (Stafford, 1971; Dolan *et al*, 1978; Leatherman, 1983; Dolan, 1991; Moore, 2000) [8, 1, 4, 2, 6]. Coastal erosion mapping was initially done manually, but later the use of different types of software has increased. Most software uses shoreline location information at different times in the past. In 1992, USGS provided the Digital Shoreline Analysis System (DSAS) software version 1.0 to determine the extent of coast deposition and erosion. Subsequently, various researchers have analyzed erosion and accretion near the shoreline in different parts of the world using this software. This work uses the Digital Shoreline Analysis System (DSAS) to calculate the amount of erosion and deposition along the Odisha coast from Ganjam to Puri.

This work has been done in a short period due to the lack of proper shoreline data. This study area was surveyed and the results of the DSAS software were verified with the actual situation.

Location of the study area

The study area is located in Puri and Ganjam districts of Orissa state in India (Figure 1). The study area is about 100 km wide along the coast. This region is formed by the accumulation of fine silts, and sands carried by the Mahanadi for a long time. This region has a tropical monsoon climate. The whole study area belongs to the sandy coast. Geologically this region is stable. This area is fairly populated. This region is also very important from the historical point of view, in the past famous ports (Palur, Khallikote, Manikapatna, etc.) developed in this region which is now covered with silt (Sinha, 2000) [7]. The major land-use types of this region are forest, agricultural lands, wetlands, wastelands and settlements, etc. The area near Puri town is the most populous. The region is being used extensively for religious and tourism purposes. The green-covered villages separated by rivers and canals are located on the west side of Puri. Chilika Lagoon is located about 40 km southwest of Puri. The historic town of Ganjam is located southwest side of the Chilika Lagoon. The Rushikulya River flows through the southwest part of the study area and meets the Bay of Bengal at Puruna Bandha in Ganjam. The historic town of Ganjam is situated on the right bank and Chatrapur is situated on the left bank of the Rushikulya River.

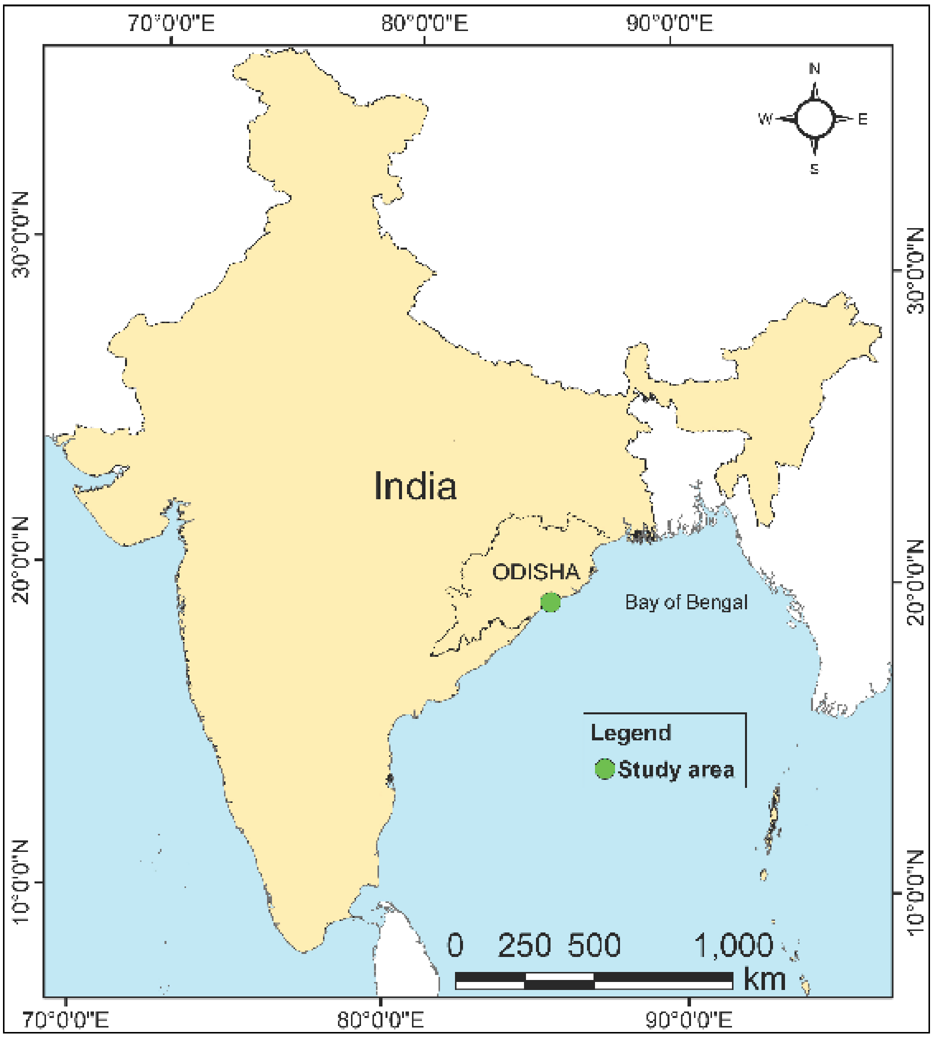

Fig 1: Location map of the study area

Material and Methodology

In the past, the work of shoreline change analysis was done manually and this work took a lot of time. The present work uses DSAS software developed by USGS. This software requires shoreline vector files at different times as raw material. A baseline is also required to calculate shoreline change. The result of shoreline change is available only if all the information is given correctly. For shoreline change analysis, images of Landsat Multispectral Scanner (MSS), Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) sensors from 1972 to 2014 have been downloaded from the Earth Explorer website (Table 1). Standard False Color Composition (SFCC) from above said images were prepared using ENVI 5.0 software. Then the shorelines are carefully digitized using ArcGIS 10.1 software.

Table 1: Details of satellite images used in this study

Sensor	WRS Path-Row	Image acquisition date	Band	Wavelength (µm)	Spatial resolution (m)
Landsat 1 MSS	(WRS1) 150-046	07/11/1972	Band 4 Band 5 Band 6	0.5–0.6 0.6–0.7 0.7–0.8	80
Landsat 5 TM	(WRS2) 140-046	08/02/1988	Band 2 Band 3 Band 4	0.52–0.60 0.63–0.69 0.76–0.90	30
Landsat 7 ETM+	(WRS2) 140-046	29/11/1999	Band 2 Band 3 Band 4	0.52–0.60 0.63–0.69 0.77–0.90	30
Landsat 7 ETM+	(WRS2) 140-046	25/02/2003	Band 2 Band 3 Band 4	0.52–0.60 0.63–0.69 0.77–0.90	30
Landsat 8 OLI	(WRS2) 140-046	17/04/2013	Band 3 Band 4 Band 5	0.53–0.59 0.64–0.67 0.85–0.88	30
Landsat 8 OLI	(WRS2) 140-046	04/04/2014	Band 3 Band 4 Band 5	0.53–0.59 0.64–0.67 0.85–0.88	30

Although various methods have been introduced for the automatic digitization of shorelines, due to accuracy problems, the automatic shoreline extraction method has not been used here. So shorelines have been digitized manually. The baseline is also manually digitized from the satellite image and the transects are also drawn at an interval of 100 meters.

Since the shoreline is very dynamic, at different times of the day, and at different times of the year the shoreline is located in different places due to the effects of waves, tides, cyclones, etc. Therefore, satellite images of roughly the same sea level should be taken when selecting satellite images for DSAS; otherwise the erosion-accretion rate may be incorrect, which may not match the reality.

Assessment of shoreline

The Digital Shoreline Analysis System (DSAS) is open-source software. DSAS version 4 is used as an extension with ArcGIS 10.1 software. There are various methods to estimate shoreline change rates, such as End Point Rate (EPR), Linear Regression Rate (LRR), Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), etc. An LRR can be determined by fitting a least-squares regression line to all shoreline points for a transect. The SCE, NSM and EPR require two shoreline positions to run the program whereas LRR requires more than three shorelines to compute the shoreline change rate. In this study, EPR has been calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline.

Result and Discussion

This software displays the erosion-accretion analysis of the shoreline through the colorful transect. The green indicates accretion; the red indicates erosion and the yellow indicates the stable condition. This study shows that most of the study area is under the ±5 meter shoreline shift zone. The New Mouth, the Old Mouth and the Rushikulya estuary areas indicate sporadic erosion-prone areas. Analysis of the erosion-accretion of the whole region shows that the maximum amount of shoreline erosion is about 40 m / year (Figure 2). The highest erosion is observed in the New Mouth area. The maximum amount of shoreline accretion is about 10 m / year (Figure 2). The highest accretion is observed on the western side of the New Mouth area, the eastern side of Puri and the western side of Rushikulya River. From this study, it is observed that most of the study area is in stable condition for a short period from 1972 to 2014.

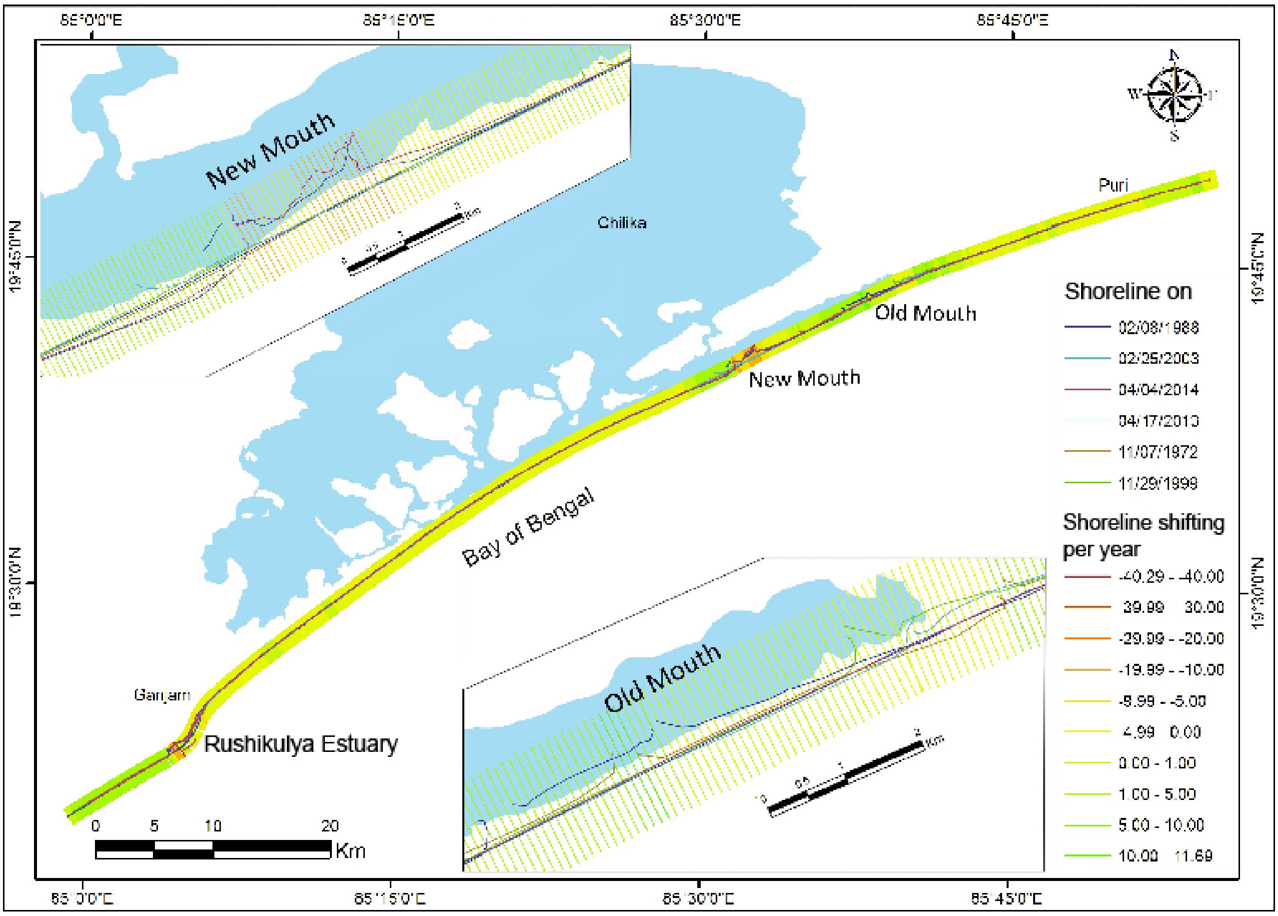

Fig 2: Shoreline change map

The combination of longshore current and washover during cyclones has changed the location of the inlets of Chilika Lagoon at different times in the past. The Old Mouth closed in the 1990s, and later the New Mouth was artificially opened. The region is moving towards the future through the formation of spit by longshore current and the erosion of spit by washover during cyclones.

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