



DETECTION OF DECADAL SHORELINE CHANGES ALONG DHAMARA AND MAIPURA COAST, ODISHA, INDIA

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ABSTRACT

Coastal erosion is one of the major problems of the coastal zone. The erosion is triggered by various reasons such as high wave energy, reduction of sediments, natural disasters and climate change etc. In the era of industrialization, major infrastructure developments are happening along the coast. Prior to the initiation of those projects, it is important to understand the coastal processes of erosion, deposition, sediment-transport, flooding and sea-level-changes of the region which continuously alters the shoreline. These processes disturb the stability and productivity of aquatic environment and may have severe implications for proprietors. This study attempts morphological assessment of shoreline in the middle coastal plains of Odisha state on the east coast of India. Shorelines changes study is carried out at Dhamra and Maipura Coast to quantify erosion and accretion during years 1990 – 2012. Satellite derived remote sensing data of LANDSAT and IRS P6 for the years 1990, 2000 and 2012 were used in this study. Dhamra coast has been modified in between these years due to anthropogenic disturbance such as port development. Maipura coast which has large mangrove cover, Bhitarkanika national park carries its ecological importance. These coasts experienced erosion during 2000-2012 compared to 1990-2000. Accretion is noticed in the nearby river mouths. Temporal variation of sediments and frequent flood events will also be discussed in the paper. The detailed analysis reveals that the maximum erosion of 227 m, 47 m in a decade at Dhamra and Maipura coasts respectively. Area of Dhamra coast was under accretion during 1990-2000 and this area experienced erosion near Dhamra port just after the development of port in 2007. This study concludes that shoreline of study area is under high risk of erosion and inundation due to natural as well as anthropogenic activities in the area.

Keywords: Remote sensing; Erosion; Accretion; Odisha coast; DSAS.

1. INTRODUCTION

The coastline of India comprises of variety of habitats and ecosystems such as sandy and rocky beaches, cliffs, water and lagoons to bays, mangrove swamps, sea grass beds, coral reefs and estuaries. Indian coastline is about 7,500 kms in length and the EEZ is having an area of 2.02 million sq. km (Ramesh *et al.*, 2011). The recognition of a "shoreline" involves the selection of a shoreline indicator within the available data source (Ron *et al.*, 2001). Shoreline change is considered as one of the most dynamic processes in the coastal region and is caused due to various physical and anthropogenic processes (Chen *et al.*, 2005). Shorelines are always subjected to changes due to coastal processes, which are controlled by wave characteristics and the resultant near-shore circulation, sediment characteristics, beach form etc. (Kumar *et al.*, 2010). Assessment of long term erosion and accretion rate of the coastal area is essential for the selection of different types of coastal structures. Erosion and accretion index is prepared for Kuwait coast (Neelamani and Uddin, 2013). This study is helpful for identifying better sites for coastal infrastructural activities in the study area. Erosion has been observed at the region around the ports of Visakhapatnam, Paradip, Ennore and Nagapattinam on the east coast of India while deposition has been observed south of these ports. These changes are attributed to construction of artificial barriers like breakwater, jetties, etc. (Nayak, 1992). The rising number of coastal disasters along the world's coastlines throws

light on the need for better and more efficient methodologies for the assessment of coastal vulnerability. A study at east coast of India was carried out to analyze and illustrate the vulnerability linked with various coastal hazards and can be used effectively by coastal managers and decision-makers to devise better coastal zone management plans as well as to ensure efficient mitigation measures to lessen the losses during disasters (Murali *et al.*, 2013).

A fruitful management of the coastal region requires alert consideration of all the components of shoreline movement, as it is a complex phenomenon resulting from both natural processes and anthropogenic effects (Camfield and Morang, 1996). Construction of seawalls has resulted in shifting of erosion sites from one place to another, whereas, breakwaters have been acting as barriers for littoral drift at Mangalore coast (Kumar and Jayappa, 2009). Accretion was predominant along the coast between Kanyakumari and Tuticorin during 1969-1999, but this area had undergone erosion from 1999 onwards. Morphologic and hydrodynamic changes arise continuously subsequent to December 2004 tsunami (Mujabar and Chandrasekar, 2011). A recent study demonstrated shoreline changes and morphology of spits for southern Karnataka area, India (1910-2005) utilizing satellite data and statistical techniques which can be incredibly practical in quantifying shoreline changes and spit morphology (Kumar *et al.*, 2010). Accurate quantification of the dimensions of material lost using erosion risk mapping assists decision making for the implementation of protective measures. A research was

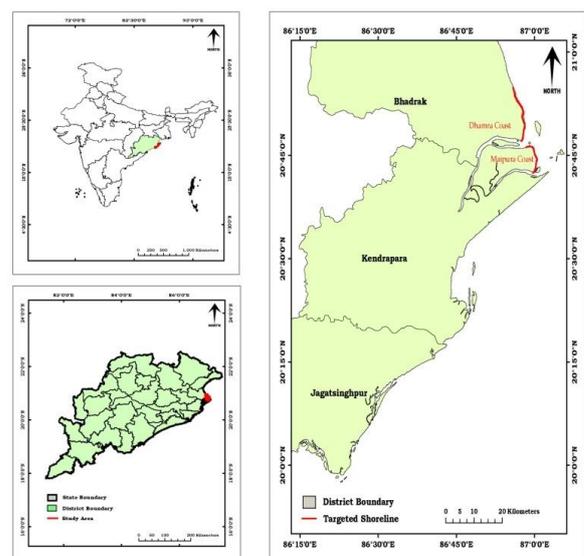
carried out to establish soil loss rates due to erosion by water and wind in protected natural areas, to predict the environmental effects of different land uses (Martinez-Grana *et al.*, 2014). Another study discussed an alternative cost-effective methodology involving satellite remote sensing images and statistics during their study for shoreline change analysis and its application to prediction (Maiti and Bhattacharya, 2008). DSAS is used for studying Quantitative analysis of shoreline changes at the Mediterranean Coast in Turkey. LANDSAT satellite data for the years 1972 (MSS), 1987 (TM) and 2002 (ETM) was used after image processing and coastline was detected by self organizing data analysis technique classifications, edge detection and overlay technique. DSAS was used to calculate erosion and accretion rate at different time intervals. A combined use of cartographic data and statistical methods could be a trustworthy technique for shoreline related studies (Kuleli, 2010). Application of such data seems to be trustworthy in qualitative monitoring of shoreline changes, while it is the only available method for long term studies (Bagdanavičiūtė *et al.*, 2012). Dynamic geomorphology of Mahanadi delta and problems of coastal dynamics and shoreline changes after the construction of Paradip port was studied (Meijerink, 1983; Rao, 1989). The extent of coastal geomorphological changes induced by the grounded ship MV River Princess was analysed on the Candolim-Sinquerim coastline of Goa, India (Murali *et al.*, 2013). In this study, dynamics behind erosion is discussed based on the southwest and northeast monsoon wave patterns and alignment of the ship with respect to the shoreline. (Rupali, 2007) studied the spit stability adjacent to the Jatadharmohan creek based on hydrodynamic conditions of the creek and slope stability. A study was conducted to understand nearshore erosion, deposition, sediment budget and longshore transports off Paradip area (Ananth and Sundar, 1990; Sarma and Sundar, 1988). Erosion, that is observed north of Paradip and Ennore ports on the east coast of India, is due to construction of artificial breakwaters and jetties (Nayak *et al.*, 1992, 1997; Chauhan *et al.*, 1996). Coastal processes along the Indian coast with reference to the erosion and accretion was studied (Sanilkumar, 2006). Another study was carried out to monitor the shoreline environment of Paradip using remote sensing for the period 1973-2005. The years 2001, 2002 and 2003 exhibited loss in length of shoreline as well as area of the beach (Murali *et al.*, 2009). The Objective of this study is to monitor and quantify the erosion and accretion for annual to decadal scales at Dhamara and Maipura coasts of Odisha coast using remote sensing data and GIS.

2. STUDY AREA

The area under investigation is the coastline of Odisha state located on the east coast of India. The Odisha coastline is 480 km in length and consists of six coastal districts. Dhamara and Maipura coasts are targeted for shoreline mapping in order to quantify the erosion and accretion during the period 1990 – 2012 (22 years). The study area (Figure 1) is located between 20°43'17.26" N - 20°2'51.875" N, and 87°4'6.915" E - 86°26'0.235" E. The study area has a tropical climate and summer maximum temperature ranges between 35-40° C and the low temperatures are usually between 12-14°C. The average rainfall is measured to be 1482 mm and receives an average of 78% of rainfall between the months of June and September and the remaining 22% of the rainfall throughout the year. The source of the sand that

feed the beaches, dunes, and barrier beaches comes primarily from the erosion of coastal landforms (Ramesh *et al.*, 2011). A unique feature of the adjacent Bay of Bengal (BoB) is occurrence of tropical cyclones during October-November and April-May (Sehgal *et al.*, 1991). Storm surges that are generated by the cyclones in the Bay of Bengal cause tremendous destruction along the east coast of India. A study was carried out for projected sea level rise estimation for regions surrounding Nagapattinam, Kochi and Paradip. According to this study, Paradip is known for the occurrence of storm surges resulting from the passage of cyclones (Unnikrishnan *et al.*, 2010). The cyclones that affected the Orissa coast between 1877 and 1987 show irregular tracks and they occurred in between the mouth of the Dhamra River and Paradip. Between 1891 and 1970, there were 1036 depressions in the Bay of Bengal and among them, 360 intensified into storms (Ramesh *et al.*, 2011). The Mahanadi River deltaic coast is micro-tidal with a mean tidal range of 1.29 m. The currents measured in the coastal waters of Odisha indicate that the flow is towards south with speeds varying from 14-29 cms⁻¹. An average annual total sediment load of 29.77 million tons are carried by the Mahanadi River at its delta head (Kumar *et al.*, 2010). Mudflats, spits, bars, beach ridges, creeks, estuaries, lagoons, flood plains, paleo-mudflats, coastal dunes and salt pans are observed along the Mahanadi delta of Orissa.

Figure 1. Location of study area



3. MATERIAL AND METHODOLOGY

3.1 Data used

The LANDSAT satellite images were downloaded from Global land- cover facility website and IRS-R2 satellite imagery was purchased from National Remote Sensing Centre, Hyderabad. The following Table shows the various images that were procured, their resolution and date of pass.

Date and Year	Path/ Row	Satellite ID	Sensor	Resolution (m)	Resolution (m) after resampling
28.11.1990	140-46	Landsat 5	TM	30	23.5
23.10.2000	139-46	Landsat 7	ETM+	30	23.5
24.02.2012	107-58	IRS-R2	L3	23.5	23.5

Table 1. Satellite data information used for Study

Table 2. Decadal shoreline mapping results

Sr. No.	Coast Name	Length in 1990 (km)	Length in 2000 (km)	Length in 2012 (km)	Net in 2012 (km)	Results
1.	Dhamara	16.94	18.22	18.83	Gain	1.89
2.	Maipura	10.71	10.01	10.24	Loss	0.47

These results show that shoreline behavior is highly dynamic in this area. This can be due to deltaic characteristics of rivers and cyclonic activities in the area. Dhamara coast showed a net increase in length of 1.89 km in 22 years. Maipura coast confirmed the net loss of 470 meters in length of coastline. Erosion and accretion measurement was done using DSAS by creating transects at a fixed distance spacing of 50 meters. High distance spacing of transects increases the uncertainty in results and very low distance spacing increase the huge amount of data values. Therefore the transect spacing was taken 50 meter in this study. These results are calculated for 1990-2000 and 2000-2012. Each coast under study area shows different behavior under different time scale.

3.2 Methodology

The satellite images of the study region were searched and accordingly, the above listed satellite images were used for this study. The important factors which need to be considered for finalizing the satellite images are cloud cover, similar tide conditions, similar season data, uniform projection factors, etc. In this study, the above factors were considered for the available images. The satellite data undergoes radiometric correction and data scaling to enable maximum visual interpretation. All images were geo-coded with UTM projection WGS 84 datum parameters. Geo-coded data are images that have been rectified to a particular map projection and pixel size, and usually radiometric corrections are already applied. About 30 Ground control points were used for this purpose.

One of the objectives was to understand and predict annual- to decadal-scale shoreline change along the study area using remote sensing and GIS. The study was conducted for different years i.e. 1990-2000, 2000-2012 depending upon the data availability.

First of all Image processing was done for different satellite images in ERDAS Imagine 9.1. The study area is a part of different scenes of satellite imagery. Mosaic image was prepared for different scenes and then subset of study area was created for further processing. All satellite imagery was geo-referenced and RMSE error was less than one only. Resampling of all satellite imagery was done in Erdas Imagine 9.1 to prepare same pixel size (23.5 m) for different datasets.

Preprocessed satellite imagery is used to digitize shorelines. Maps are line digitized so that shoreline can be marked. These marked boundaries are then overlaid for different years and difference can be brought out using ARC GIS 10.1. DSAS is used to compute rate-of-change statistics for a time series of shoreline vector data (Thieler *et al.* 2009). Transects were created on baseline at a distance of 50 m for all shorelines under study area.

4. RESULTS

Mapping of shoreline lengths for Dhamara and Maipura coasts were done at a temporal scale of 22 years. Detailed results of length of shoreline are given below.

Dhamara Coast

A maximum erosion of 227 m at transect id 42 and accretion of 537 m at transect no 136 is observed in 1990-2000 at Dhamara coast. Transect id 69 shows 269 m erosion and transect id 150 shows 513 m accretion in 2000-2012 (Figure 2).

Maipura Coast

A maximum erosion of 47 m at transect id 44 and accretion of 183 m at transect id 66 is observed in 1990-2000 at Maipura coast. Transect id 02 showed 93 m erosion and transect id 186 shows 177 m accretion in 2000-2012 (Figure 3).

Dhamara coast has undergone an average erosion of 5.05 m/year from 1990 to 2000, which is increased in next decadal interval i.e. 8.57 m/year during 2000 - 2012. Net erosion increase during 2000-2012 was 34% as compared to 1990 - 2000 (). Dhamara port is constructed in 2007 is also located in the area under erosion. Erosion at this site might be because of anthropogenic activities. Middle part of the coast is accreted and erosion is observed in northern and southern part. The area near Dhamara river mouth is accreted; this may be because of heavy sediment transport activities at river mouth. Northern part of coast is under high erosion.

Maipura coast experienced an average erosion of 1.41 m/year from 1990 to 2000, which is increased to 3.87 m/year in 2000 - 2012. Net erosion increase during 2000 - 2012 was 12% as compared to last decade. This coast has sediment transport activities at both ends. North part of the coast is affected by Dhamara river and southern part is affected by Maipura river. In northern part near mouth of dharma, maximum erosion is observed and the area near maipura mouth is maximum accreted during 2000 - 2012.

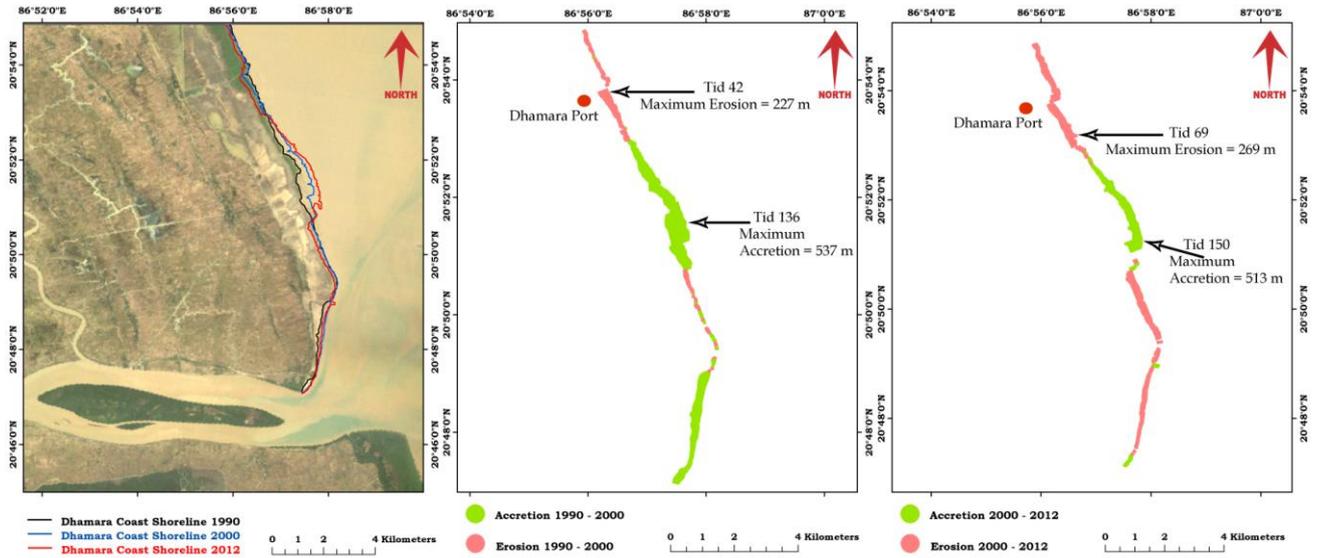


Fig 2. Erosion and accretion mapping for Dhamara coast for years 1990-2000 and 2000-2012

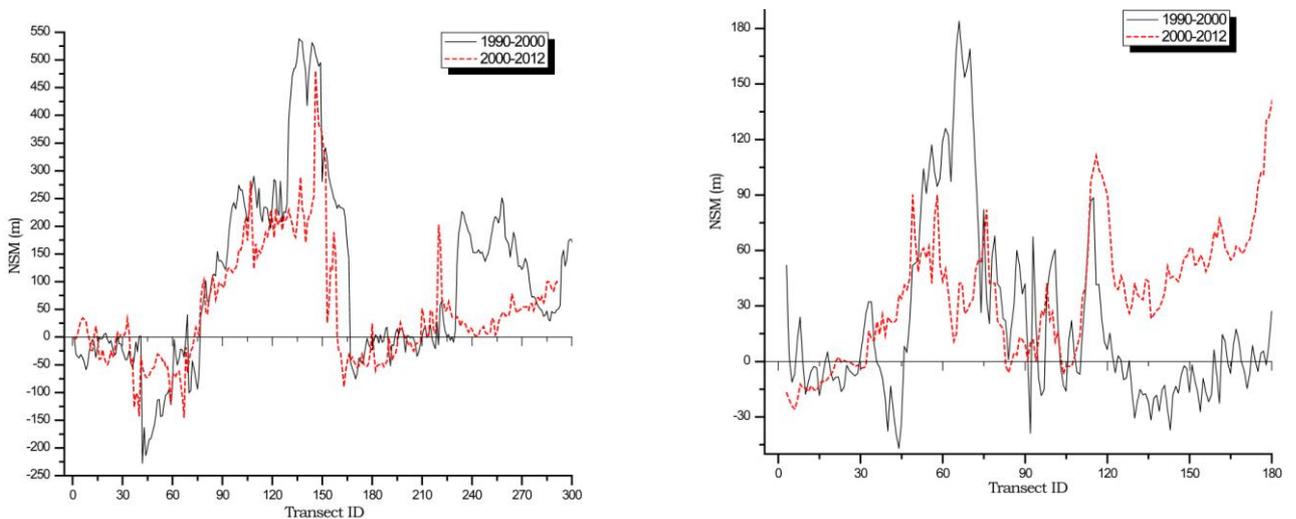
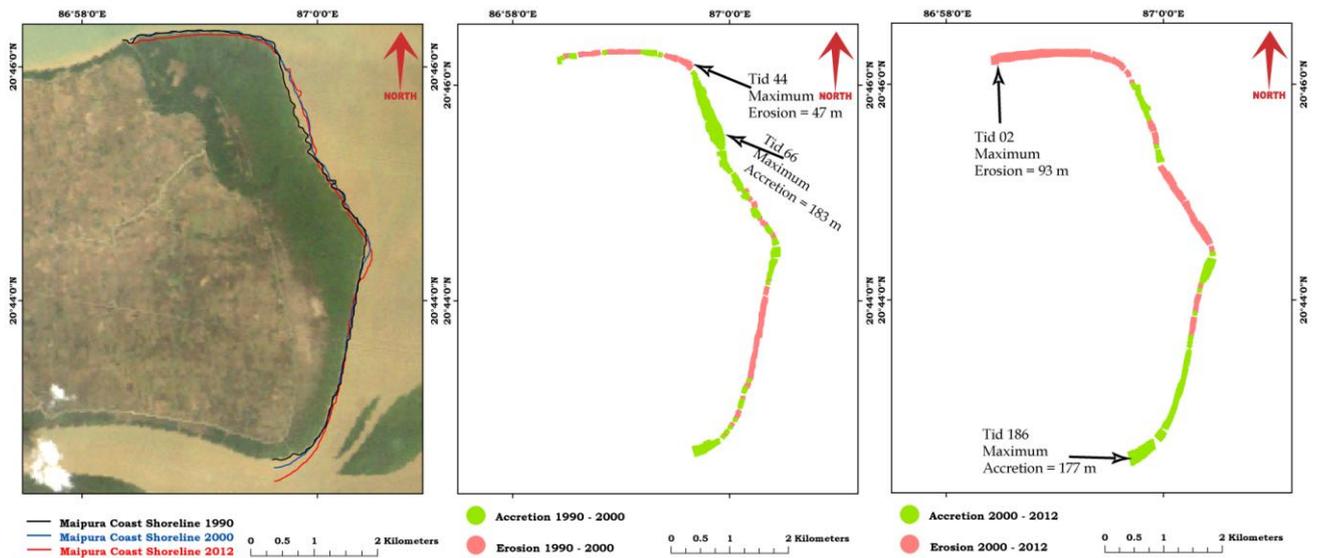


Fig 3. Erosion and accretion mapping for Maipura coast for years 1990-2000 and 2000-2012

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5. CONCLUSIONS

This study concludes that shoreline of Odisha coast is under high weight of erosion and this might be due to natural as well as anthropogenic activities in the area. Erosional activities increased during last few years compare to the last few decades. There may be some natural causes, for example – wave energy, cyclones from Bay of Bengal, floods in coastal plains and deltaic characteristics of rivers in the area. Area of Dhamara coast under accretion during 1990-2000 resulted into erosional area near Dhamara port just after the development of port in 2007. It is due to the anthropogenic involvements on the shoreline, the shoreline conservation measures are recommended near to the port areas. Dhamara coast is under accretion in northward direction and erosion is elucidating in southward direction, which shows dynamic ocean current flow direction from northward to southward. This result can be helpful in study of sediment transportation from Dhamara River into Bay of Bengal. Large mangrove area at Maipura coast revealed erosion, which is not a good indicator for biodiversity. Biodiversity conservation measures are recommended near the Maipura coast.

A physical approach of shoreline change detection is recommended for better accuracy of morphological assessment. Anthropogenic activities such as dredging, mining, etc. also contributed in quantum of erosion at study site. Studies of sediment dynamics from land into oceans by rivers in this region is also an inevitable in the study. Increased activities including anthropogenic emissions, erosions and their intended conservation draw the attention of scientific community to this region.

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