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***Research Article***

# SEA LEVEL RISE AND SHORELINE CHANGES: A GEOINFORMATIC APPRAISAL OF CHANDIPUR COAST, ORISSA

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## ABSTRACT
Spatial modelling along with efficient temporal representation of the dynamic coastal environment is a very challenging research area in coastal studies. The coast constitutes one of the most dynamic parts of the earth surface. It is continuously undergoing both gradual and sudden changes with physical processes. These changes occur over both long and short terms and involve hydrodynamic, geomorphic, tectonic and climatic forces. The present study analyse the coastal erosion and associated shoreline change in relation to sea surface height anomaly in the Chandipur coast in Balasore district of Orissa using multi temporal satellite imagery during the period 1990 to 2010. The coastline is delineated using image classification method and validated. The positional shifting and erosion of the coastal area is calculated and the rate of erosion/accretion has also been estimated. It is found that during 1990 to 2005, accretion occur in the northern part, but the middle and southern part of the coastline are erosion prone. But from 2005 to 2010 it is found that the entire coastline is suffering from erosion and high erosion is seen in the north eastern part. It is also found that the sea surface height is increasing during 1993 to 2011 which is possibly the major cause of coastal erosion.

***Key Word:*** *Shoreline Delineation, Coastline Erosion, Sea Level Rise, Chandipur Coastline*

## INTRODUCTION
The coasts constitute one of the most dynamic parts of the earth surface. It is continuously undergoing both gradual and sudden changes with many physical processes, such as tidal flooding, sea level rise, land subsidence, volcanic activity and erosion-sedimentation (Maiti and Bhattacharya, 2009). Shoreline change is considered to be one of the most dynamic processes in the coastal area and the change in shoreline, caused due to physical as well as anthropogenic process, have large environmental significance (Chen et al. 2005). These changes occur over both long and short terms and involve hydrodynamic, geomorphic, tectonic and climatic forces (McBride et al., 1995; Scott, 2005; Thom and Cowell, 2005). Therefore, the study of shoreline position is of utmost importance for management purposes like developmental planning and hazard zonation or academic endeavors, determination of erosion and accretion, estimation of regional scale sediment budgets etc. (Sherman and Bauer, 1993; Zuzek et al., 2003).
According to the researchers, the major cause of coastal erosion and shoreline change is sea level rise. Sea level rise is one of the oft-cited effects of global warming which has a direct role in coastal erosion. It is a particularly ominous threat to the human community because a number of large cities and 10% of the world's population lives in coastal areas within an elevation of 10 m from mean sea level (McGranahan et al., 2007). According to Miller and Douglas (2004), the global sea level has risen, on average, by 1.5-2.0 mm/year in the last century and since 1993, the rate has increased to 3 mm/year (Church and White, 2006). The latest IPCC Report (Solomon et al., 2007) predicts that the global sea level will rise by about 60 cm by 2100 AD. Furthermore, if the ice caps continue to melt, there could be a 1 m rise of the sea level by the end of the twenty first century (Pfeffer et al., 2008). This rise of sea level will manifest itself along the coastal stretches in five forms such as erosion of beaches and bluffs, increased flooding and storm

damage, inundation of low-lying areas, intrusion of salt water into aquifers and higher water tables (Healy, 1991; Nicholls and Leatherman, 1995). Several models have developed by the researchers that evaluate the impacts of sea level rise on sandy beaches (Brunn, 1962; Dean, 1977; Everts, 1985;). All these models indicate that coastal erosion is one of the most well-known effects of sea level rise. This occurs because the rising water level, causes long-term or permanent loss of sand from beaches, thereby affecting the sediment reservoirs. It is now well established that sea level rise causes erosion of sandy beaches. In fact, Leatherman et al. (2000) found out that long term retreat rate of sandy shores averages about 150 times of the sea level rise. One of the major causes of the sea level rise is the thermal expansion of the sea water. Sea surface air temperature of North western portion of Bay of Bengal has been found to be rising. The analysis of surface air temperature data, indicates an increasing mean annual temperature of 0.019ºC/year (Hazra et al. 2002). Sea level fluctuation in Bay of Bengal is observed based on Gauge data (1985-2000) of Sagar observatory and it has been found that the mean sea level is rising at the rate of 3.15 mm/year which is significantly higher than the present average global sea level rise (2 mm/year) (Hazra et al. 2003). The analysis of cyclonic data over the Bay of Bengal adjoining to the Sundarban, exhibits an increase in the degree of intensity but decrease in frequency of occurrence. The analysis of remote sensing and field data of the past 3 decades reveals the reduction of huge land area due to erosion as well as morphological change is continuously seen in the various locations in the northern portions of Bay of Bengal between 1967 and 1995 (Hazra et al. 2002;). Because of increased sea level and associated coastal erosion, it is estimated that a large number of people are at a risk due to coastal inundation and shoreline shifting, especially in the low elevation coastal zones. The impacts are spatially variable but developing countries are likely to be worst affected (Nicholls et al., 2007; Dasgupta et al., 2009).

Spatial modelling and temporal representation of the dynamic coastal environment using satellite remote sensing is a very challenging research area in coastal studies. It this process, it is necessary to create a digital database of historical shoreline position, implement standardized remote sensing and GIS technology as well as create a data inventory that can be used to facilitate current position, changes and erosional trend analyses of shoreline change. The present study analyses the coastal erosion and associated shoreline change in relation to sea surface height anomaly in the vicinity of Chandipur (part of Bay of Bengal coastline) coast using multi temporal optical satellite images and satellite radar altimeter data.

***Study Area***

Chandipur coast in Balasore district of Orissa (Fig. 1) can be described as a tidal or marshy flat that emerges during low tide and submerges during high tide (intertidal zone). The zone above the high water line is supratidal zone, and the area below the low-water line is subtidal zone. There is, however, no clear demarcation between superatidal and intertidal areas (Chakrabarti, 1991). It has a very wide tidal flat surrounded by a narrow beach in the north direction. The beach is abutted by Aeolian dunes and recent alluvium can be found covering further land ward. In the east, river Buribalam is present along with its emerged terrace covered with marsh. Southward beyond the tidal flat and shoreface of the Balasore shelf is planar. Due to infringement of sea, the coastal zone is suffering severe erosion. The geomorphic components are not in symmetry with the present wave dynamics. The shoreline here inclines in a NE-SW direction .

The physical setting of the study area mainly geology, geomorphology and climate is also important for coastal erosion. The coastal plains in the eastern and northeastern part of the district is characterized by semi-consolidated to unconsolidated quaternary sediments and alluvial deposits of recent origin, characterized by pebbles, sand, silt, sandy clay with iron nodules, fluvial silt, clay and deltaic deposits, old dune sand and marine clay, clay with calcareous concretions etc. representing both fluvial and fluvio-marine faces. The area is falling under the tropical monsoon climate with mean annual temperature of 27º C which varies between 37ºC to 13ºC. The mean monthly rainfall is 120 mm and maximum rainfall occurs during the monsoon period; Jun to October (Source: IMD).

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The vast stretch of Chandipur beach bounded by Latitude- 21° 25′ 35.05″ N & 21° 28′ 25.75″ N and Longitude- 87° 00′ 13.90″ E-, 87° 04′ 38.69″ E. Around Chandipur, (southwest of the estuary of the river

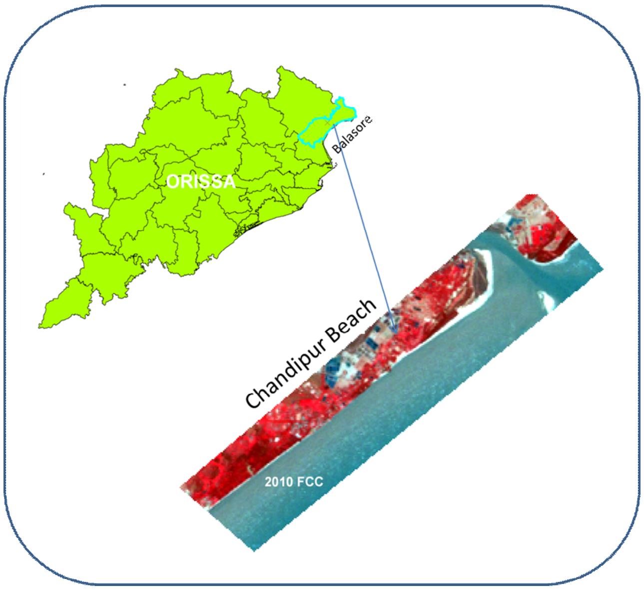


**Figure 1:** Study area

Subarnarekha), the coast can be divided into two broad morphozones: a) landward zone characterized by monotonous lowland modified by fluvial processes of the main river Burahbalang and b) seaward zone bordered by a single line of shore parallel coastal dune lying on old marine terraces. The line of coastal dune is fronted by the open sea tidal flat. The tidal flat has two distinct morphometric facets a) a sandy sloping (average 6º) shoreward zone with an average width of 30 m, and b) a wide silty flat matted with ripples, having an average width of 1.5 km. Near the Burahbalang estuary, the silty intertidal flat is ornamented with clusters of river-mouth bars of varying dimensions, criss-crossed by tidal channels of varying depths (Mukherjee et al., 1987). Texturally speaking, the size characteristics of different intertidal sediments show wide variation.

The upper sandy part of the Chandipur tidal flat is composed mostly of fine sand (2 to 3 phi size), whereas in the wide silty flat more than 80% of the sediments are finer than 3.5 phi size. Sediments in the river-mouth bars are generally found to be coarser in size. In the Chandipur tidal flat, manifestations of wave energy in the form of swash/backwash system dominates over tidal energy, the intertidal surface, barring runnels and tidal channels, is observed to be intensely matted with ripples. Climbing ripple lamination with different angles of climb has been observed in coastal tidal flats of Chandipur area where the paradeltaic fan surfaces are composed of fine sand and silt. These climbing ripple laminated units were eroded and covered by scour-and-fill laminations. In regards to the manifestations of sea level change, paleostrand lines, beach ridges mostly in the form of stabilized dunes are observed, particularly in the northeastern extremity of Chandipur.

## MATERIALS AND METHODS

### *Data Used*

Four satellite Landsat TM-5 & ETM+ data are taken into consideration over the 20 years time period (1990 – 2010). The details of the satellite imagery, acquisition details and resolution are given in the Table-1.

**Table 1:** Details of satellite data, date of acquisition and resolution

| Satellite and Sensor | Date of acquisition | Path/ Row | Band used | Spatial resolution |
|---|---|---|---|---|
| LANDSAT TM | 1990-11-21 | 139/045 | VNIR | 30 m |
| LANDSAT ETM+ | 2000-11-08 | 139/045 | VNIR | 30 m |
| LANDSAT TM | 2005-11-14 | 139/045 | VNIR | 30 m |
| LANDSAT TM | 2010-04-18 | 140/046 | VNIR | 30 m |

The other data used in this study for the analysis of sea surface height measurement, is taken from satellite altimeter data of TOPEX/ POSEIDON (Source: NASA) for measuring sea surface height from the year 1993 to 2011. TOPEX sensor use Nadir Pointing Radar Altimeter of C band (5.3 GHz) and Ku band (13.6 GHz) and POSEIDON use CNES-built solid state Nadir pointing Radar Altimeter using Ku band (13.65 GHz).

Numerous techniques for mapping shoreline change have been forwarded since the 1970s (Stafford, 1971; Leatherman, 1983;). In the recent years, however, the advent of remote sensing and GIS techniques coupled with field instrumentation (Davidson et al., 2004) has enabled high resolution measurement of coastal areas. The methodology adopted in this study, to delineate the shoreline and its shifting and estimation of erosion, is given in the sequential manner as follows:

***Pre-processing of satellite imagery***

Four satellite imageries of the years 1990, 2000, 2005 and 2010 have been considered in this study. Landsat TM-5 & ETM+ data sets have been downloaded from the USGS & GLCF website. All the data sets are projected in UTM projection with zone no 44 and WGS 84 datum. Satellite imagery of 1990 has been considered as base data and image of 2000, 2005 and 2010 have been co-registered using first order polynomial model with base data with 0.5 pixel (RMSE) accuracy.

***Detection of Shoreline***

Automatic shoreline delineation is a complex process due to presence of water saturated zone in the contact of land-water boundary (Ryu et al. 2002; Maiti and Bhattacharya 2009). Satellite imagery is very much useful to identify the shoreline position and coastal change (Boak 2005; Coyne et al. 1999). In order to determine the actual coastline position, two methods have been applied in this study- image classification and vegetation indexing. The histogram of MSS and TM images have been found to be bimodal in nature with two different peaks for land and water. Based on the histogram observation, images have been classified using the ISODATA classification technique and two classes (land and water) have been taken to demarcate the land water interface. In the vegetation indexing processes, Normalized Differential Vegetation Index (NDVI) has been used to differentiate between the land water boundary. The pixels representing the shoreline have been converted into vector layer to get the actual shoreline. The shoreline obtained from the 2010 satellite by the above mentioned processes is validated with the 30 Ground Control Points (points taken from the field with the help of GPS) and accurate method for shoreline extraction has been determined. After delineation of the coast line, the rate of shifting of the coast line has been estimated. Measurements from the TOPEX and Jason series of satellite radar altimeters have been analysed since 1993 to understand the sea surface height anomaly.

***Estimation of islands erosion***

Extent of shoreline erosion has been estimated from multi temporal satellite data for the period of 1990 - 2000, 2000-2005 and 2005-2010 using binary change detection approach. The multi-temporal classified images have been combined to extract the erosion and accretion areas using change detection.

***Shoreline shifting during the period 1990 to 2010***

The 15 km long Chandipur shoreline has been delineated from the satellite imageries of different years 1990, 2000, 2005 and 2010 using image classification and vegetation indexing technique. The position of 2010 shoreline is validated using 30 GCPs and the positional shift (shifting of shoreline in meter) in each GCP is plotted in the Fig. 3, shows that image classification technique is more accurate for delineation of shoreline in comparison with vegetation indexing. The positional shift is also express in terms of RMSE which is 2.31m and 4.65m for the classification and vegetation indexing respectively. It is found that the shift in the classification detected shoreline varies from 1.3 to 3.75 m while in vegetation indexing the shift varied from 2.0 to 9.35m. Based on this analysis for all other application classification delineated shoreline has been considered.

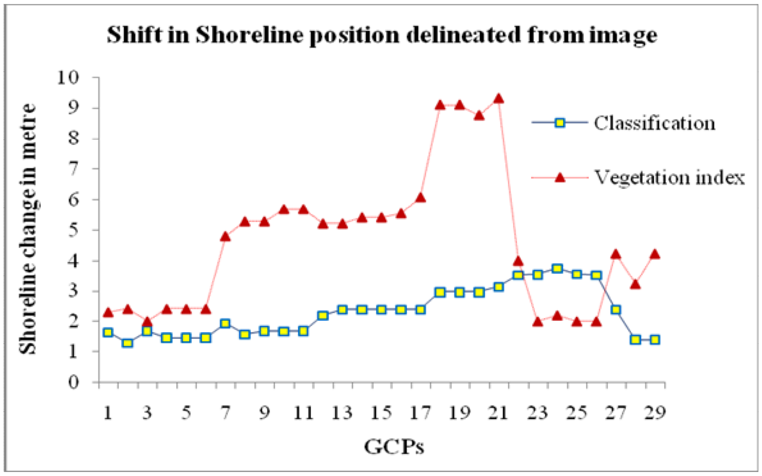


**Figure 2:** Validation of delineated shoreline from satellite imagery with respect to GCPs

***Erosional scenario in Chandipur shoreline during the period 1990 to 2010***

Analysis of the multi temporal satellite images is one of the best techniques to estimate the coastal erosion and coastline shifting, the satellite images of 1990, 2000, 2005 and 2010 of the Chandipur beach area have been analyzed. It is found that the erosion and accretion both are happening in the coastline of Chandipur. Fig. 3 shows the erosion and accretion scenario for the period of 1990 to 2010 in a sequential manner which indicates during 1990 to 2000 accretion occur in the north eastern part and northern most, middle and southern part of the coastline and it continues till the year 2005. But from 2005 to 2010 it is found that the entire coastline is suffering from erosion and high erosion is seen in the north eastern part. The accretion and erosion of the coastline has been estimated and it revealed that in spite of the presence of a long (≈4km) continental self, the coastal stretch of Chandipur is not in stable condition. Simultaneously accretion and erosion are happening in a moderate rate (Table: 2). Rate of erosion is subsequently increasing since 2000 and after 2005 there is a sudden hike in erosion (Fig: 6). The main zone of accretion is the manly in Budhabalang estuary area and the southern part of the Chandipur coast is erosion prone (Fig: 4).

**Table 2:** Erosion and accretion during 1990 to 2010

| Year | Accretion (Hectare) | Erosion (Hectare) |
|---|---|---|
| 1990-2000 | 84.23 | 53.12 |
| 2000-2005 | 56.77 | 35.82 |
| 2005-2010 | 1.89 | 70.92 |

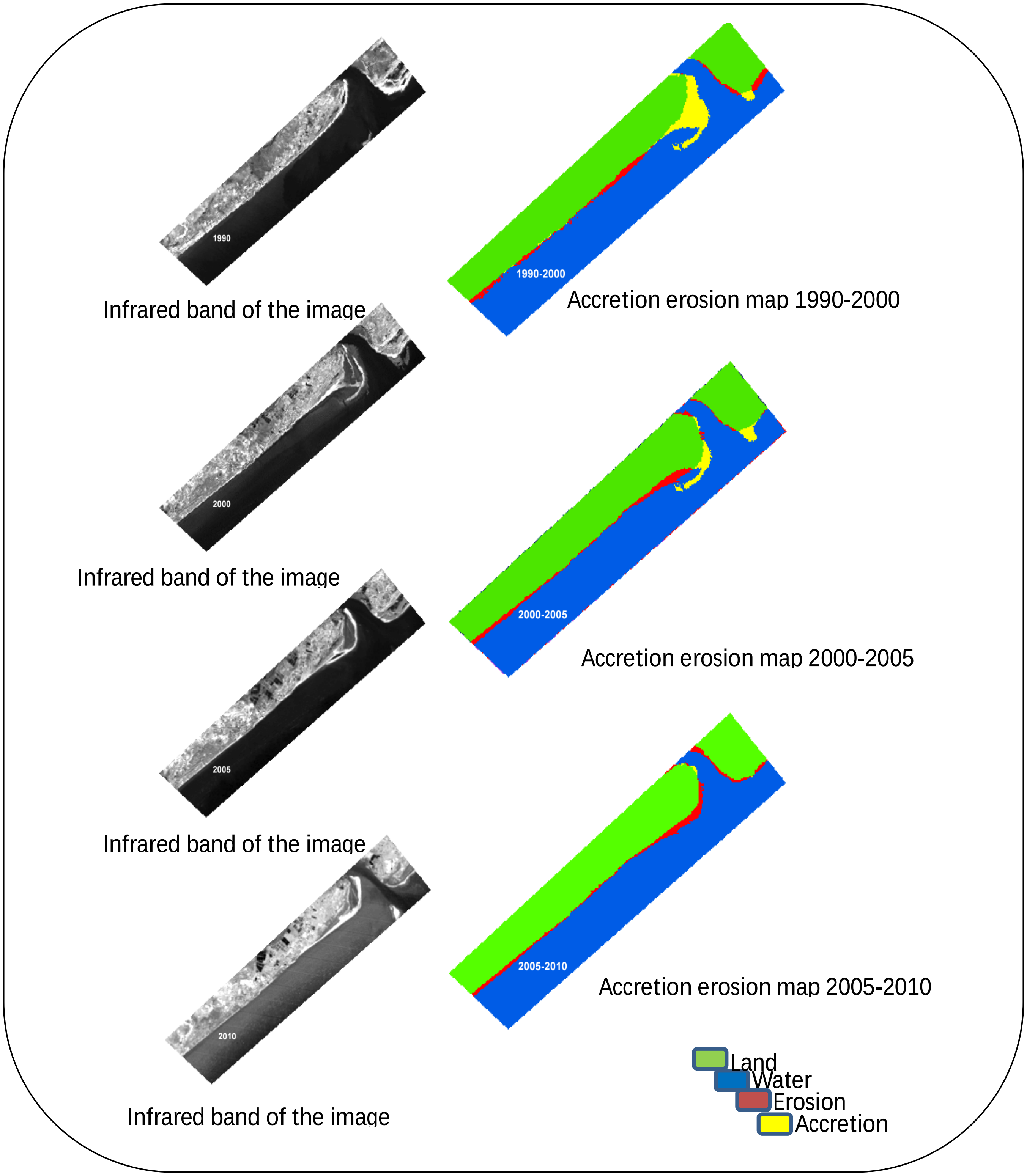


**Figure 3:** Chandipur coastline, erosion and accretion during 1990-2010

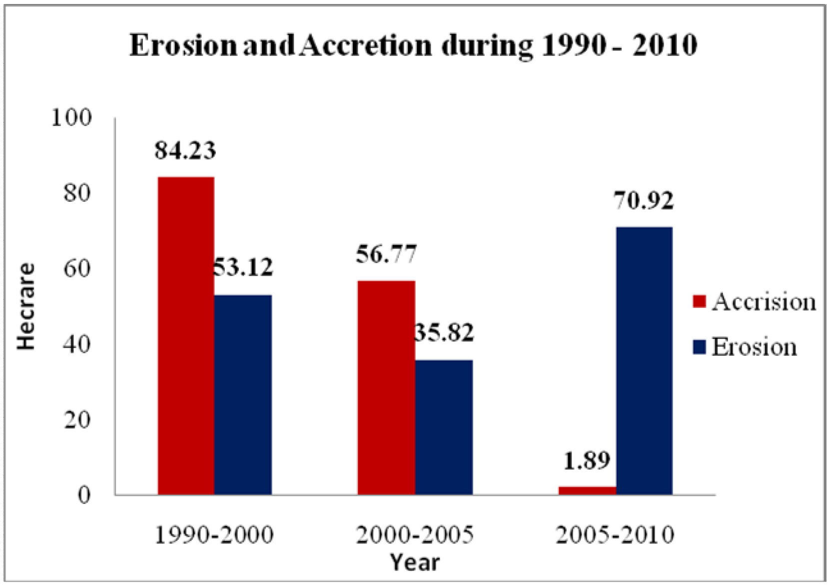


**Figure 4:** Erosion and Accretion in Chandipur coastline

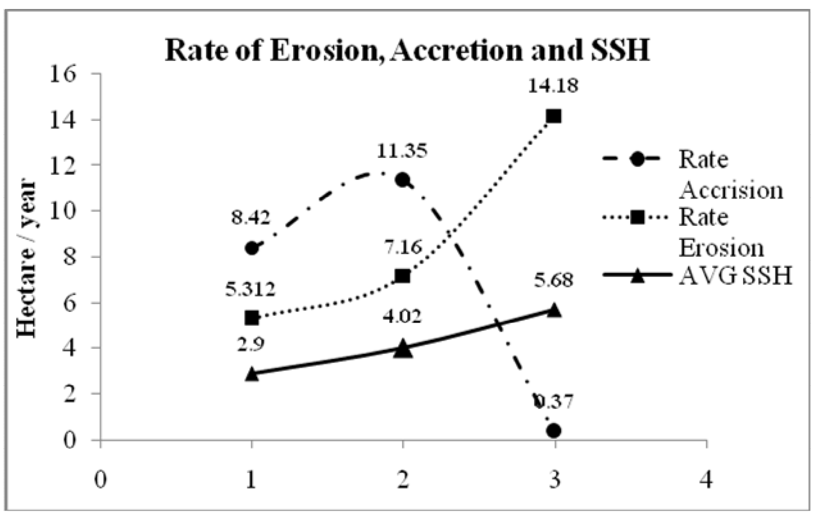


**Figure 5:** Rate of erosion, accretion and Sea surface height in the coastline during 1990 to 2010

***Sea level changes in Chandipur coastline***

To understand the condition of the sea level, sea surface altimetry data of the local sea surface has been analyzed from the year 1993 to 2011, and the result shows a steady increase in Sea surface height (**Fig: 6**). Analysis of rate of erosion and sea surface height anomaly clearly indicates that along with the steady increase of Sea surface height the rate of erosion is increasing in the Chandipur coast and the rate of accretion is become lower (**Fig: 5**). It is also suggests that the sea level rise is primary cause of coastline erosion and shifting.

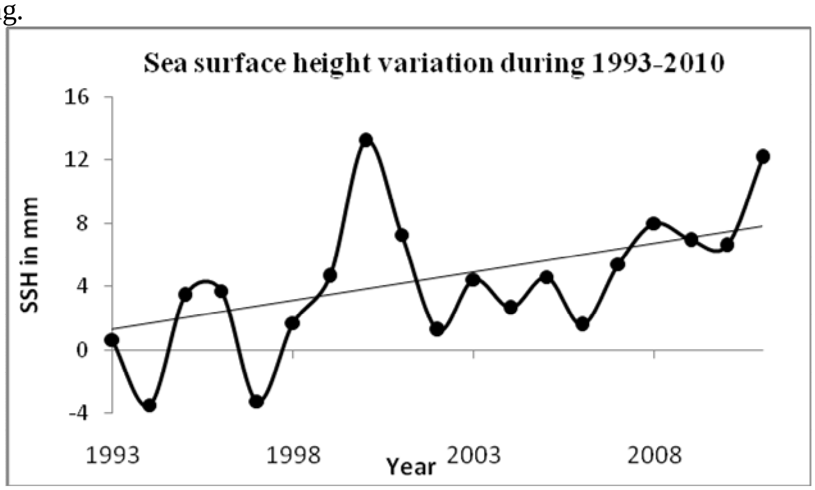


**Figure 6:** Sea surface height from satellite altimeter data during 1993 to 2011

***Conclusion***

Regional sea level rise is a major problem for the coastal people now days it increases the rate of erosion which results in loss of assets and livelihood. Within the stretch of 15 kilometer coast in Chandipur lot of dynamic changes has been seen within the last two decades. What is alarming in this area is that along with regional sea level rise the rate of erosion is also increasing in this area which may implies a lot of losses of the coastal peoples and as the area is also important for tourism point of view this is the high time to be aware and be prepare to address this problem.

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