Shoreline change and sea level rise along coast of Bhitarkanika wildlife sanctuary, Orissa: An analytical approach of remote sensing and statistical techniques
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ABSTRACT
The shoreline is one of the rapidly changing linear features of the coastal zone which is dynamic in nature. The issue of shoreline changes due to sea level rise over the next century has increasingly become a major social, economic and environmental concern to a large number of countries along the coast, where it poses a serious problem to the environment and human settlements. The global effects of sea-level rise on coasts will vary spatially. As a consequence, some coastal scientists have advocated analyzing and predicting coastal changes on a more local scale. The need to predict and manage the potential impact of sea-level rise on coasts necessitates accurate study on micro level. The present study demonstrates the potential of Geospatial and statistics technique for monitoring the shoreline changes along the coast of Bhitarkanika Wildlife Sanctuary, Orissa, India since such kind of changes stand as a testimony for the past and present coastal environment. In the present study, multi-resolution and multi temporal satellite images of Landsat have been utilized to demarcate shoreline positions during 1973, 1989, 2000 and 2009. The Statistical techniques called as linear regression and regression coefficient ($R^2$) have been used for find out the change rate during the period of 1973-2009. Finally, an attempt has been made to find out any interactive relationship between the sea level rise and shoreline change in the concerned area. The present study demonstrates that combined use of satellite imagery and statistical methods can be a reliable method for analyzed the shoreline changes in relationship to sea level rise.

Keywords: Shoreline, Sea level rise (SLR), Landsat, Rationing method, Histogram thresholding, Linear Regression, End-point Rate and Regression Co-efficient ($R^2$)

1. Introduction
The shoreline is one of the rapidly changing linear features of the coastal zone which is dynamic in nature. The issue of shoreline changes due to sea level rise over the next century has increasingly become a major social, economic and environmental concern to a large number of countries along the coast, where it poses a serious problem to the environment and human settlements. Shoreline recession as a result of rising sea level has been recognized as a potential near-future hazard by a number of countries and this is same for the states of India along the coast. Shoreline is boundary between land and water body. An idealized definition of shoreline is that it coincides with the physical interface of land and water (Dolan et al., 1980). Accurate demarcation and monitoring of shoreline changes are necessary for understanding and deciphering the coastal processes.
operating in an area. Whereas it is also important for a wide range of coastal studies such as coastal zone management planning, hazard zoning, erosion-accretion studies, analysis and modelling the coastal morphodynamics. In recent time the integration of latest techniques of remote sensing with geographical information system (GIS) has been proven to be an extremely useful approach for the shoreline changes studies due to synoptic and repetitive data coverage, high resolution, multi-spectral database and its cost effectiveness in comparison to conventional techniques. Today the issue of shoreline changes due to sea level rise which caused by Globe warming has increasingly become a major issues in terms of its impact on the population along the coastal area. Changes in mean sea level as measured by coastal tide gauges are called relative sea-level changes (Church and Gregory, 2001). There are number of reports and studies on sea level rise and its impact on shoreline changes which motivate us to carry out the study on shoreline changes in response to sea level rise along the coast of Orissa. In IPCC (Intergovernmental Panel on Climate Change) Third Assessment Report (2001) shows that global average surface temperature is projected to increase by 1.4 to 5.8° C over the period 1990 to 2100. This projected warming will be greater than that experienced over the last 10,000 years. Moreover, the global mean sea level is projected to rise by 0.09 to 0.88 m over the same period, as a result of the thermal expansion of the oceans, and the melting of glaciers and polar ice sheets. The physical effects of sea level rise are categorized into five types, inundation of low lying areas, erosion of beaches and bluffs, salt intrusion into aquifers and surface waters, higher water tables and increased flooding and storm damage (Nichols and Leatherman, 1994). Sea-level has been rising 1.7–1.8 mm/year over the last century and the rate has increased to 3 mm/year in the last decade (Church et al., 2004; Holgate & Woodworth, 2004; Church & White, 2006). Sea-level rise is contributing to coastal erosion in many places of the world (Rosenzweig et al., 2007). The tide gauge records at five coastal locations in India; Mumbai, Kolkata, Cochin, Kandla and Sagar Islands have reported an increase in sea level. The change in sea level appears to be higher on eastern coast compared to western coast. The average sea level rise for India has been reported as 2.5 mm/year since 1950’s (Das and Radhakrishnan, 1993). The present study which is motivate by above statement demonstrates the potential of Geospatial and statistics technique for monitoring the shoreline changes along the coast of Bhitarkanika Wildlife Sanctuary, Orissa, India since such kind of changes stand as a testimony for the past and present coastal environment. In the present study, multi-temporal satellite images of Landsat have been utilized to demarcate shoreline positions during different times in the past. The Statistical techniques called as linear regression and regression coefficient ($r^2$) have been used for find out the change rate during the period of 1973-2009. Finally, an attempt has been made to find out is there any interactive relationship between the sea level rise and shoreline change in the concerned area.

2. Materials and Methodology Developments

2.1 Study Area
The study area of the analysis is Bhitarkanika Wild Life Sanctuary in central coast of Orissa which is a rich, lush green vibrant eco-system lying in the estuarine region of Brahmani- Baitarani in the North-Eastern corner of Kendrapara district of Orissa. It is surrounded by the Bay of Bengal in the east, villages of Kendrapara District in the west, Baitarani and Dhamra rivers in the north and the Mahanadi delta in the south. It covers an area of 672 sq. km of mangrove forest & wetland which is extending between 86°48–87°03E longitude and 20°33N–20°47N latitude (Figure.1). The general elevation above mean tide level is between 1.5 and 2 meters (Dani and Kar, 1999). Higher ground extends up to 3.4 meters. The river flow is influenced twice daily by high and low tides at approximately six hourly intervals. The maximum and minimum tide level varies according to lunar days and seasons. Siltation is a common phenomenon in the river systems. Soil erosion is taking place on the banks of the Baitarani, Honsua, Bramhani and Dhamra rivers. This area experiences tropical warm and humid climate, with no distinct season. Rain occurs due to the southwest monsoon from May to September, and the northeast monsoon from November to December. The average rainfall is about 1642 mm, bulk of which is received during June to mid October. The maximum temperature recorded is 41°C and the minimum is 9°C during May and January respectively. Mean relative humidity ranges from 70 to 85% throughout the year. The most important weather phenomenon is the prevalence of tropical cyclones.

![Figure 1: Location of Study Area](image)

### 2.3 Data used

This study has been used Multi-resolution satellite data of Landsat series such as Landsat MSS, Landsat TM, and Landsat ETM+ which have been acquired on cloud free days of
different dates, since as same resolution data is not available over the chosen period (1973 to 2009). Reason to use Landsat data is that Landsat type of remote sensing data has been used in coastal applications for decades (Munday and Alfoldi, 1979; Bukata et al., 1988; Ritchie et al., 1990). The multispectral capabilities of the data allow observation and measurement of biophysical characteristics of coastal habitats (Colwell, 1983), and the multi temporal capabilities allow tracking of changes in these characteristics over time (Wang and Moskovits, 2001). As archived Landsat images have been made available at no cost to user communities since early 2009 (Woodcock et al., 2008), coastal applications can take advantage of this type of data. Survey of India (SOI) toposheet 73 L/13 (1:50,000 scale) was used as base map for the study. All the data have been checked using SOI toposheet. Monthly/Annual means value of sea level data for nearby two stations one is Paradip and second is Haldia has been retrieved from the database of the Permanent Service for Mean Sea Level (PSMSL). PSMSL is based at the Proudman Oceanographic Laboratory, Merseyside, United Kingdom. PSMSL contains annual mean values of sea level from almost 2000 tide gauge stations around the world. The PSMSL receives annual mean values of sea level from almost 200 national authorities, distributed around the world, responsible for sea level monitoring in each country or region. In this study ERDAS and ARCGIS software has been used to carry out digital analysis, vector analysis and transect wise shoreline changes analysis.

2.4 Methodology Used

Two types of approaches have been attempted in the study to analyze the shoreline changes in response to sea level rise along the coast of Bhitarkanika wild life sanctuary, Orissa. (1) To analysis and interpretation of optical remote sensing data (Landsat) for shoreline-change mapping and statistical techniques for shoreline change rate over the four decades. (2) To trace out is there any the interactive relationship between sea level changes and shoreline change.

2.4.1 Shoreline Mapping

Shoreline is boundary between land and water body. The term is considered synonymous with coastline but it considers as different so the precise definition of shoreline given by (CERC, 1984), shoreline is defined as the line contacting between the mean high water line and the shore. Various methods for shoreline extraction from optical imagery have been developed. Shoreline can even be extracted from a single band image, since the reflectance of water is nearly equal to zero in reflective infrared bands, and reflectance of absolute majority of land covers is greater than water (Figure 2). For this reason in initially, the shorelines have been identified and delineated using the processed NIR bands of Landsat MSS, TM and ETM+. The processing of the NIR bands included ‘Histogram/gray level thresholding’ (Lee and Jurkevich, 1990). Analysis has shown that the mid infrared band 5 of TM and ETM is the best for extracting the land water interface (Kelley, et al., 1998), since Band 5 exhibits a strong contrast between land and water features due to the high degree of absorption of mid-infrared energy by water (even
turbid water) and strong reflectance of mid infrared by vegetation and natural features in this range. This study finally used the Band Rationing method, this method is to use the band ratio between band 4 and 2 and other between band 5 and 2. From this method water and land can be separated directly.

Figure 2: Methodology Framework for Shore line changes

Generally the ratio $b_2/b_5$ is greater than one for water and less than one for land in large areas of coastal zone. These results from above ratioing method are correct in coastal zones which covered by soil, but not for land with vegetative cover since it mistakenly assigns some of the vegetative lands to water due to aggregate background reflectance. To solve this problem, the two ratios are combined in this investigation. It gives the final binary image (Figure 3) which represents the shoreline. At last to refine the overall results from above method the visual interpretation has been carried out to editing the error part of extracted shoreline mainly near the outlet of river. For this purpose a color
composite can be used and the best suited false color composite (FCC) band 432 in MSS and 543 in TM and ETM nicely depicts water-land interface.

2.4.2 Shoreline Changes and Change Rate Assessment

The study of historical shoreline data can be useful to identify the predominant coastal processes operating in specific coastal locations using change rates as an indicator of shoreline dynamics. Shoreline changes and change rate can be measured by quantifying the amount of shoreline shift along transects. This procedure involved the establishment of a baseline in the direction of general orientation of shoreline, establishment of transects perpendicular to baseline in the desired spacing, and measurement of distances between shorelines along transects. Several statistical methods are used to calculate the shoreline change rates with the most commonly used being end-point rate (EPR) calculations or linear regression (LRR) (Dolan et al. 1991). End-point rate calculations are simply the rates determined based on the changes in position between the oldest and most recent shorelines in a given dataset. Linear-regression rates are the result of estimating the average rate of changes using a number of shoreline positions over time. The shoreline change rates can then be used to extrapolate future changes in the shoreline (Crowell et al. 1997, Ferreira 2006).
To carry out shoreline changes this study has been incorporated Digital Shoreline Analysis System (DSAS), which is an extension for ArcGIS software developed by USGS was employed. This extension contains three main components that define a baseline, generate orthogonal transects at a user-defined separation along the coast, and calculate rates of change (linear regression, endpoint rate, jackknife, etc.). The first step in the analysis was quantified changes and change rate for each period of observation. Change rate was calculated using End Point Rate (EPR). The end point rate is calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements (i.e., the oldest and the most recent shoreline). Second is linear regression method have been used since it is most commonly applied statistical technique for expressing shoreline movement and estimating rates of change (Crowell et al. 1997). The linear regression method is susceptible to outlier effects, and also tends to underestimate the rate-of-change relative to other statistics, such as EPR (Dolan, et. al., 1991). In Linear regression, rate-of-change statistic can be determined by fitting a least squares regression line to all shoreline points for a particular transects. The rate is the slope of the regression’s line (Thieler et al. 2003) (Figure 4).
Figure 4: Cross-plot of time versus amount of shoreline shift with respect to 1973 shoreline position, along transect 85 and 129

3. Results and Discussion

3.1 Shoreline Changes

First, the baseline was generated onshore which is parallel to general orientation of the shoreline. Cast transects were regularly built at a spacing of 250 m along the approximately 36 km long stretch of the beach. Thus, 144 transects were built from that 142 were considered since two transect didn’t orient on shoreline direction and finally all the 142 transects attributed with ID ordered from west (transect ID 1) to east (transect ID 142) (Figure 5).
The analytical techniques that are used here are EPR (End point Rate), LRR (Linear Regression Method), R\(^2\), NSC (Net Shoreline Change). EPR for the entire shoreline shows that transect 2 to 13 records the advancing shoreline during the time span of 1973-2009. Whereas rest of the transect lines experience retreating shoreline during the same time span. Transect 2 to 13 fall at the western end of the shoreline where substantial amount of sediment load is been transferred by the river Honsua. The accretion of sediment leads to advancement of shoreline. On the other hand, rest of the shoreline (transect 14 to 142) is affected by the shore zone erosion by the strong long shore drift associated with the wave action that pushed the shoreline back from its earlier position. Table (1) summarises the shoreline change and change rate for each period. The greatest drawback of EPR is that it suppresses the shoreline behaviour for long term shoreline analysis because under the presence of more than two shorelines, it only considers the earliest and the latest shoreline position. The fluctuation in shoreline within this time span doesn’t take into account. Therefore it is good for the short term shoreline change analysis rather than longer period. Uses of LRR on the other hand eliminate this difficulty. LRR is selected because it considers all the intersection points of the multiple shorelines.
along the transect line and thereby it calculates the shoreline movement and estimate the change rate (Crowell et al. 1997).

**Table 1:** Statistics of shoreline changes in different time interval

<table>
<thead>
<tr>
<th></th>
<th>Year (mt/y)</th>
<th>1973-89</th>
<th>1989-2000</th>
<th>2000-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPR</td>
<td>Mean</td>
<td>-0.78</td>
<td>-8.65</td>
<td>-8.15</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>7.15</td>
<td>6.64</td>
<td>7.21</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>25.91,-14.09</td>
<td>21.63,-17.41</td>
<td>18.66,-22.15</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-0.06</td>
<td>0.26</td>
<td>0.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Year (mt/y)</th>
<th>1973-89</th>
<th>1989-2000</th>
<th>2000-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSM</td>
<td>Mean</td>
<td>-12.64</td>
<td>-101.86</td>
<td>-73.18</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>115.58</td>
<td>78.17</td>
<td>64.78</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>418,-227.58</td>
<td>254.51,-204.82</td>
<td>167.49,-198.84</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-0.97</td>
<td>3.07</td>
<td>4.11</td>
</tr>
</tbody>
</table>

In LRR, the shoreline shift rate can be predicted by fitting a least square regression line with the observed shoreline position along a transect line. The distribution of $R^2$ value for all the transect lines throughout the shoreline shows some distinctive distribution pattern. Transect 9 to 85 have the $R^2$ value > 0.9 and shows a linear pattern, transect 2 to 8 and 86 to 141 have the $R^2$ value < 0.9 based on the $R^2$ value entire shoreline is categorised into two zone. Zone I includes transect 2 to 8, and 86 to 141 which show lesser degree of conformation with the observed shoreline positions. Zone II includes transect 9 to 85 which have the higher degree of conformation with the observed position. This in fact emphasises that the prediction of the future shoreline position will be highly accurate (10% uncertainty) for the transect lines which have high $R^2$ value (>0.9) (Figure 6).

![Figure 6: $R^2$ value distribution](image-url)
The classes based on $R^2$ value fit well with the shoreline category i.e. advancing and retreating shoreline, classified based on the yearly change rate. Transect 2 to 12 fall in the category of advancing shoreline whereas transect 13 to 141 come under retreating shoreline. Within retreating segment transect 20 to 45 shows the highest retreating rate almost $> -10$ m/year whereas from transect 94 to onwards up to 142 retreating rate decreases with a value $< -5$ m/year. The net shoreline change over the span of 36 years from 1973 to 2009 for all transect lines is given below. The average change of shoreline position within this period is $-187.59$ m with standard deviation 229.96 m. In order to assess the rate of change of shoreline among four consecutive decadal years of available satellite images, entire span of 36 years has been grouped into 4 time interval. The summary of shoreline change of each time group is figured below (Figure 7).


**Figure 7:** Rate of Shoreline changes in different time interval

Among all three time intervals, the period of 1989-2000 has experienced highest change rate of shoreline position followed by the period of 2000-2009. Records of MSL over the years reveals that 1989-2000 was the period when sea level along this shoreline experienced a substantial increase in its height which in association with strong long shore current and wave action shift the shoreline back at a greater magnitude. However, as a whole the period from 1989 to 2009 had experienced highest magnitude of net shoreline shift with an average of -176.44mt and s.d. of 130.61mt. However, zone based analysis of the shoreline based on the rate of shifting shows that an extensive part of the shoreline is affected by the shore zone erosion (Table 2 and Figure 8). Except some portion of the western end of the shoreline which receives a substantial amount of sediment load from river Honsua that advanced the shoreline, the rest of the shoreline is affected by erosion. Thus depending on the shoreline change rate (calculated by LRR method), it has been classified into four zone. Zone I constitute the western end of the shoreline which includes transect number 1 to 12. Accretion of sediment that transferred at the river mouth helps to build up the shore zone and pushes the shoreline forward. Zone II consists of transect number 13 to 56 which have the high magnitude of shoreline shift. Zone III includes transect number 58 to 94 which show a moderate amount of shoreline shift and finally zone IV comes under transect number 95 to 142 that shows low
magnitude of shifting. The intricate mechanism behind this oscillating process of shoreline shift is the balance between the up coast and down coast movement of sediment with long shore drift that determines the sediment budget in the shore zone. If the down coast movement of the sediment is higher than the up coast movement, then the net sediment budget would be negative and the shoreline experiences retreat. In the contrary to it, the positive net sediment budget would lead the shoreline to advance.

Table 2: Statistics of shoreline changes in different Zone and individual Transect wise

<table>
<thead>
<tr>
<th>Zone</th>
<th>Zone I</th>
<th>Zone II</th>
<th>Zone III</th>
<th>Zone IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg(mt/y)</td>
<td>9.25</td>
<td>-10.47</td>
<td>-6.97</td>
<td>-2.66</td>
</tr>
<tr>
<td>Sd(mt/y)</td>
<td>6.89</td>
<td>4.01</td>
<td>0.90</td>
<td>1.13</td>
</tr>
<tr>
<td>Max(mt/y)</td>
<td>17.44</td>
<td>-16.19</td>
<td>-9.14</td>
<td>-4.9</td>
</tr>
<tr>
<td>Min(mt/y)</td>
<td>-0.19</td>
<td>-0.78</td>
<td>-4.88</td>
<td>-0.34</td>
</tr>
</tbody>
</table>
3. Zone 3 (T58 – T94)

4. Zone II (T95-T142)

Figure 8: Shoreline change rate between 1973 – 2009 in four different Zone and Transect wise

Thus, the seasonal variation of long shore drift pattern that makes the littoral cell dynamics, the geometric configuration of shoreline and the associated net sediment budget are the most important aspect that makes the spatial changes of shoreline over the years. Zone II, III and IV come under negative net sediment budget that makes the shoreline to move backward. In zone II, it is probable that the difference between up coast and the down coast sediment movement is high which would lead to high negative net sediment budget and the result is the high annual rate of shifting over the span of 36 years. At the extreme western end of the shoreline where Honsua river enters into sea comes under zone I. Substantial amount of sediment load transfer at the river mouth and low wave action make the positive net sediment budget which pushes the shoreline forward into the sea. So the general trend of the shoreline erosion is that it decreases eastward and become less near to the spit at the eastern end. The transfer of huge amount of sediment load into the sea and merely a meagre transport of that sediment load by the wave action built up the spit at the end of the right bank of the river Maipura through accretion of sediment seaward. The shoreline in this portion is so complex that it is hard to analyse the shoreline shifting pattern from transect line. The interplay between
erosional and depositional activity oscillate the shoreline over the years from 1973 to 2009, but as a whole the spit experienced increase in length from 1973 to onwards except 2000 when it lost some of its area either by submergence or active erosion.

3.2 Sea level rise and shoreline changes

Sea shore is the most sensitive to sea level change. In the present world due to the hype of Global Warming mainly there is a general tendency comes that shoreline fluctuate in response to sea level fluctuation. But this sometimes may not be the exact reason of shoreline shifting. Beach erosion through wave action, long shore drift and rip current that moves the beach sediment perpendicular to the shoreline is some other ways of altering the shoreline position over the time. Sea level observation shows that whatever the time span has been considered, it shows the global as well the regional variability. A number of processes can cause mean sea level (MSL) to fluctuate such as Thermostatic expansion, Tidal effect, Atmospheric pressure, Isostatic adjustment, melting of polar ice shelf and sea ice.

To assess the average MSL of the coastal region two sets of point data have been taken from PSMSL (Permanent Service of Mean Sea Level) for Paradip (located at the west) and Haldia (located at east) from 1966 and 1973 to 2006 respectively. The data set shows the monthly average which is transformed into yearly average. The standard deviation and co-efficient of variation of the entire period have been calculated for both the stations. Both stations show high deviation closer to 2004-05 and that indicates to the surge of tsunami waves that was hit the entire east coast at the end of 2004 (Figure 9).

However, such fluctuation in MSL leads to significant shifting of shoreline. In order to assess the shoreline response to sea level change, yearly average MSL data of both the stations have been filtered so that shoreline changes can be compared with the MSL data of same year or to its corresponding one. The MSL records of the target years for both the stations are averaged again in order to get grand average MSL of the same periods for the entire coast under study. The linear trend of the MSL height fluctuation indicates it is increasing over the period for both the stations and C.V shows a significant variation in MSL especially from the period of 1990 to 2005 (Table 3 and Figure 10).

However, the grand average MSL for the entire coastline shows the decreasing linear trend that some where strongly oppose our finding of shoreline shifting over a period of 36 years because of the sea level rise (SLR). Average shoreline shift also calculated from transect lines spreading throughout the part of the Orissa coast and that shows a retreating linear trend of shoreline (Figure 10). The degree of association between MSL and shoreline shift can well be displayed by “r” statistics, shows the value 0.31 which indicates a lower degree of relationship between these two.
The graph shows that MSL height was in an increasing trend during the period of 1990-2000 which in fact the same time span when shoreline also experience high magnitude of shifting from its earlier position. But the correlation between the shoreline shift and sea level rise suggests the shift was more because of some other processes rather than SLR. This in fact given the opportunity to think about the “storm surge” which is one of the most important intervening controlling factor in association with the processes mentioned above for monitoring the shoreline position over the years.

During the time of onset as well as retreat of Monsoon, several depressions are used to occur over the Bay of Bengal that in fact causes sea level rise when it moves towards land as an impending storm. The potential energy of the atmosphere is transformed into enormous kinetic energy which is transferred into the sea surface produces surge of sea water in association with elevated sea waves that engulf the shore zone and make a positional shift of the shoreline from its earlier position. So, all these controlling factors should be taken into account alongside the sea level change in order to capture the exact mechanism of shoreline dynamics over time.
Figure 10: Average mean sea level variation from 1973-2006 and Net Shoreline and mean sea level fluctuation over the period from 1973-2009.

Table 3: Statistics shows the interactive relationship between shoreline changes and sea level rise (SLR)

<table>
<thead>
<tr>
<th>Year</th>
<th>Avg. MSL (mt)</th>
<th>Avg.</th>
<th>S.D.</th>
<th>Avg. shoreline shift (mt)</th>
<th>Avg.</th>
<th>SD</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>7.044</td>
<td>7.03</td>
<td>0.02</td>
<td>0</td>
<td>46.922</td>
<td>48.596</td>
<td>0.31</td>
</tr>
<tr>
<td>1989</td>
<td>7.052</td>
<td>6</td>
<td>6</td>
<td>-12.6424</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>7.050</td>
<td>6</td>
<td>6</td>
<td>-101.862</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>6.997</td>
<td>6</td>
<td>6</td>
<td>-73.1835</td>
<td></td>
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</tbody>
</table>

4. Conclusion

The primary objective of the study was to find out interactive relationship between shoreline changes and sea level rise and second was the applicability of multi-resolution satellite data along with statistical techniques in the prediction of shoreline changes and
its dynamic nature which is very valuable in regards to coastal hazard assessment. The zone based analysis of shoreline changes shows that an extensive part of the shoreline is affected by the shore zone erosion during last 36 year. Except some portion of the western end of the shoreline which receives a substantial amount of sediment load from river Honsua that advanced the shoreline, apart from that rest of the shoreline is affected by the combined action of erosion by wind & tidal waves as well as the long shore drift. The shoreline mapping was given contribution to analyze the shore zone morphological dynamics and their process in the coastal area. Historic rates of shoreline change provide valuable data on erosion and sedimentation trends and permit limited forecasting of shoreline movement. From the interactive relationship between sea level rise and shore line changes this study can concluded that Mean Sea Level height was in an increasing trend during the period of 1990-2000 which in fact the same time span when shoreline also experience high magnitude of shifting from its earlier position. But there are some other processes also that mentioned before, should be taken into account alongside the sea level change in order to capture the exact mechanism of shoreline dynamics over time in this area. Based on the present study, it can be concluded that accurate prediction of shoreline changes can be done cost effectively using satellite data of higher resolution at smaller intervals and selecting short spaced transects. in order to carry out the analysis to study the interactive relationship between sea level rises and shore line changes at high precission level, it is necessary to quantify the net sediment budget flux and its tuning with the sea level change at maximum accuracy level over the years and that in fact needs integration of rigorous field data collection and high resolution satellite images as mentioned before with monthly repetition of the orbit over the same area. It also needs some further enhancements related to continuous monitoring of sea level rise along the coast of India that should be made for a future version.

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5. Reference s


