Quantitative estimation of shoreline changes using remote sensing and GIS: A case study in the parts of Cuddalore district, East coast of Tamil Nadu, India

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ABSTRACT

An attempt is being made to elucidate the effect of shoreline changes erosion and accretion along the parts of Cuddalore district coastal area. The spatial variability of shoreline changes are studied using IRS 1B LISS-I 1991, IRS 1D LISS-III 2001 with IRS 1D PAN merged data, IRS P6 LISS-IV data 2006 and Resourcesat-2 data 2012. The Survey of India toposheets of (1971) used for this study. The kind and extent of shoreline changes were investigated by using GPS during ground truth verification. Erosion during the period 1971 to 1991 was 0.81 km², 1991 to 2001 was 4.91, 2001 to 2006 was 0.39 and 2006 to 2012 was 1.27 km² respectively. The accretion during the period 1971 to 1991 was 4.07 km², 1991 to 2001 was No change, 2001 to 2006 was 1.13 and 2006 to 2012 was 0.21 km² respectively. Erosion and accretion were also observed in specific geographical areas such as beach, plantation, land with scrub, river, mangrove forest, villages and urban coast. In overall these areas the erosion dominates, suggesting the many of the natural disasters occur in the study period. The results are analyzed and presented in this paper. The study results revealed that 3.21 km² area erosion of the shoreline occurred in the past 41 years.

Keywords: Coastal Zone, Sea water, shoreline changes, GPS

1. Introduction

In world, many areas are being eroded and threaten the life and property of local population. The economic and human costs of the coastal erosion are growing as more people migrate towards coast. Healthy coastal ecosystems cannot completely protect coast from impacts of storms and floods, but they do play an important role in stabilizing shorelines and buffering coastal development from impact of storm. One of the major requirements of planning coastal protection work is to understand coastal processes of erosion, deposition, and sediment-transport, flooding and sea level-changes, which continuously modify the shoreline. Beach erosion is a universal problem and it has been estimated that 70% of all the beaches in the world are eroding (Ramesh et al. 2008). Coastal zone monitoring is an important task in sustainable development and environmental protection. For coastal zone monitoring, coastline extraction in various times is a fundamental work. Coastline is defined as the line of contact between land and the water body. Coastline is one of the most important linear features on the earth’s surface, which has a dynamic nature (Winarso, et al., 2001). Remote sensing plays an important role for spatial data acquisition from economical perspective (Alesheikh, et al., 2003). Optical images are simple to interpret and easily obtainable. Furthermore, absorption of infrared wavelength region by water and its strong reflectance by
vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water.

The historical and functional approaches to study shoreline changes along with various landforms help in deciphering the coastal processes operating in an area (Shaikh et al. 1989, Nayak, 2000). Multi-date satellite data have been used to study shoreline change and coastal landforms, which provided insight into large area sediment transport studies and detecting long-term change in entire coastline (Nayak, 2000). These changes were attributed to construction of dams on the Mahi and Panam rivers in upstream regions during 1975. Remedial measures in the form of diaphragm wall and spurs are certainly helpful to check the erosion. Recently available high-resolution images will be extremely useful for such analysis.

1.1 History

From 1807 to 1927, all coastline maps have been generated through ground surveying. In 1927 the full potential of aerial photography to complement the coastline maps was recognized. From 1927 to 1980, aerial photographs were known as the sole source for coastal mapping. However, the number of aerial photographs required for coastline mapping, even at a regional scale, is large (Lillesand, et al., 2004). Collecting, rectifying, analyzing and transferring the information from photographs to map are costly and time consuming. In addition to cost, using black and white photographs creates several other problems. First, the contrast between the land and water in the spectral range of panchromatic photographs is minimal, particularly for the turbid or muddy water of coastal region, and the interpretation of the coastline is difficult (De Jong and Van Der Meer, 2004). Second, the photographs and the resultant maps are in a non-digital format, reducing the versatility of the data set. Labor intensive digitization is required to transfer the information to a digital format, and this process introduces additional costs and errors. The geometric complexity and fragmented patterns of coastlines compounds these problems. In addition to the above, other possible limitations are: (1) the lack of timely coverage, (2) the lack of geometrical accuracy unless ortho-rectified, (3) the expense of the analytical equipment, (4) the intensive nature of the procedure (Miao and Clements, 2002), and (5) the need for skilled personnel. In addition to high costs and difficulties, generation of coastline maps has fallen sadly out of date. From 1972 the Landsat and other remote sensing satellites provide digital imagery in infrared spectral bands where the land-water interface is well defined. Hence remote sensing imagery and image processing techniques provide a possible solution to some of the problems of generating and updating the coastline maps (Winarso et al., 2001).

2. Study area

The study area (Figure 1) lies in the coastal belts and parts of Cuddalore and Chidambaram Taluk of Cuddalore District, Tamil Nadu, India. It is bounded on the north by Pondicherry Union Territory, south by Nagapattinam district, east by Bay of Bengal and west by Panruti and Virudhachalam Taluks of Cuddalore district. It lies between 11°23’57” and 11°48’03” N latitudes, and 79°38’11” and 79°51’08” E longitudes covering an area of 836.86 km². Gadilam River flows through the town and separates the Cuddalore Old town from the new one. River Uppanar is one of the rivers passing through the industrial coastal town of Cuddalore in southeast coast of India along with River Gadilam in the north, which drains into the Bay of Bengal. The river runs parallel to the coast south of Cuddalore to a distance of about 20 km and the tidal influence extends to about 1.5 km. A number of surface water bodies are found in this region, of which, Perumal Eri (Lake) in the western side is connected with the river and a large thermal power plant effluent finds its way into the river through this
water body. During the past two decades, industrial development has increased three times with many large and small-scale industries being established along the Uppnar river bank.

Figure 1: Key map of study area

The coastal zone of Cuddalore includes production of fertilizers, dyes, chemicals and mineral processing plants, and metal-based industries. The Pitchavaram Mangrove forest is an important eco-tourist spot. Cuddalore is known for its picturesque beaches, particularly Silver Beach and Samiyarpettai beach.
2.1 Data products


**Table 1: Satellite data details**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Name of the Satellite</th>
<th>Date of Acquisition</th>
<th>Sensor Type</th>
<th>Date of Acquisition</th>
<th>Sensor Type</th>
<th>Path</th>
<th>Row No.</th>
<th>Spectral Bands</th>
<th>Resolution (m)</th>
<th>Swath (Km)</th>
<th>Revisit (days)</th>
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<tr>
<td>1</td>
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<td>MS</td>
<td>23</td>
<td>060</td>
<td>0.45 - 0.52 (B) 0.52 - 0.59 (G) 0.62 - 0.68 (R) 0.77 - 0.88 (NIR)</td>
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<td>LISS III</td>
<td>MS</td>
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<td>0.52 - 0.59 (G) 0.62 - 0.68 (R) 0.77 - 0.86 (NIR)</td>
<td>23.5</td>
<td>142</td>
<td>24-25</td>
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<td>3</td>
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<td>12.02.20 01</td>
<td>PAN</td>
<td>PA</td>
<td>102</td>
<td>065</td>
<td>0.50 - 0.75</td>
<td>5.8</td>
<td>70</td>
<td>24-25</td>
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<td>4</td>
<td>IRS P6 (Resourcesat-1)</td>
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<td>LISS IV</td>
<td>MS</td>
<td>144 &amp; 145</td>
<td>0.52 - 0.59 (G) 0.62 - 0.68 (R) 0.77 - 0.86 (NIR)</td>
<td>5.8</td>
<td>24</td>
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<td>5</td>
<td>Resourcesat-2</td>
<td>18.03.20 12</td>
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<td>MS</td>
<td>102</td>
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<td>0.52 - 0.59 (B2) 0.62 - 0.68 (B3) 0.77 - 0.86 (B4)</td>
<td>5.8</td>
<td>23</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

3. Materials and methods

The Survey of India Toposheet map Nos. 58 M/9 (1970), 10 & 14 (1971), 11 (1971), 13 (1973), & 15 (1970) Scale 1:50,000 were used as a base map. They were registered and base map preparation in GIS environment. It is very limited on the east coast by using IRS satellite data of 1991, 2001, 2006 and 2012. As the digital data did not corrected using ground control points viz. road–road intersection, etc. were taken from the Survey of India Toposheet using ERDAS IMAGINE 9.2 image processing package. False Color Composite of the study area was generated with the band combinations of 3, 2, and 1 in Red Green Blue data (Figure 2). The displayed image with the above classes was spectrally enhanced by histogram have real earth coordinates, data were geometrically intersection, road–rail intersection, canal–road
equalization method. To eliminate the effect of tidal influence in shoreline change study, low tide satellite data were used. SOI toposheets 1971, IRS 1B LISS-I 1991, IRS 1D LISS-III 2001 with IRS 1D PAN merged data, IRS P6 LISS-IV data 2006 and Resourcesat-2 data 2012 satellite data were used to assess the changes in shoreline for 41 years period from 1971 to 2012. Though there is resolution difference, edge detection technique gives a clear demarcation of land and water boundary.

4. Results and discussion

Shoreline is one of the important dynamic coastal features where the land, air and sea meet. In any open coast, when manmade structures such as harbour or breakwaters interfere with the littoral currents shoreline changes drastically. Chauhan and Nayak (1995) have studied the shoreline changes using the satellite data covering low tide period. During the low tide condition, maximum land is exposed and even low water line/land water boundary and high water line are distinctly visible. This enables better mapping of the shoreline. The demarcation and the areal extent of the sites of erosion and accretion are queried and estimated through Arc GIS 9.3 package (Figure 2). The total areas of erosion during the periods 1971 to 1991, 1991 to 2001, 2001 to 2006 and 2006 to 2012 are given in table 2. It was observed that during 1971 to 1991 the erosion along the coastline of parts of Cuddalore area was 0.81 km$^2$. During the period of 1991 to 2001 it was 4.91 km$^2$, the period of 2001 to 2006 it was 0.39 km$^2$ and in the period 2006 to 2012 it was 1.27 km$^2$. Most of the erosion was observed in beach, beach ridge, brackish water creeks, coastal plain deep and sand spit coast (Figure 2). The total areas of accretion during the periods 1971 to 1991, 1991 to 2001, 2001 to 2006 and 2006 to 2012 are given in table 3. The accretion during the different periods were 4.07 km$^2$ (1971 to 1991), nil accretion (1991 to 2001), 1.13 km$^2$ (2001 to 2006) and 0.21 km$^2$ (2006 to 2012) (Figure 2). Since erosion was more than the accretion, the entire shoreline could be considered as the study period.

**Table 2: Erosion observed at parts of Cuddalore coast during 1971, 1991, 2001, 2006 and 2012**

<table>
<thead>
<tr>
<th>Year</th>
<th>Erosion area in km$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971 - 1991</td>
<td>0.81</td>
</tr>
<tr>
<td>1991 – 2001</td>
<td>4.91</td>
</tr>
<tr>
<td>2001 – 2006</td>
<td>0.39</td>
</tr>
<tr>
<td>2006 – 2012</td>
<td>1.27</td>
</tr>
<tr>
<td>1971 – 2012</td>
<td>3.21</td>
</tr>
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</table>

For analyzing the shoreline change in the study area specific sites such as Chinnur, Kuchipalayam and Cuddalore OT beach, beach ridge, brackish water creeks, coastal plain deep, swale, sand spit and Mangrove forest were studied for erosion and accretion. In Chinnur (Figure 3 & 4), during the period of 1971 to 1991 accretion was 479 m, during 2001 to 2006 accretion was 244 m and during 2006 to 2012 accretion was 377 m. The erosion observed in chinnur during the period of 1991 to 2001 was 457 m, during 2006 to 2012 erosion was 385 m. During this period erosion activities are high compare to accretion in study area. Meddle of the study area is not an erosion activity because that area occur in high protective mangrove forest. The study indicates that an area mainly erosion activities during the 41 years.
Quantitative estimation of Shoreline changes using remote sensing and GIS: A case study in the parts of Cuddalore district, east coast of Tamil Nadu, India

Figure 2: Erosion and Accretion observed in the parts of Cuddalore district Coastal area (East Coast of Tamil Nadu) Using SOI toposheets 1971, IRS 1B LISS-I 1991, IRS 1D LISS-III 2001 with IRS 1D PAN merged data, IRS P6 LISS-IV data 2006 and Resourcesat-2 data 2012 satellite data
Figure 3: Map of accretion – 1971 – 2012


<table>
<thead>
<tr>
<th>Year</th>
<th>Accretion area in km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971 - 1991</td>
<td>4.07</td>
</tr>
<tr>
<td>1991 – 2001</td>
<td>Nil</td>
</tr>
<tr>
<td>2001 – 2006</td>
<td>1.13</td>
</tr>
<tr>
<td>2006 – 2012</td>
<td>0.21</td>
</tr>
<tr>
<td>1971 – 2012</td>
<td>1.26</td>
</tr>
</tbody>
</table>
5. Conclusion

The coastal processes in parts of Cuddalore district coastal area, the shoreline change were analysed using Remote Sensing and GIS tools. The integrative approach using Remote Sensing and GIS tools clearly illustrates that erosion is predominant in the study area. Both natural and anthropogenic processes along the coast modify the shoreline configuration and control the erosion and accretion of the coastal zones. Thus, the present study clearly focuses the influences of both natural and anthropogenic coastal processes on the study area. It also recommended that proper beach filling and nourishment projects be made along the coast to save the coastal area from severe hazards.

6. References


