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Shoreline Mapping and Coastal Change Studies Along Chennai Coast Using Remote Sensing and GIS

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ABSTRACT

Shoreline change dynamics along the coastal zones of Chennai district is studied by the application of geospatial technology. The parameters analyzed for the study includes bathymetry and shoreline changes. These are integrated to assess the changes along the coastal zone. This study evaluates the two decadal changes in historical shoreline changes, using satellite images of Landsat TM. Digital Shoreline Analysis System (DSAS) helped in extracting the erosional and accretional area by calculating the Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE) and End Point Rate (EPR). The analysis of shoreline changes along the coast revealed significant variations both in the forms of shoreline erosion and accretion.

Keywords: Shoreline Change, DSAS, NSM, SCE, EPR, Bathymetry, Remote sensing, GIS

I. INTRODUCTION

Coastal zone is the transition area between land and ocean it has a complex, dynamic and delicate environment. Shoreline is one of the most rapidly changing landforms of the coastal zone. The shorelines are continuously modifying due to the geomorphic processes such as erosion, deposition, sedimentation, periodic storms, flooding and sea level changes. The coastal zone is receiving an increasing attention due to the pressure of uncontrolled population and industrial developments. Erosion is also caused by shifting of river mouth and spits. Conservation of natural resources, the loss of habitats, dynamic coastlines, municipal and industrial pollution are major fields of concern nowadays.

Remote sensing technology had been used commonly for shoreline mapping and offers the potential of updating data frequently. Satellite remote sensing has proved its utility in all fields of earth studies including the study of coastal processes, because of the repetitive, synoptic and multispectral coverages of the satellites. Satellites imageries are the useful tool for analyzing the changes in coastal morphology. RS data can be used to assess coastal processes like erosion/accretion and shoreline changes. Geographic Information System (GIS) is the powerful technology designed to analyze and manage the data referenced by spatial/geographical coordinates. The major advantage of GIS is that it allows identifying the spatial relationships between features and temporal changes within an area over time. Remote sensing satellite images have been effectively used for monitoring shoreline changes of different locations. This study has been done to evaluate the shoreline changes in terms of accretion, erosion, geomorphology using Geospatial techniques along (Vinayaraj et al., 2011) the Chennai coast, east coast of India.

II. STUDY AREA

The study area chosen in the present work is the coastal stretch of Chennai, the capital city of Tamil Nadu, is situated on the north-east end of Tamil Nadu on the Coromandel coast of Bay of Bengal (http://www.chennai.tn.nic.in). The area lies between $13^{0}0'0''$ and $13^{0}5'0''$ of the northern latitude and $80^{0}15'0''$

and 80⁰20'0" of the southern longitude. The north stretch includes Thiruvottiyur to Royapuram fishing harbor and the southern part includes various tourist beaches i.e., Marina, Foreshore, Besant Nagar and Thiruvanmiyur etc.

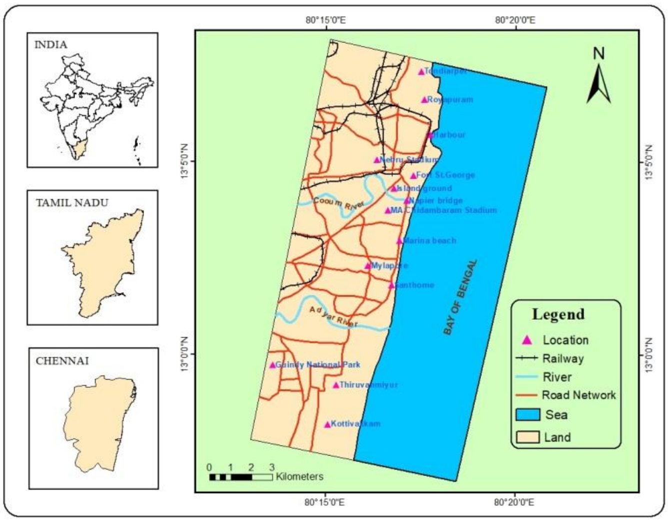


Figure 1. Base map of the study area

In between them, Chennai port is located. Marina beach, it is the second largest beach in the world. The area is bounded by Buckingham canal flows from northern to southern direction, the rivers Cooum and Adyar intercept the coastline and joining the Bay of Bengal. The study area comes under the two taluks of Chennai district which are Tondiarpet and Mylapore. The study area (Fig.1) covers an area of about 199.67 km^2 and the coastline extends over a length of about 19.97 Km. It falls under the Survey of India (SOI) toposheet numbers 66 C/4, 66 C/8, 66 D/1 and 66 D/5.

III. DATA AND METHODOLOGY

3.1 Data source

The toposheet maps of Chennai district were acquired from Survey of India. The satellite data of Landsat for the years 1996, 2006 and 2016 were used for the study purpose and was downloaded from the website http://earthexplorer.usgs.gov/. The multi-resolution satellite data Landsat TM was used as primary data to assess the shoreline changes of the study area. Table (1) clearly shows the details regarding the data used in the present study.

Table 1. Datasets Used In The Present Study And Their Source

Sl.No.	Data Type	Year of Product	Scale/ Resolution	Source
1.	Topographic Sheet (66 C/4, 66 C/8, 66 D/1, 66 D/5)	1970-1971	1:50,000	SOI
2.	Geology Map	1995	1:50,000	GSI
3.	Geomorphology	2005-06	1:50,000	Bhuvan
4.	Bathymetry Map	2010	1:150,000	National Hydrographic Office
5.	Landsat 5 (TM)	1996,2006,2016	30m	USGS

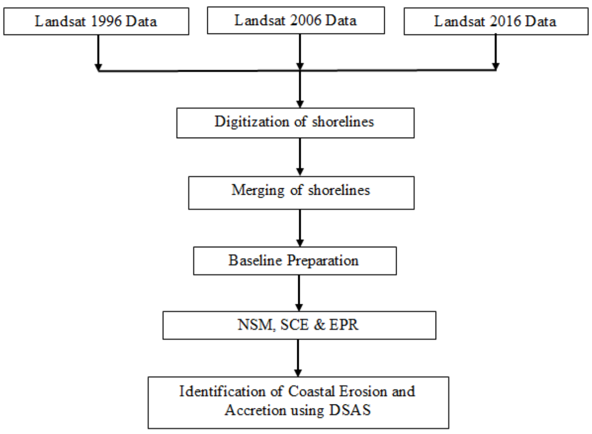
3.2 Shoreline change study

Landsat TM images covering the Chennai coastline for the years 1996, 2006, 2016 were digitized using ArcMap 10.2.2. The near-infrared band that is most suitable for the demarcation of the land-water boundary has been used to extract the shoreline. The digitized shorelines were used as the input to calculate the rate of shoreline change using the Digital Shoreline Analysis System (DSAS). The rate of shoreline change is calculated for the entire study area;

thus, the risk ratings are assigned (Siva Sankari et al.,2015).

3.2.1 DSAS (Digital Shoreline Analysis System)

In the present study, the shoreline change along the Chennai Coast was analyzed by using Digital Shoreline Analysis System (DSAS) version 4.3, an extension to ESRI Arc GIS v.10.2 and accessed at http://woodshole.er.usgs.gov/projectpages/dsas/ (Thieler et al.,2009). There were numerous applications of DSAS in the study of coastal behaviour and shoreline dynamics. There are various methods adopted to calculate the shoreline change such as



Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM) and End Point rate (EPR) (Manik Mahapatra et al.,2013). The methodology adopted for shoreline change is shown in Figure 2.

3.3 Bathymetry

For the present study, the Naval Hydrographic Chart No.313 for Mamallapuram to Point Pudi of 2nd edition on 31.10.2010 was collected from the National Hydrographic Office, Dehradun for bathymetry mapping. The depth contours were vectorized and Triangulated Irregular Network (TIN) model was developed using ArcGIS after georeferencing with Universal Transverse Mercator (UTM) projection system with WGS-84 datum.

IV. RESULTS AND DISCUSSION

4.1 Shoreline Mapping

Shoreline is the interface between land and sea undergoes changes continuously due to dynamic environmental conditions. The waves, tides, winds, periodic storms, sea level changes, the geomorphic processes of erosion, accretion and human activities make changes over shorelines. Further, the changes are due to manmade structures such as harbor or breakwaters interfere with the littoral currents. Shoreline changes are dynamic in nature and demand constant monitoring.

4.2 Shoreline Change Assessment

The shorelines of 1996, 2006, 2016 years were digitized and given as the input for the DSAS model to calculate the rate of change. Baselines were constructed seaward and parallel to the general trend of all the shorelines. Transects with a spacing of 100m apart and length 1500m are used to estimate the different shoreline change rates (Figutr 3). With reference to the baseline, seaward shift of the shoreline along with the transect is considered as a positive value, while landward shift is considered as negative (Manik Mahapatra et al., 2014).

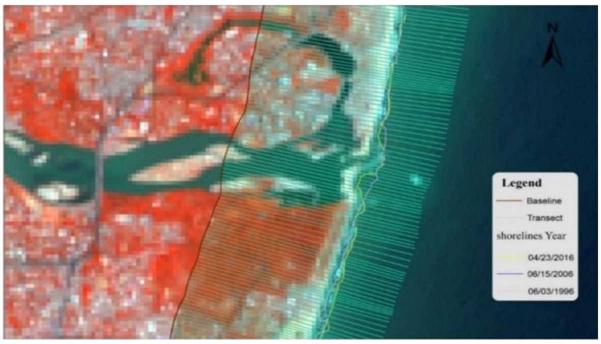


Figure 2

The shoreline study area is about 19.97 km along the coastal stretch of Chennai. The parameters involved in this study were EPR, which is the distance of shoreline movement elapsed by the time duration used between the oldest and the recent shoreline; NSM, the distance between the oldest and the youngest shoreline; SCE, the distance between the shorelines farthest and closest to the baseline.

Based on the rate of shoreline changes of EPR method, the coastal stretches of study area have been classified into five categories. These are high erosion (>- 4 m/yr), low erosion (>- 1 to <- 4 m/yr), stable (- 1 to 1 m/yr), low accretion (>1 to < 4 m/yr), and high accretion (> 4 m/yr) coast (Fig. 4). The study finds that about 1% of the study area over a length of 0.2 km is only under high erosion categories mostly along the Adyar river mouth region. About 1.34 km long coastal segment which accounts for 6.71% of the total length is under low erosion category mostly along the Royapuram Harbor region. Stable coastal length of the study area is 6.54 i.e., 32.74% of the total length of the study area and mostly found in Marina beach areas. High accretion (12.58%) is found at Tondiarpet, Fort St. George, Cooum river and Kottivakkam areas over a length of 2.51 km and showed low accretion with length of 9.38 km (46.97%) at the Santhome and Thiruvanmiyur locations of the study area. Analysing the EPR results, the study finds that accretion is dominant in the region which is about 59.55 % and about 32.74% of area is found stable in nature. The location wise statistics of the coast is shown in Table (2).

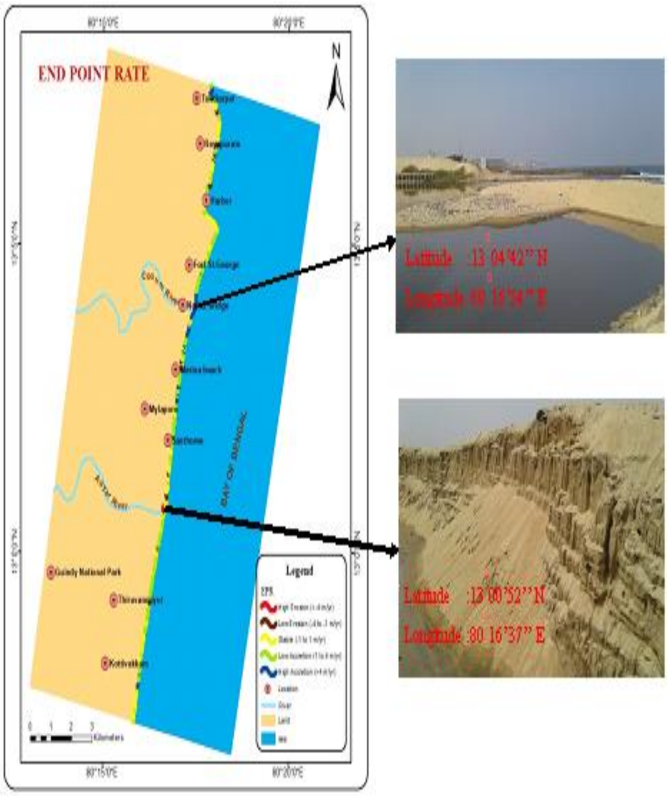


Figure 4. End Point Rate map showing high and low erosion areas

Table 2. Shoreline Change Rates

Sl.No.	Location	EPR (m/yr)	NSM (m)	SCE (m)
1.	Tondiarpet	4.41	87.69	87.69
2.	Royapuram	1.55	30.91	30.91
3.	Harbor	-0.77	-14.22	36.21
4.	Fort St. George	4.08	81.19	81.19
5.	Cooum river	7.34	145.94	145.94
6.	Marina beach	-0.39	-7.77	7.77
7.	Santhome	1.89	37.66	60.44
8.	Adyar river	-2.4	-47.82	47.82
9.	Thiruvanmiyur	2.18	43.32	43.32
10.	Kottivakkam	6.27	61.84	61.84

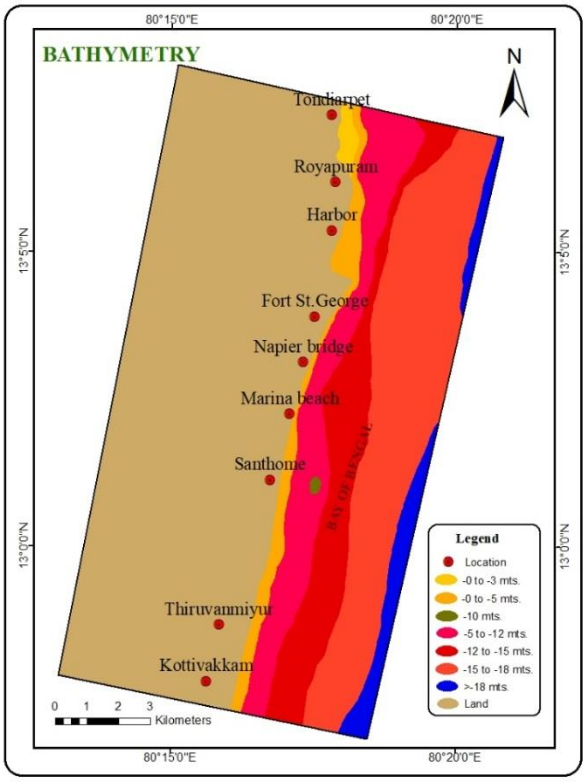


Figure 5. Bathymetry Map

Bathymetry shows the depth from the coast toward the open ocean; it is the underwater equivalent of contour lines on the land. Bathymetry is the essential baseline for all forms of hydrodynamic, wave, and inundation modeling. Degree of near-shore slope can be estimated using bathymetry of region. Near-shore slope characteristic is an important parameter in deciding the degree to which the coastal land is at the risk of flooding from storm surges and during a tsunami. Locations having gentle land slope values have a great penetration of seawater compared with locations with fewer slopes and resulting land loss from inundation is simply a function of slope: the lower the slope, the greater the land loss (Klein et al., 2000). Thus, coastal and near-shore areas having gentle slope are considered as highly vulnerable areas and areas of steep slope as areas of low vulnerability. The region, where there is an active accretion, is classified as low vulnerable area, since the deposit reduces the wave energy, whereas the area where the erosion is pronounced is marked as highly vulnerable and thus risk rating was assigned (Fig.3).

V. CONCLUSION

From the above analysis, during the period of 1996-2016, the Chennai coast is found to be both eroded and accreted. The erosion observed is not continuous in manner but in isolated stretches along the coast. The high rate of erosion has been observed at the estuarine mouth of Adyar due to the sediment erosion from the banks because of complex interactions between river flow, waves and their tides. North Chennai (Tondiyarpet, Royapuram) was found to be less eroded and the south (Marina Beach, BesantNagar) was found to be stable and less accreted. The erosion state remains at the north Chennai due to the influence of Chennai port and this rate was increased due to the second construction made very next to the port that is Royapuram fishing harbour. Hence, in order to stop the erosion rates in the northern region groins constructions across the coastal region. Because of these groins across the coast, wave actions were really controlled. For the two decades of the study period, the analysis shows that southern part (Tondiarpet, Fort St. George, Cooum river and Kottivakkam) of the coast is being accreted.

VI. ACKNOWLEDGMENT

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