Shoreline Change Detection of a Part of Thoothukudi Coast using Remote Sensing and GIS

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Abstract— Coastal studies is a wide field, which mainly indicates the changes in the earth surface easily and clearly due to the actions that take place in its surface and subsurface rapidly due to various parameters like wind, wave, tides, eruption, faulting etc. All these help in, identifying the proper changes that take place in the area frequently. In the present study, the erosion and depositional activities that happened along the coastline from Thoothukudi to Vembar was studied in detail with the help of Geology, Geomorphology and Bathymetry and the Digital Shoreline Change Analysis technique and the shoreline changes for a time period of 22 years in the study area. From the field study the area under high erosion was noted and the area that has undergone deposition was determined. The area where remedial measures has to be taken is been noted and the places where vegetation has to be raised were also identified. Remedial measures include beach nourishment and dune grass planting in the study are suitable for the reduction of the erosion in the place. From the study, it is been confirmed that erosion occurs at a higher rate when compared with accretion in the area.

Key words: Coastal erosion, Accretion, Remote Sensing, GIS, Management

I. INTRODUCTION

The modification of the coastal landforms is mainly due to the earthly and aquatic forces which in turn gives rise to various landform features. Coastal erosion poses serious threat to life, properties and economic development of the nation (Amlalo 2006). The anthropogenic activity that takes place along the coastal regulation zone is also a reason for the erosion and deposition of sediments along the coast. The stress produced by these factors results in the instability of the coastal environment. A detailed study has to be done to know about the changes that have taken place in the study area. A systematic approach towards the influencing parameters gives an outline about the various landforms that are formed by erosion and accretion (Goung Jianya et al, 2008). Ly (1980) argued that coastal erosion in Ghana was caused by the removal of sand from the unconsolidated Quaternary sediments eroded at the shoreline to compensate the loss of sand caused by the dominant West-to-East littoral drift. Coastal erosion is controlled by multiplicity of factors including: coastal geology, waves, tidal waves (tsunami), tidal range, sea level, increased storminess, height of cliff and human induced factors (Pethick 1984; Bird 2008). This takes of a long time to be surveyed and if the region is large it may be difficult to survey and the data might be incomplete if the traditional methods are used. In most cases, such 'ad hoc' management interventions classically tend to stabilize the shoreline at the protected section and exacerbate the situation elsewhere along the shoreline (knock-on effects) (French 2001). To overcome this difficulty, satellite data interpretation techniques can be used to demarcate the change detection using remote sensing platform to bring out the changes that took place in the area periodically.

II. STUDY AREA

The area extends from (78°8'12"E & 78°21'21"E Longitudes and 8°48'50"N & 9°6'4"N Latitudes) Thoothukudi to Vembar along the coastal belt of TamilNadu, India. It comprises of a total length of 41.96 kilometres. The study area falls under Survey of India (SOI) toposheet numbers, 58 I 1 & 5, 58 K 4 & 8 respectively. The Thoothukudi district was bifurcated from the combined Tirunelveli district on 29th, October, 1986 (Selvam, 2012), The salient features of the district include its lengthy, curvy and scenic sea coast with enormous palmyrah trees, The district is known for pearl cultivation, with an abundance of pearls being found in the seas offshore, from which the name "Pearl City" came; the ancient port of Korkai through which trade with Rome happened, The Coral islands of the Gulf of Mannar Marine Biosphere Reserve, The beautiful coastal villages with their sacred temples, churches and mosques. The Tropical climate prevails in the district throughout the year. The rainfall is mainly due to the north east monsoon. The area comprises of Red loamy soil, Lateritic soil, Black soil, and Sandy coastal Alluvium and Red Sandy soil. The prominent geomorphic units identified in the district are 1) Fluvial, 2) Marine, 3) Fluvio-marine, 4) Aeolian and 5) Erosional landforms depending on the environment of formation. The district is well connected by two national highways and nine state highways with various rural road networks [Fig.1]

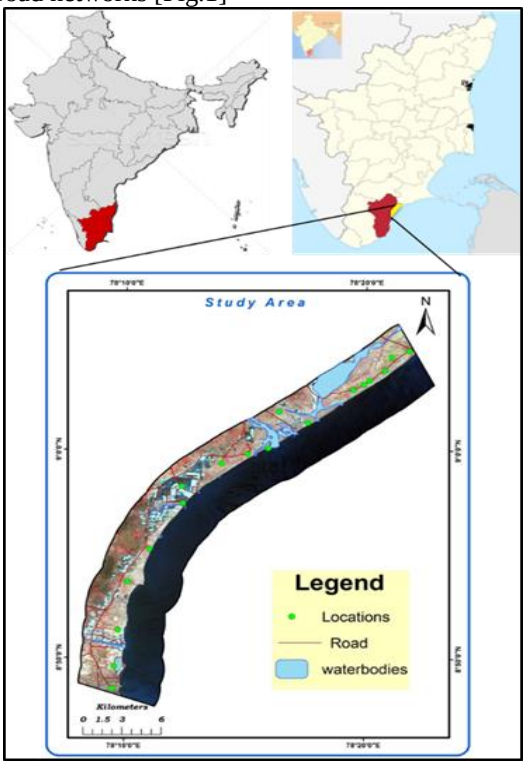

Fig. 1: Study area map

III. METHODOLOGY

The study was carried out in the coastal region of part of Thoothukudi district of Tamilnadu. A detailed study of geology, geomorphologic mapping, bathymetry and shoreline changes was undergone. Thematic maps of the above said parameters were prepared from multiple sources and also with remote sensing and Geographic Information System (GIS). Then the layers were interpreted using the Digital Shoreline Change Analysis System technique in the ArcGIS platform. The Satellite images of the years 1992, 2001, 2009 and 2014 were used to demarcate the changes along the shoreline. The methodology used has been given in the below flowchart [Fig. 2]

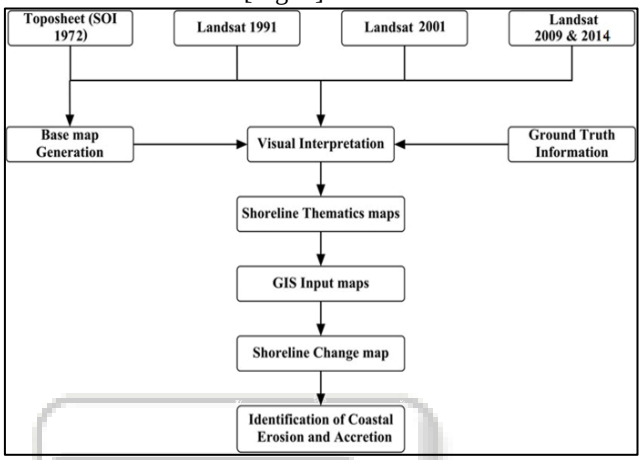

Fig. 2: Methodology flow chart

IV. GEOLOGY

The study area comprises the rocks and unconsolidated sediments of Archaean to Recent age, deposited during Recent to late Pleistocene epochs occurring over most part within the study area. Marine sediments are noted throughout the entire area. The fluvio-marine sediments are confined to the southern and central part within the study area. Rock types found within the area belong to the Khondalite and Charnockite groups and Migmatite Complex of Archaean Age, which are overlaid by Tertiary and Quaternary sediments with unconformity. Garnet-biotite-sillimanite gneiss, quartzite, calc-granulite and Khondalite limestone with epidiorite, occurring as narrow linear bands. The acid variants represents the Charnockite Group.

V. GEOMORPHOLOGY

The noticeable geomorphologic features recognized in the district are 1) Fluvial, 2) Marine, 3) Fluvio-marine, 4) Aeolian and 5) Erosional landforms. The red sandy tracts and the sand dunes which are locally known as *Teri* sand complex are the important features along the coast. These Teri sands extend in width from 6 to 8 km from the coastal shoreline. The important geomorphological features of the study area are, Active Flood Plain, Anthropogenic Terrain, Older Coastal Plain, Pediplain Complex, Waterbody and Younger Coastal Plain [Fig.3].

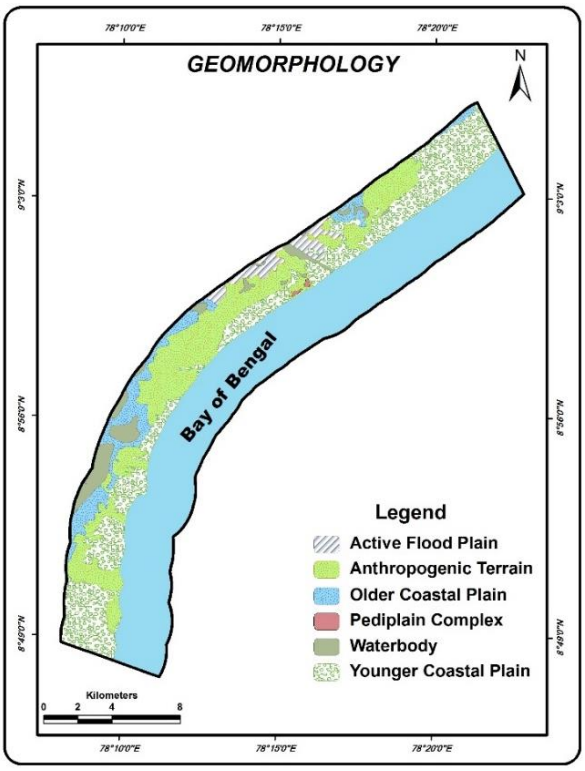

Fig. 3: Geomorphology map

VI. BATHYMETRY

The term "bathymetry" originally referred to the ocean's depth relative to sea level, although it has come to mean "submarine topography," or the depths and shapes of underwater terrain. In the same way that topographic maps represent the three-dimensional features (or relief) of overland terrain, bathymetric maps illustrate the land that lies underwater. Variations in sea-floor relief may be depicted by color and contour lines called depth contours or isobaths. Bathymetry is the foundation of the science of hydrography, which measures the physical features of a water body. Hydrography includes not only bathymetry, but also the shape and features of the shoreline; the characteristics of tides, currents, and waves; and the physical and chemical properties of the water itself. (Noaa.gov)

Generally, the beaches of the study area are sloping with an inclination of 3° to 7°, with a beach width of 26 to 40 m. North of Thoothukudi, the beach has an inclination of >5° and a width of ~16–26 m. The shoreline configuration in the present study area is mainly controlled and influenced by the predominance of NE and SW monsoonal wind directions (Solai et al, 2012)

The depth of the study area varies from about 15 mts to a maximum of about 25 mts in the study area. The minimum depth is noted along the entire coast near to the shore. In this area the bathymetry was demarcated using the naval hydrographic chart of 2010. A value of 0 to -3 was assigned to note the changes. In this area, the depth of -0 to -3 values from the depth of 72.64 mts. The area is highly supported by the less wave action which in turn deposits enormous amount of sand and silt along the shoreline.

The areas with values of -0 to – and -2 to -3 metres experiences a higher amount of deposition covering an area of about 45.7 sq.km. This is due to the presence of port,

which acts as a barrier and reduces the wave action and wind movement to a greater extent. The Kallar estuary also plays a major role in this depositional activity by supporting to the deposition of sediments from the inland.

The areas with -0 to -1 indicates a land in the sea seen only during low tide period and the coral islands in the study area. Only erosion can be noted in these areas with accretion to a certain limit. This covers an area of 1.42 sq.km of the study area. [Fig 4]

VII. SHORELINE CHANGE ANALYSIS

Shorelines are very important dynamic coastal features where the land, air and sea meet. In any open coast, when man-made structures such as harbor or breakwaters interfere with the littoral current shoreline changes drastically. Chauhan et al., (1995) have opined that the shoreline changes using the satellite data along the Indian coast. He has stated that during the low tide, maximum land is exposed and even low water line/land water boundary and high water line are distinctly visible. He has also highlighted that this technology enables better mapping of the shoreline. In this study, the shoreline positions and the changes for the last 22 years period i.e., during 1992 to 2014 were studied.

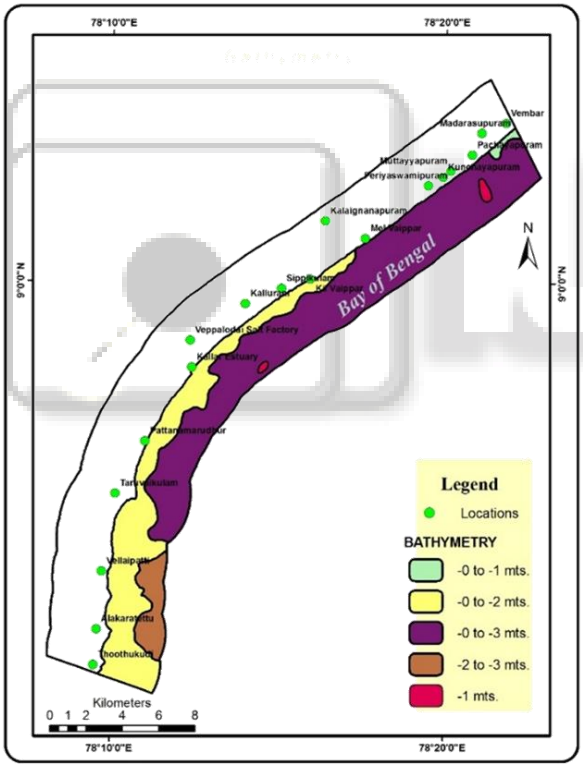

Fig. 4: Bathymetry map

VIII. SHORELINE CHANGE ASSESSMENT

The Digital Shoreline Analysis System (DSAS) is a software computes rate-of-change statistics for a time series of shoreline vector data. This software utility is based on use in a coastal environment; the DSAS application is also useful for computing rates of change for any boundary-change problem that incorporates a clearly-identified feature position at discrete times.

The shoreline change status for the periods of 1992, 2001, 2009 and 2014 was analyzed for the study area from Thoothukudi to Vembar which constitutes a shoreline length of 41.96 kms.

The following coastal villages falls under high vulnerable zones where the erosion rate is very high to high. Vembar, Periyasamypuram, Melvaippar, Kilvaippar, Sippikulam, Kallurani and Veppalodai are the areas which express high rate of erosion. This was also observed in the field studies [Fig.5]. This is due to the high wave action and wind movement prevailing in the area. Moreover, the area is also subjected to anthropogenic disturbances.

The remaining villages falls under medium vulnerability zones in which the erosion rate is slow. The villages are Alankarathettu, Vellaipatti, Taruvaikulam, Pattanamarudhur, Kallar estuary, Kunchayapuram, Muttayapuram, Pachayapuram and Madarasupuram. The Thoothukudi area falls under urban limit, so the precautionary measures are taken and continuously monitored and thus the erosion rate is controlled to a higher level in the area, but in a part just behind the port area erosion is noticed due to the port extension activities and a sewage canal constructed by the corporation. [Fig 6]

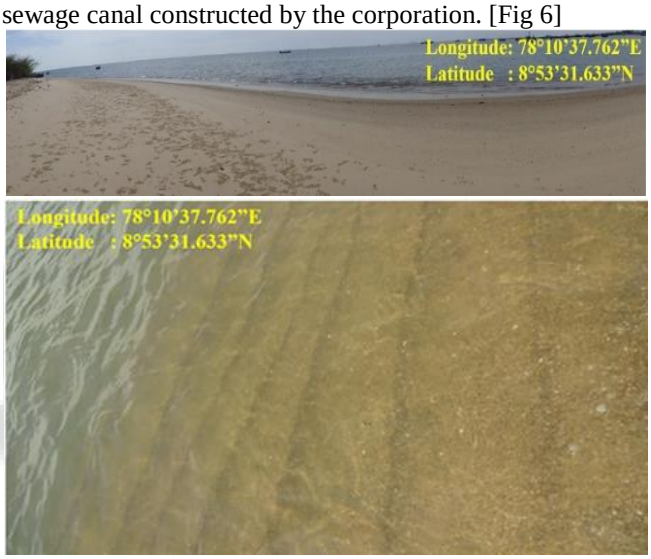

Fig. 5: Field identification of erosional activities

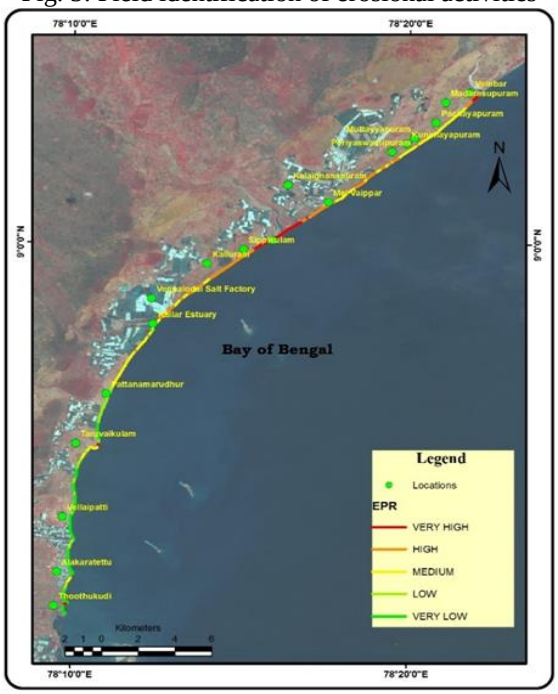

Fig. 6: End Point Rate

IX. CONCLUSION

The study proves that majority of the villages in the study area has been subjected to erosion and certain parts had undergone accretion. The geomorphology, Bathymetry and EPR spatial distribution maps proves that the erosion rate is higher when compared with deposition in the study area in the recent years. The remote sensing studies undergone and the field studies have proved the changes happened along the shoreline throughout the study area.

The Landsat images were interpreted to bring out the changes precisely for the entire coastline of 41.96 kms. The Shoreline Change Environment ranges from 10.64 mts to 164.8 mts throughout the coast. The Net Shoreline Movement ranges from 164.8 mts to 7.42 mts. The End Point Rate of the shoreline has experienced a lot of changes ranging from 7.49 mts to 0.33 mts and is noted in Kilvaippar and Kallar estuary area respectively. From the study, it is suggested to do beach nourishment and dune grass planting to safeguard the shoreline and the coastal areas**.** Moreover, the measures to safeguard the coastal estuarine eco-systems has to be carried out without disturbing the existing vegetation cover. The established groins and jetties along the shoreline has to be taken into account and their impact on the shoreline has to be studied periodically and remedial measures has to be taken.

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