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ORIGINAL RESEARCH ARTICLE

Analysis of shoreline changes along the coast of Tiruvallur district, Tamil Nadu, India

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ABSTRACT

Shore line change is considered as one of the most dynamic processes, which were mapped along the coast of Tiruvallur district by using topographic maps of 1976 and multi-temporal satellite images. The satellite images pertaining to 1988, 1991, 2006, 2010, 2013 and 2016 were used to extract the shorelines. It is important to map and monitor the HTL (High Tide Line) at frequent time intervals as the shoreline was demarcated by using visual interpretation technique from satellite images and topographic maps. Followed by this, an overlay analysis was performed to calculate areas of erosion and accretion in the study area. The results revealed that the coast of Tiruvallur district lost 603 ha and gained 630 ha due to erosion and accretion respectively. It was confirmed after the ground truth survey carried out in the study area. The high accretion of 178 ha was found nearby Pulicat Lake and low accretion of 19 ha was seen between Pulicat Lake and Kattupali Port. The high erosion area was found along the Pulicat Lake, Kattupali and Ennore ports, and Ennore creek mouth and southern Ennore such as Periya Kuppam, Chinna Kuppam, Kasi Koil Kuppam, and Thyagarajapuram. It may be concluded that the coastal erosion and accretion in the study area were mainly caused by anthropogenic and natural factors, which altered the coastal environment.

Keywords: Erosion; Accretion; Shoreline; Multi-temporal; Overlay Analysis; Coastal Zone

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1. Introduction

India has a long coastline extending over a length of 7,517 km, in which 5,423 km belongs to the mainland covering 9 states, while 2,094 km belongs to islands territories including two union territories according to India State of Forest Report in 2015. Tamil Nadu constitutes a length of coastline 1,075 km, of which 27.9 km occupied by Tiruvallur district. It is straight and also the twelfth largest coast in Tamil Nadu and falls on the Bay of Bengal. The major coastal land form features of the coast of Tiruvallur district include rivers, beaches, coastal dunes, mudflats, backwater, mangroves, saltpans, aquaculture, spits and strand features[1]. The shoreline is one of the most dynamic coastal landform features in the coastal zone and various geological processes are involving and altering the shore line, which includes deposition, erosion, sedimentation, tsunami, cyclone, storm surge, flooding, waves, winds, tides, currents, and sea level raises and so forth. On the other hand, man-made disturbances, like construction of jetties, ports, sea walls, groins, mining of the beach sand, breakwaters, urbanization, garbage dump, industrialization, discharge of domestic wastages, industrial effluent, recreational activities and reduction in sediment supply from the rivers etc. are also changing the shoreline.

These two factors are the main causes for shore line changes which lead to erosion and accretion in short-term and long-term[1-5], which play a crucial role in impacting the surrounding habitats and shore lines as well. Remote sensing technology was employed, since 1980, throughout the world to understand the shore line changes and explain their causes and quantum[6-9].

As modern scientific tools, remote sensing and GIS have benefited us a lot in mapping and monitoring the shoreline changes for long time periods, thus helping evaluate erosion and accretion[3–5,8]. In the study of Manik Mahapatra *et al.*[4], digital shoreline analysis system has been used to analyze the coast of south Gujarat, India. Saranathan *et al.*[3] have used remote sensing and GIS tools to explain how the shoreline changes in Tarangampadi village, Nagapattinam district, Tamil Nadu, India. Anil Cherian *et al.*[10] studied the assessment of coastal erosion along the southern Tamilnadu coast and carried out a risk assessment by setting indicators of coastal erosion. Jayakumar and Malarvannan[1] have developed WebGIS for managing the shoreline changes in the Northern Tamil Nadu coast. In Faik Ahmet Sesli's study[8], aerial images and digital photogrammetry data was used to monitor the coast from 1935 to 2006 in Samsun, Turkey. Another study by Bertacchini and Capra[11] provided very high resolution satellite images for two places in Italy, which was very useful for map updating and environmental monitoring. The present study is intended to use multi-temporal satellite images to record the impacts from both natural and human on the coast of Tiruvallur district and to analyze morphological differences, variations in shoreline changes, erosions and accretion. Since there were no details of shoreline changes study conducted on the coast of Tiruvallur district, it is the need of hour to address the changes in shoreline along the coast of Tiruvallur and frequently publish the reports for formulating policies, which will better improve planning and management of coastal resources. The aim of the present study is to analyze the shoreline changes along the coast of Tiruvallur and evaluate erosion and deposition over the periods of 40 years from 1976-2016.

2. Study area

Tiruvallur district is located in the Northern-most district in Tamil Nadu, India. There are two taluks consisted by the coast of Tiruvallur district, namely Ponneri and Thiruvottriyur (**Figure 1**). As per census of India 2011, the total population of Tiruvallur district is about 3,728,104, of which the total population of the Ponneri taluk is about 389,862, and the Thiruvottriyur taluk is about 596,156. The population statistics showed that these two taluks are highly populated and all people are living in the coastal area itself, which made these taluks economic centres of the district and state as well. The major economic activities of these two taluks include fishing, shipping, tourism, agriculture, aquaculture, salt pans and industrial activities. Benefited by these activities, these taluks support the overall economy of the district and state. The total number of fishing communities in the district is about 54,420, which comprises of 58 fishing villages, 17 revenue villages and 28 fish landing center. The present study area lies between 13°26′41″-12°23′25″ N latitudes and 80°19′31″-80°6′9″ E longitudes. The coastal zone of Tiruvallur district is very narrow and a few places where extensive mud flat is present because of Ennor Creek and Pulicat Lake. The coastline length of Tiruvallur district covers 27.9 km with an elevation of 5 meters. In the recent past, reports and articles highlighted the vulnerability of the coast of Tiruvallur district. The major impacts include shoreline changes and erosion due to a thropogenic and natural factors affecting the study area because it is located close to road, residency and businesses all along the shoreline. Additionally, ecological sensitive areas of Pulicat Lake, Ennore Creek, Kattupali and Ennore ports are also presented along this coastline within 100 meters distance. If there occur any natural calamities, the impact would be very high. For example, land submerged in the sea due to coastal erosion. The coast showing direct or indirect connections with shoreline changes have been selected and examined in detail with

respect to present shore line. The main objective of this study is to analyze the shoreline changes along the coast of Tiruvallur and evaluate erosion and deposition from 1976 to 2016.

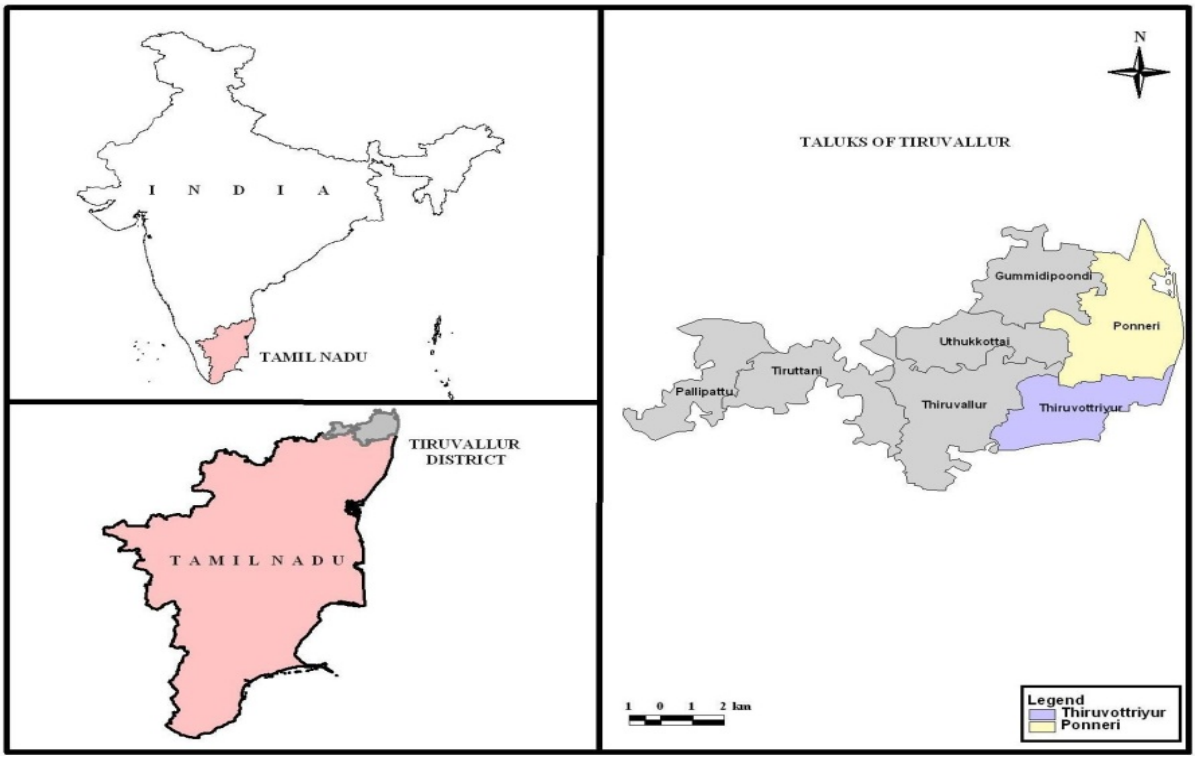

Figure 1. Study area map of taluks of Tiruvallur coast**.**

3. Materials and methodology

In this study, two types of data have been used, including topographical maps and satellite data. First, the satellite data of Landsat-5 TM (Thematic Mapper) data of 1988, 1991 and 2006 and Landsat-7 ETM+ (Enhanced Thematic Mapper Plus) data of 2010, 2013 and 2016 were downloaded from the U.S. Geological Survey (USGS) website[12]. Second, the topographic maps of the 66 C2, C6, C7 and C8 were purchased from Survey of India (SOI) at 1:50,000 for the year of 1976, which were scanned and georeferenced. The satellite images of study were imported to ERDASIMAGINE 2011 software and performed layer stacking followed by gap filling for the image of 2010 of Landsat-7 ETM+. All these images were corrected with reference to topographic maps for distortion and adjusted to the correct scale using ground control point sand rectified by using UTM projection with WGS 84 datum. Finally, visual interpretation technique was adopted to digitize the shorelines of Tiruvallur for all the different years (line of the high water level). Erosion and accretion in different shorelines along the coast of Tiruvallur were compared and calculated, as is shown by a flow chart of methodology in the **Figure 2**. The digital datasets of shore line changes were finalized after ground truth verification and Google earth images.

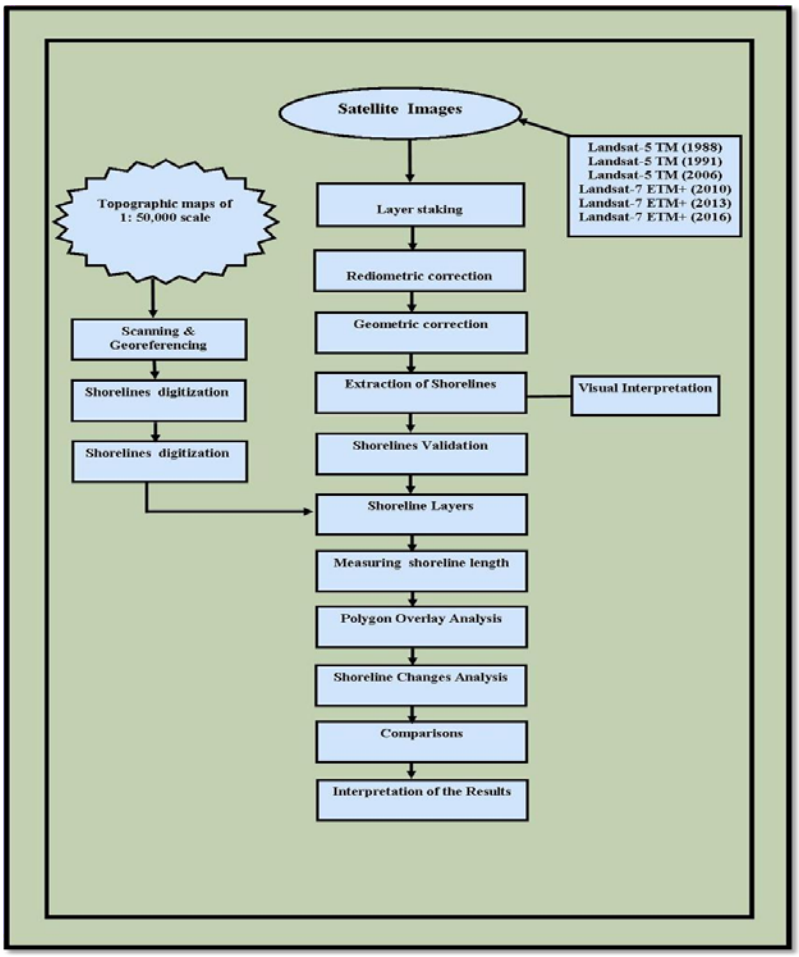

Figure 2. A flow chart of methodology**.**

4. Results and discussion

In this study, application of remote sensing and GIS technology were used, which are known as the most effective scientific tools for mapping, monitoring and analyzing shoreline changes and evaluating erosion and accretion along the coast of Tiruvallur district for the period of four decades from 1976 to 2016. The coast of Tiruvallur is shrinking and changing as it becomes increasingly vulnerable to storms, flooding and other natural disasters, which cause coastal erosion and the retreating of shore line. Apart from this, the man-made coastal erosion has reached alarming proportions in Tiruvallur, which is threatening the future of the two taluks Ponneri and Tiruvattriyur as well as the fishing villages within them. Coastal erosion, in which waves, is destroying around a half meter to one meters of shoreline every year. In some locations, up to two meters has disappeared over the same period. There is a chance to submerge of land area, when sea level is increasingly rising so as to impact infrastructures like roads, buildings, vegetation and ground water sources, coastal and terrestrial environment. A similar study by Gnanappazham[13] used remote sensing to manage shoreline changes in the Pichavaram mangrove wetland over the 76 years, in which the author highlighted that the natural and anthropogenic factors were the main causes for shrinking coastline. Another study by Jayakumar[5] was also confirmed by using remote sensing technology for the management of Godavari wetland from 1938 to 2012, in which the author highlighted that shoreline changes, erosion and accretion were occurring mainly due to anthropogenic causes, which would impact the coastal environment in the near future. The shore line for 1976, 1988, 1991, 2006, 2010, 2013 and 2016 were generated in **Figure 3**. These shore lines were overlaid one over the other in order to find out areas of erosion and accretion between 1976-

1988, 1988-1991, 1991-2006, 2006-2010, 2010-2013 and 2013-2016 (**Figure 4**). A similar study from Jayakumar and Malarvannan[1] on shore line change was carried out to find the changed and unchanged part of the shore line with overlay analysis. For example, **Figure 4** showed that the shoreline of 1976 was used as a reference line followed by an inner line and an outer line of 1988 as called erosion and accretion respectively. The erosion and accretion are represented by red and green colours respectively. It is easy to find the amount of erosion and accretion from 1976 to 2016, which will help users to predict the amount of erosion and accretion in future as well. This study can be considered as a decision support system with regard to Tiruvallur coast, as it shows spatial and temporal changes in the study area, which is priceless for the users who are working on the coastal zone managements.

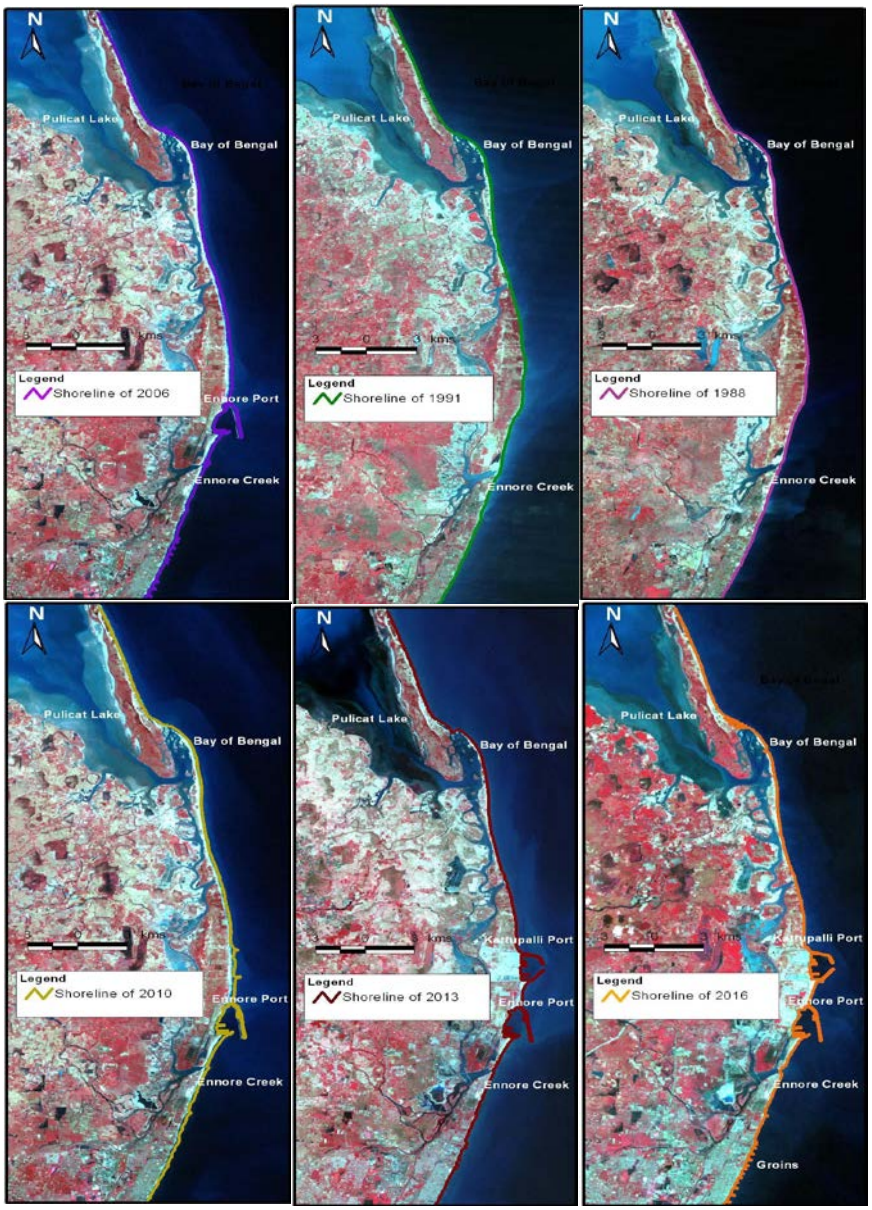

Figure 3. Shore line changes maps of Tiruvallur from 1976 to 2016**.**

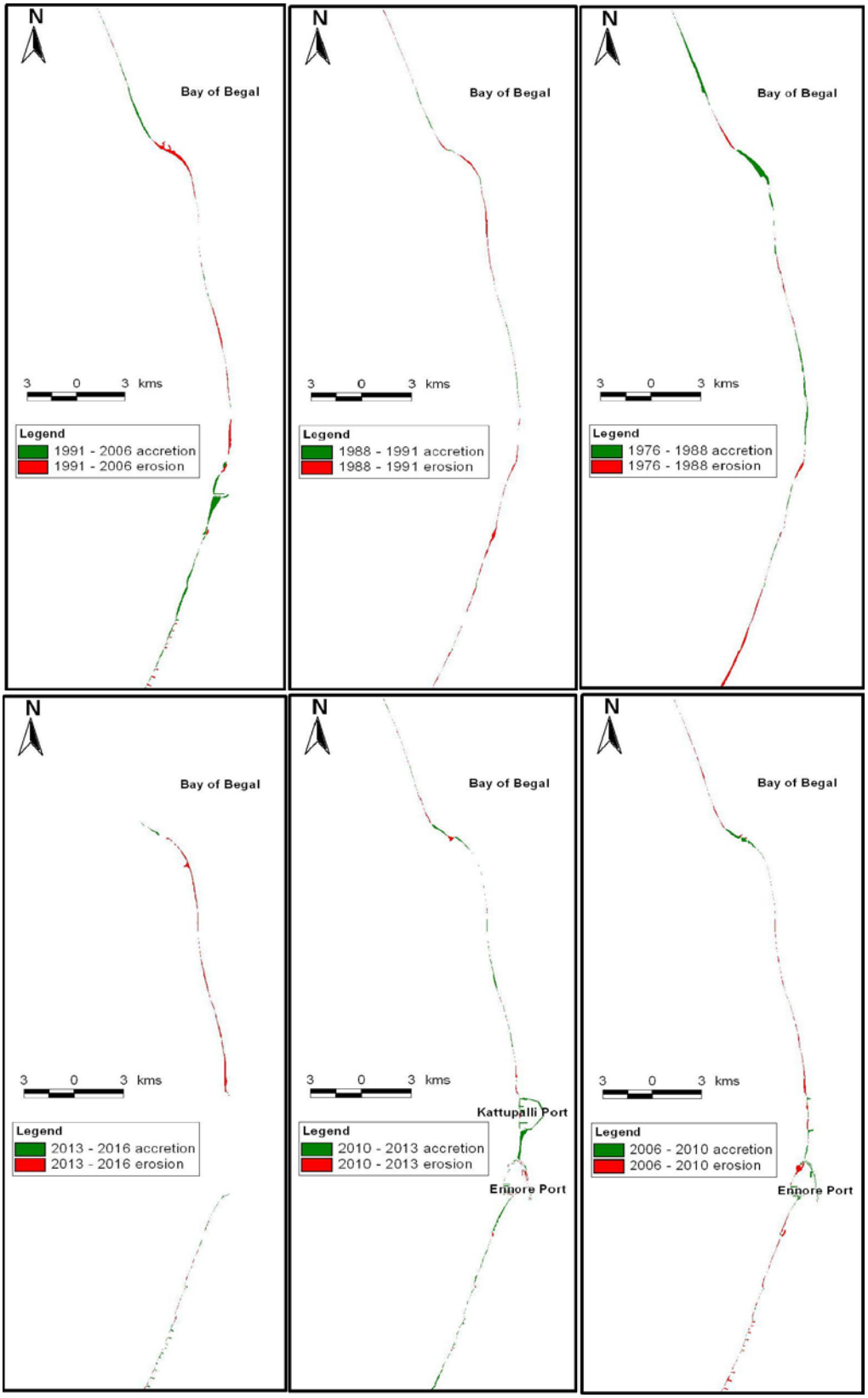

Figure 4. The maps displayed erosion and accretion variation between 1976 and 2016**.**

4.1 Tiruvallur coast

The total coast line length of Tiruvallur coast is 27.9 km and covers two taluks, namely Ponneri and Thiruvottiyur taluks, which have a total of 53,007 fishing communities; 58 fishing villages; 17 revenue villages; 28 fish landing centers. Within the study area, it was identified that the most hazardous zones include Kattupalli, Ennore Creek and from Ennore to Thygarajapuram. The main coastal villages of Pulicat, Minjur, Ennore and Thiruvottiyur are dominated by fishermen community and their primary occupation is also fishing. The results revealed through remote sensing about 178 ha of accretion and 126 ha of erosion were observed in the study area over a period of 40 years as shown in **Table 1**. In detail, the erosion was about 108 ha between 1988 and 1991 followed by 126 ha during 1991 to 2006, 120 ha during 2006 to 2010, 37 ha during 2010 to 2013, 100 ha during 2013 to 2016, and 112 ha during 1976 to 1988. The accretion was observed about 178 ha during 1976 to 1988, 19 ha during 2010 to 2013, 172 ha 1988 to 1991, 76 ha during 1991 to 2006, 161 ha during 2006 to 2010, and 24 ha during 2013 to 2016 (**Figure 4**).

Table1. Erosion and accretion mapped using multi-temporal remote sensing (ha)

Districts		**Tiruvallur**	
Sl.No.	Year	Erosion	Accretion
1	1976-1988	112	178
2	1988-1991	108	19
3	1991-2006	126	172
4	2006-2010	120	76
5	2010-2013	37	161
6	2013–2016	100	24
Total		603	630

The following satellite images of 1988, 1991, 2006, 2010, 2013, 2016 and topographic maps of 1976 were used to delineate the shoreline positions for above mentioned years and they were overlaid one by one to calculate erosion and accretion over the period of 40 years from 1976 to 2016. The coast of Tiruvallur shoreline changes was mapped and then areas of erosion and accretion were calculated as shown in **Table 1** and **Figure 5**.

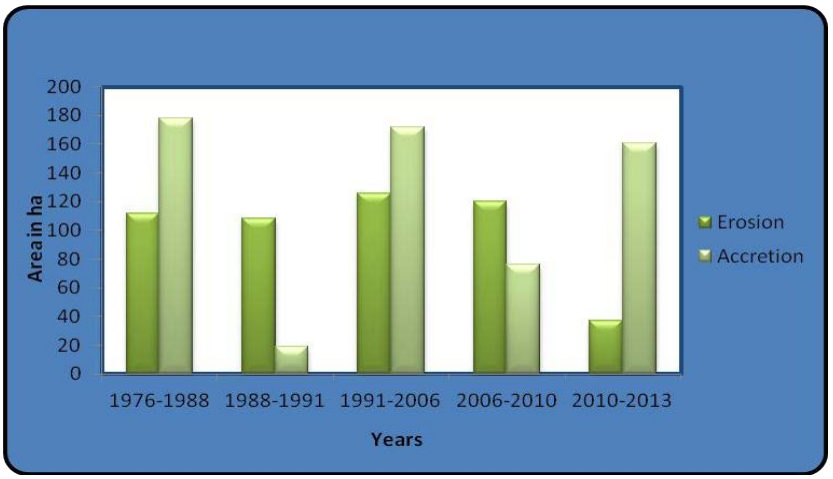

Figure 5. Changes in the area of erosion and accretion from 1976 to 2016**.**

4.2 Morphological changes of Tiruvallur district coast as follows

The coastline of Tiruvallur district coast is highly vulnerable under both human and natural interference, which played a crucial role over the four decades. The total length of coastline of the Tiruvallur district is about 27.9 km. The analysis of survey of India topographic maps and satellite images of Tiruvallur district indicated that the coastline is narrow and both Pulicat Lake and Ennore Creek were covered with extensive mud flat. Followed by this, man-made structures were observed in a few locations, including Ennore Thermal Power Station established in the year of 1970, Ennore Port constructed on 1st February, 2001, Kattupalli Port by 30th January, 2013 and various groins. The man-made structures coupled with dense inhabitation, industrialization, urbanization, development activities of port and fishing made shoreline more vulnerable under erosion, leaving less depositions. The analysis of shoreline changes with the support of satellite images and topographic maps showed the vulnerability zone of the Tiruvallur district coast. It may be pointed out that the construction of artificial structures such as ports, jetties, groins, beach nourishment, etc. and the presence of dense population are the main reasons for the negative effect of coastal environments. The study of Kasinatha Pandian *et al.*[14] also confirmed that the natural events such as tides, waves, currents, tsunami, coastal floods, climate changes and bathymetry effects are adding the changes in the coastal environment as well. A study from Jayakumar and Malarvannan[1] have confirmed that the reasons of shoreline changes are mainly due to development and extension activities of ports and other structures like construction, dredge, transportation, excavation, building, machinery on offshore, which induce several changes along the coast.

5. Conclusion

The coastal zone of Tiruvallur coast is highly vulnerable due to anthropogenic and natural causes. In this study, remote sensing and GIS technology were applied along the coast of Tiruvallur district for a period of 40 years from 1976 to 2016. It may be concluded that the construction of artificial structures coupled with natural events and the presence of dense population were the main reasons impacting coastal environment. The present study may benefits different stakeholders for developing policies and making decision to perform better management. It is the need of the hour to address and regularly update relevant study results on the coastal area environment, which will help the decision makers to immediately view scientific findings and addresses so as to speed up the evaluation process during the disaster periods.

Conflict of interest

No conflict of interest was reported by the author.

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