Analysis of Shoreline Changes along the Chennai Coast, Tamil Nadu, India

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Abstract

The shoreline change is considered one of the most complex processes, mapped along Chennai coast using multi-temporal satellite images. The satellite images used to capture the shorelines from 1988, 1991, 2006, 2010, 2013 and 2016. The HTL (High Tide Line) must be periodically mapped and observed as a coastline that has been demarcated by using satellite images by visual interpreting techniques. It was then accompanied by an overlay analysis to quantify erosion and accretion areas in the region under study. The findings showed that, due to erosion and accretion, the coast of the Chennai district lost 273 hectares and increased by 423.4 hectares. After the ground truth survey in the study area, this was confirmed. High erosion and accretion were reported along the Chennai's Northern and Southern part of district, respectively. The conclusion can be reached that anthropogenic and natural factors influencing the coastal ecosystem are the key causes of the coastal erosion and accretion in the region under study.

Keywords –*Erosion, Accretion, Shoreline, multi-temporal, overlay analysis, Coastal zone*

1. Introduction

The coast, also known as the coast or the seashore, is the area where the land meets the sea or the ocean or the line between the land and the ocean or the bay. A particular line that can be considered a coastline can't be defined by the principle of the coastline. India extends 3,214 km (1,997 mi) north to south and 2,933 km (1,822 mi) east to west. This has a land border of 15,200 km (9,445 mi) and a coastline of 7,516.6 km (4,671 mi) (India State of Forest Report, 2015). The coastline of Tamil Nadu is approximately 1076 km long, accounting for about 15 percent of the national length of the coastline of India and extends along the Bay of Bengal, the Indian Ocean and the Arabian Sea. Tamil Nadu is one of the 29 states of India. Chennai, the capital of the Tamil Nadu state and an important commercial and industrial center in the country is located in the northern part of the state under the Tiruvallur district and has coastline length of 19 km (11.8 mi). It is straight and also last or thirteen largest coast in Tamil Nadu and falls on the Bay of Bengal. The major coastal landform features of the coast of Chennai district include rivers, beaches, coastal dunes, mudflats, backwater and mangroves etc., (Jayakumar and Malarvannan, 2016). Shoreline transition is one of the most common natural processes in coastal areas, including winds, tidal currents, waves, earthquake, cyclone, storm surge, floods, and ice. For instance, the recent effect of natural disasters continues to strike the coasts of the tsunami of the Indian Ocean on 26 December 2004, the Jal Cyclone on the 10th of November 2010, the Cyclone Nilam on the 30th of December 2011 and the South Indian Ocean on the 8th of November 2015 and the Cyclone Nilam on the 6th to the 13st of November 2012 and the Cyclone Gaja on the 10th-16th of November 2018. On the other hand, the man-made disturbance like pollution, coastal development, and the introduction of non-native species to an area, mining of the beach sand, urbanization, garbage dump, industrialization, recreational activities and reduction in sediment supply from the rivers. In order to improve planning and management, it is important to evaluate shoreline changes and determine their threat to the natural resources of the Coastal Region. Those two factors are the main causes of shoreline changes that contribute to short-term and long-term erosion and accretion. These two factors play a crucial role which also affects the local ecosystems and shores.The most critical aspect of coastal area management is the classification of the location and the transition over shoreline time. It requires frequent observation of the shoreline over time using satellite images (To and Thao, 2008; Saranathan *et al.*, 2011; Manik Mahapatra *et al.*, 2014; Jayakumar, 2014, 2018; Jayakumar and Malarvannan, 2016).

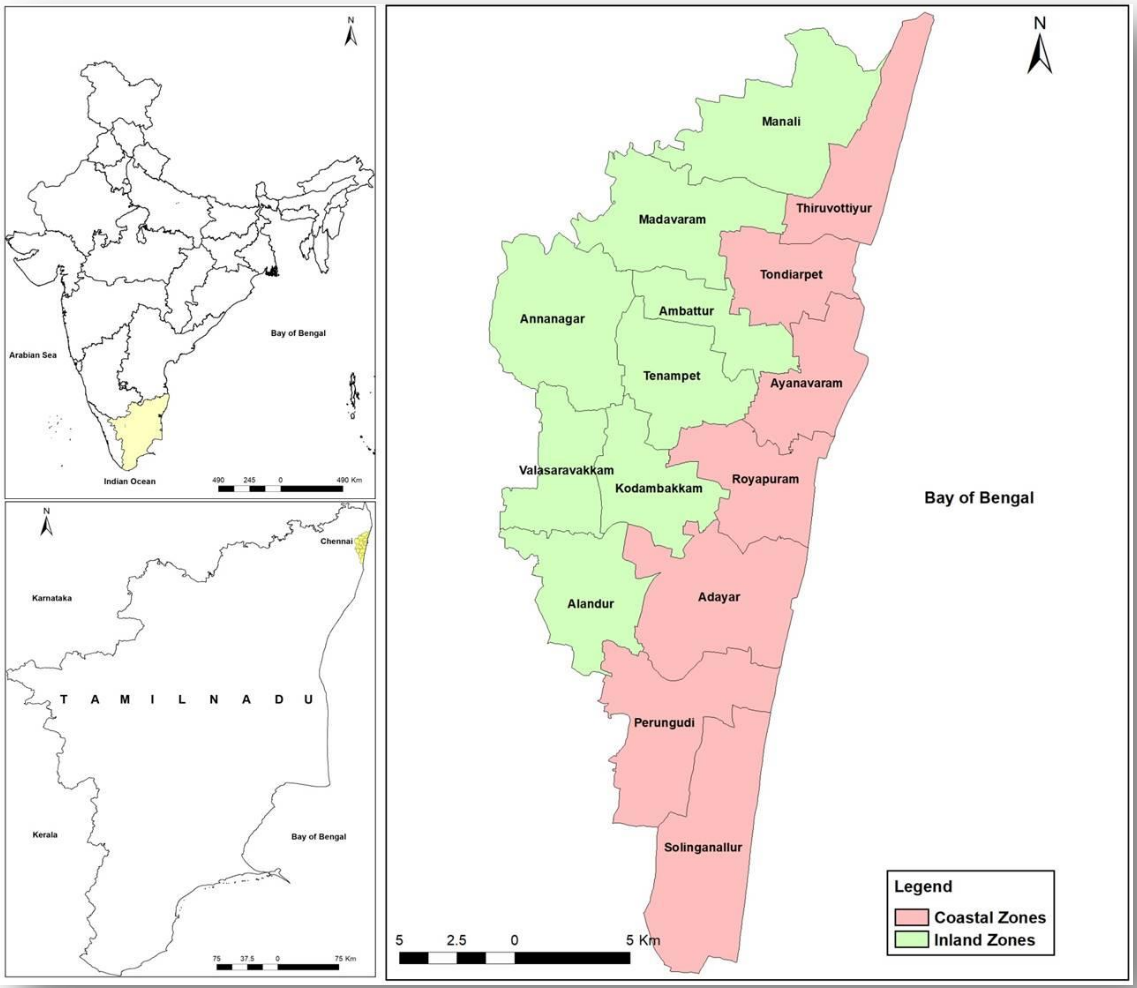
1.1 Role of Remote Sensing Technique for the delineation of shoreline change:

Remote sensing techniques have been used worldwide since 1980 to identify and illustrate the causes and amount of shoreline changes (Marfai *et al*., 2007; Zhang *et al*., 2007; Faik Ahmet Sesli, 2010; Doug Ramsay, 2011). Remote sensing and GIS techniques are often used in geomorphology, particularly for monitoring the natural processes along the shore and the shoreline patterns over time. and to evaluate erosion and accretion (Faik Ahmet Sesli, 2010; Saranathan *et al.,* 2011; Manik Mahapatra *et al.,* 2014; Jayakumar, 2014). A recent study from Lemonia Ragia and Pavlos Krassakis (2019) highlighted using high resolution satellite images such as Quickbird and WorldView-3 for an analysis of shoreline changes in the coastline of Georgioupoli, a part of the island of Crete. Luca Cenci *et* al. (2017) had used remote sensing and GIS tool for mapping and modelling evolution of two different coastal environments including, Oceanic and Mediterranean from 1980 to 2011. According to Mishra Monalisha, Panda GK (2018) had examined the shoreline changes along the Ganjam Coast, South Coast of Odisha by using geospatial techniques. Hashmi and Ahmad (2018) studied coastal erosion and accretion along the coast of Sindh Pakistan by using GIS and Digital Shoreline Analysis System (DSAS) modelling. Jayakumar (2018) had used multi temporal satellite images and evaluated accretion and erosion in the coastal district of Tiruvallur, Tamil Nadu, India. A study from Faik Ahmet Sesli (2010) had examined multi temporal images including aerial images and digital photogrammetry data and monitored the coast from 1935 - 2006 in Samsun, Turkey. Another study from Jayakumar and Malarvannan (2016) had used WebGIS tool, which was developed by using open source software for the better management of the shoreline in the Northern Tamil Nadu coast, India. The purpose of this study is to use multi satellite images and to document the impact both from natural and human on the Chennai Coast and also to examine morphological differences, shoreline changes variations, erosion and accretion. The coastal change survey carried out on the coast of Chennai district was not extensive. It is time to discuss shoreline changes along the Chennai coast and often publish policies that lead to better coastal resource planning and management. This study aims to investigate coastal changes on the Chennai coast and assess erosion and deposition over the 28 years period from 1988-2016.

2. Study area

Chennai district is situated in the northernmost district below Tiruvallur District in Tamil Nadu, India. The district is divided into 15 administrative zones, seven of which come within the coastal area of Tiruvottiyur, Tondiarpet, Ayanavaram, Royapuram, Adayar, Perungudi and Sholinganallur (Figure 1). According to census of India (2011), the Chennai district population is about 4,681,087 of which more than half of the total population of the city living in coastal zones itself. According to Census of India, it is India's sixth-most populous city and fourth-populous urban agglomeration. Chennai has a strong industrial base in the automobile, computer telecommunications, hardware, and healthcare industries, fishing, shipping and tourism, which made these zones economic centre of district and state and country as well. The present study area lies between 12° 59'and 13° 9' of the northern latitudes and 80°12' and 80° 19' of the eastern longitudes at an elevation with 6 meters. The coastal zone of Chennai district is flat coastal plain known as eastern coastal plains and it is location on the north-eastern corner of Tamil Nadu along the Coramandel coast, a region bounded by the Bay of Bengal and is surrounded inland by the districts of Tiruvallur and Chengalpattu. The main impact involves shoreline changes due to anthropogenic and natural factors affecting the area of research as it is situated along the coastline near the road, residence and companies. In addition, Ecologically Sensitive Areas (ESA) are also located along this coastline within a distance of 100 meters: Ennore Creek, Ennore and Chennai Ports, Rayapuram Fishing Harbor, Cooum and Adyar Rivers Mouth, Marina Beach and Besant Nagar Beach etc. When there have been any natural disasters, the impact on an example of a region sunk in the sea due to coastal erosion would be very high. The shoreline improvements were identified and analysed in detail in relation to the present shoreline, whether direct or indirect. Analysing coastal changes for the Chennai coast and evaluating erosions and deposition between 1988 and 2016 is the main aim of this review.

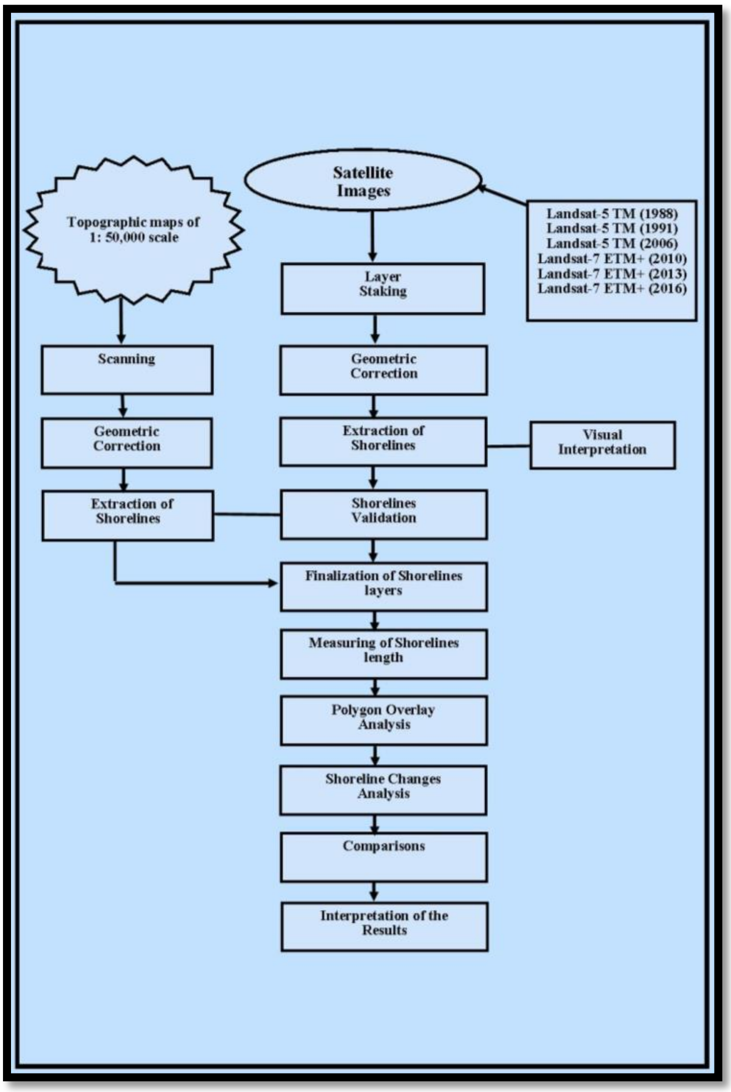
Figure 1. Study Area Map of Chennai’s Coast



3. Materials and Methodology

Two types of data were used in this study which includes topographic maps and satellite data. First, the topographical 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 and scanned them and Geo-referenced and used as a base map as well as GCP (Ground Control Points) used to rectification of satellite data. Second, The Landsat-5 TM (Thematic Mapper) data for the years 1988, 1991 and 2006 and Landsat-7 ETM+ (Enhanced Themetic Mapper Plus) data for 2010, 2013 and 2016 were downloaded from the United States of Geological Survey (USGS) website at https:/glovis.usgs.gov. The satellite images of the study area were imported into ERDAS IMAGINE 2014 software, and layer stacking was done, followed by gap filling for Landsat-7 ETM+'s 2010 image. All of these images were corrected for distortion with reference to topographic maps and adjusted to the correct scale using ground control points and rectified using WGS 84 datum UTM projection. After the projection process, a visual interpretation technique was employed to demarcate the Chennai shorelines for all the different years (high water level line). And then overlay analysis for the different shorelines was performed, compared and calculated the erosion and accretion for the Chennai coast as shown in Figure 2 of a methodology flow chart. After verification of ground truth and images from Google Earth, digital datasets of shoreline changes were finalized.

Figure 2. A flow chart of methodology

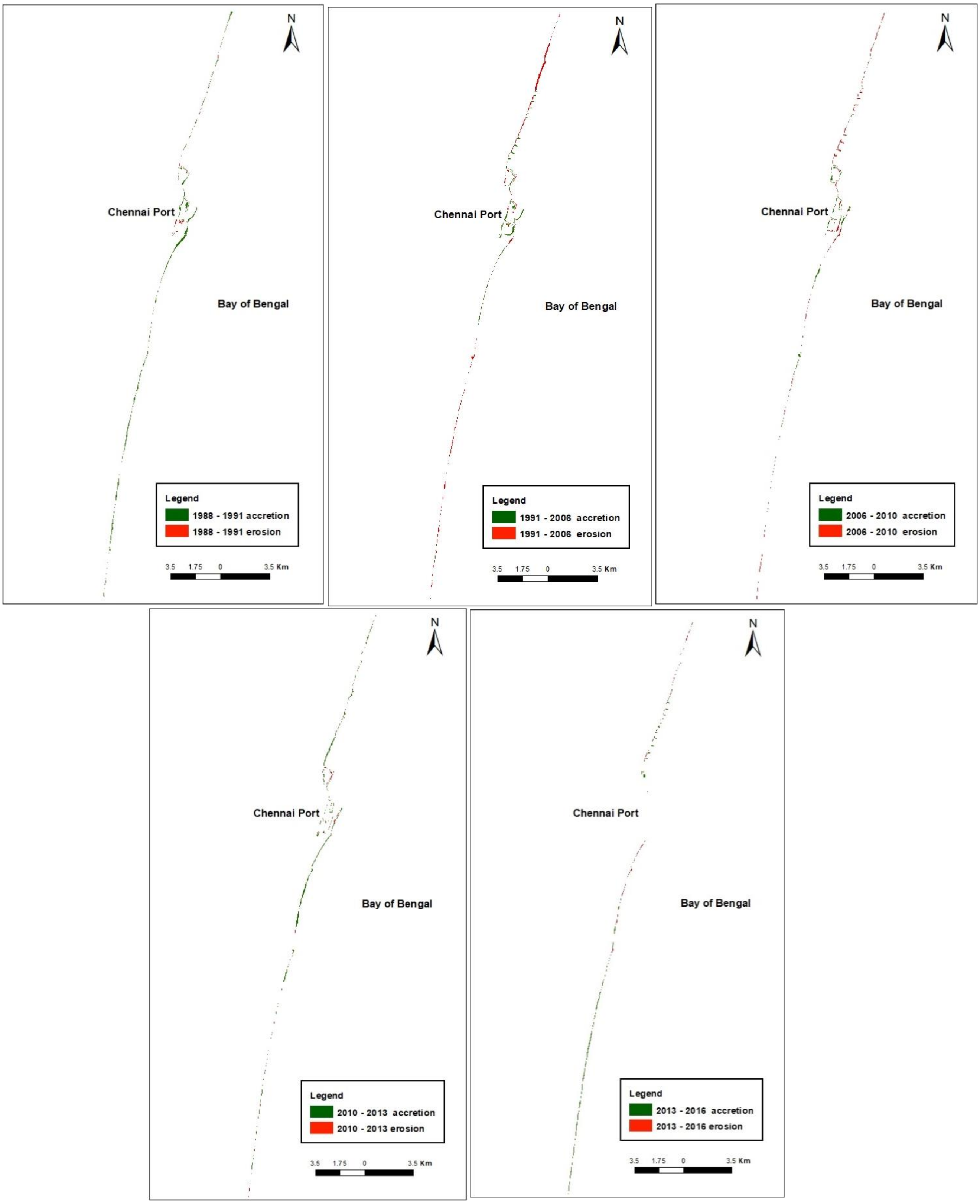


4. Results and Discussion

Application of remote sensing and GIS technique has been used in this study, which is known as one of the most effective scientific tools for mapping, monitoring and analyzing shoreline changes and assessing erosion and accretion on the Coast of Chennai district for the four decades period from 1988 to 2016. Chennai's coastline is shrinking and shifting as it is becoming increasingly vulnerable to storms, floods and other natural disasters that cause coastal erosion and shoreline retreat. In addition, the man-made coastal erosion in Chennai has reached alarming proportions, threatening the viability of city zones including, Tiruvottiyur, Tondiarpet, Royapuram, Ayanavarm, Adayar, Perungudi and Sholinganallur as well as the fishing villages with them. Coastal erosion, in which waves, is losing about an half meter to one meters of shoreline per year. Up to two meters have gone missing over the same time in some area. When sea level raises that affect infrastructure such as roads, buildings, plants and freshwater supplies, coastal and terrestrial ecosystems, there is a potential to submerge of land area. A similar research by Jayakumar (2014, 2018) used remote sensing for the management of shoreline changes for Tiruvallur over the past 4 decades and Godavari wetlands over the past 7 decades, the author had pointed out in that reports that the natural and anthropogenic factors were the key causes of shrinking coastline and its environments in the near future. The shorelines were demarcated for 1988, 1991, 2006, 2010, 2013 and 2016 (Figure 3). These shorelines were overlaid between 1988-1991, 1991-2006, 2006-2010, 2010-2013 and 2013-2016 in order to identify areas of erosion and accretion (Figure 4). Studies on shoreline shifts from Ramasubramanian *et* al. (2006), Jayakumar and Malarvannan (2016) and Jayakumar (2018) were conducted to find the altered and unchanged portion of the shoreline with overlay analysis. For instance, Figure 4 showed that the 1988 shoreline was used as a reference line followed by an inner line and a 1991 outer line respectively called erosion and accretion. The erosion and accretion are depicted respectively in red and green colours. The amount of erosion and accretion from 1988 to 2016 is easy to find and will help users predict the amount of erosion and accretion in the future as well. This research can be regarded as a decision support system with respect to the Chennai coast, as it shows spatial and temporal changes in the study area, which is invaluable for users working on the management of the coastal region.

Figure 3. Shoreline changes maps of Chennai from 1988 to 2016

Figure 4. The Maps showed erosion and accretion variation between 1988 and 2016



4.1. Chennai Coast:

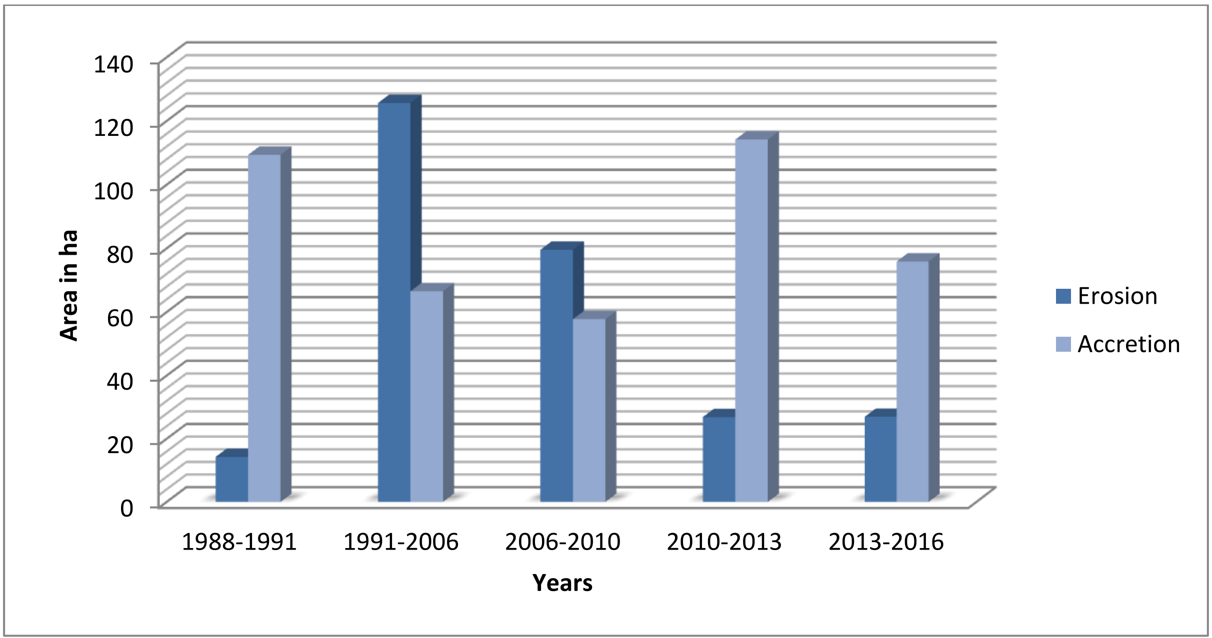
The total length of the Chennai coastline is 19 km, covering six administrative areas, namely Tiruvottiyur, Tondiarpet, Royapuram, Teynampet, Adyar, Perungudi and Sholinganallur, with a total population of 8,917,749 of which 9,101 fishing communities; 44 fishing villages; 2 revenue villages; 12 fishing centres. Within the study area, Ennore, Mastan Koil Kuppam to Popular Weigh Bridge, a stretch between Savorit to Northern breakwater of fishing port, Chennai port to Foreshore estate and Besant Nagar have been described as the most hazardous zones. Fishermen's society dominates the major coastal villages of Ennore, Thiruvottiyur, Royapuram, Ice House, and Foreshore Estate and their primary occupation is also fishing. The results revealed by remote sensing about 418.3 ha of accretion and 273 ha of erosion were observed over 28 years in the study region, as shown in Table 1. In detail, between 1988 and 1991, the erosion was approximately 14.2 ha followed by 125.6 ha between 1991 and 2006, 79.5 ha between 2006 and 2010, 26.8 ha between 2010 and 2013, 26.9 ha during 2013 and 2016. The accretion was noticed at around 109.3 ha between 1988 and 1991, 66.5 ha between 1991 and 2006, 52.7 ha between 2006 and 2010, 114.1 ha between 2010 and 2013, 75.8 ha between 2013 and 2016 (Figure 4).

Table 1: Details of Erosion and accretion (Areas in ha)

District		**Chennai**	
Sl. No.	**Year**	**Erosion**	**Accretion**
1	1988 - 1991	14.2	109.3
2	1991 - 2006	125.6	66.5
3	2006 - 2010	79.5	52.7
4	2010 - 2013	26.8	114.1
5	2013 - 2016	26.9	75.8
Total		273.0	418.3

The following 1988, 1991, 2006, 2010, 2013, and 2016 satellite images were used to delineate the shoreline positions for the above-mentioned years and to overlay them one by one, calculating erosion and accretion over the 28-year period from 1988 to 2016. Additionally, the topographic maps of Survey of India from 1976 were used as a reference map. The coast of Chennai shoreline changes were mapped and then the erosion and accretion areas were estimated as shown in Table 1 and Figure 5.

Figure 5. Changes in the area of erosion and accretion from 1988 to 2016



4.2. Morphological changes of Chennai District Coast as follows:

The Chennai district coastline is highly vulnerable as a result of both human activity and natural intervention, which has played a crucial role over the three decades, which was observed using remote sensing. The total length of the Chennai district coastline is around 19 km. Analysis of Survey of India's topographic maps and satellite images of the district of Chennai showed that the coastline is narrow and both at Cooum and Adyar Rivers Mouth were covered with mud flat. Following this, man-made structures were found in a few locations including Chennai Port, built in 1881, Navy Quarters near the mouth of Cooum River, and groins in the northern part of Chennai coast. The man-built structures combined with dense housing, industrialization, urbanization, port growth and fishing activities built shoreline more fragile, dominated by erosion, while the deposits were fewer. This study of shoreline changes with satellite image support showed the Chennai district coast vulnerability zone. It can be noted that the development of artificial structures such as ports, jetties, groins, beach nourishment, etc. and the presence of dense population are the key reasons for the negative impact of coastal ecosystems. Kasinatha Pandian *et* al. (2004) also reported a study that the impact of natural disasters such as tides, waves, currents, tsunami, coastal floods, climate change and bathymetry also contributes to the changes in the coastal environment. A study conducted by Jayakumar and Malarvannan (2016) confirmed that the reasons for the change in shorelines are mainly due to the development and expansion of port activities, other structures such as construction, dredging, transport, excavation, construction, offshore machinery, which cause a number of changes along the coast.

5. Conclusion:

The coast of Chennai is very vulnerable due to anthropogenic and natural causes. In this study, the use of remote sensing and GIS technology has been applied over the Chennai coast for a period of 28 years from 1988 to 2016. It can be argued that the construction of artificial structures combined with natural occurrences and the existence of dense population were the key reasons for the effects of the coastal environment. That kind of research would offer a lot of advantages for various stakeholders in designing policies and making decisions for better management. It takes hours to review and periodically monitor the coastal area environment, which lets decision-makers quickly interpret and discuss research results and speed up the evaluation process during the times of the disaster.

6. References

1. Doug Ramsay. 2011. Coastal erosion and inundation due to climate change in the Pacific and East Timor. Report, Department of Climate Change and Energy Efficiency, Government of Australia.
2. Faik Ahmet Sesli. 2010. Mapping and monitoring temporal changes for coastline and coastal area by using aerial data images and digital photogrammetry: A case study from Samsun, Turkey. *International Journal of the Physical Sciences,* 5, 10: 1567-1575.
3. Hashmi and Ahmad. 2018. GIS-Based Analysis and Modeling of Coastline Erosion and Accretion along the Coast of Sindh Pakistan. *Journal of Coastal Zone Management*, 21:1, DOI: 10.4172/2473-3350.1000455.
4. India State of Forest Report, 2015. Forest Survey of India, Ministry of Environment, Forest and Climate change, Government of India, Dehraun. pp 300.
5. Jayakumar, K and Malarvannan, S. 2016. An Assessment of Shoreline Changes over the Northern Tamil Nadu Coast using Open source based WebGIS Techniques.*The Journal of Coastal Conservation*, 20:6, 477-487.
6. Jayakumar, K. 2014. Remote Sensing and GIS Application in the Management of Godavari Mangrove Wetland, Andhra Pradesh, South India. Thesis submitted to University of Madras. pp 150.
7. Jayakumar, K. 2018. Analysis of Shoreline Changes along the Coast of Tiruvallur District, Tamil Nadu, India. *Journal of Geography and Cartography,* 1, 1-9. DOI:10.24294/jgc.vli3.764
8. Kasinatha Pandian, P., Ramesh, S., Ramanamurthy, M.V., Ramachandran, S and Thayumanavan, S. 2004. Shoreline changes and nearshore processes along Ennore Coast, East Coast of South. *India. J. Coastal Res.*, 20, 828-845.

9. Lemonia Ragia and Pavlos Krassakis 2019. Monitoring the changes of the Coastal Areas using Remote Sensing Data and Geographic Information Systems, In: Seventh International Conference on Remote Sensing and Geoinformation of Environment' RSCys2019, Cyprus, DOI:10.13140/RG.2.2.17273.9328
10. Luca Cenci, Leonardo Disperati, Maria Giuseppina Persichillo, Eduardo R Oliveira, Fátima L Alves and Michael Phillips. 2018. Integrating remote sensing and GIS techniques for monitoring and modeling shoreline evolution to support coastal risk management. *GIScience & Remote Sensing*, 55:3, 355-375, DOI: 10.1080/15481603.2017.1376370
11. Manik Mahapatra, R., Ratheesh, Rajawat, A.S. 2014. Shoreline Change Analysis along the Coast of South Gujarat, India, Using Digital Shoreline Analysis System. *Journal of Indian Society of Remote Sensing*, 42, 4:869–876
12. Marfai, M.A., Almohammad, H., Dey, S., Susanto, B and King, L. 2007. Coastal Dynamic and shoreline mapping: multi-sources spatial data analysis in Semarang Indonesia. *Environ Monitoring and Assessment*, doi:10.1007/s10661-007-9929-2
13. Mishra Monalisha and Panda Gk. 2018. Coastal Erosion and Shoreline Change in Ganjam Coast along East Coast of India. *J Earth Sci Clim Change*, 9:4, DOI: 10.4172/2157-7617.1000467.
14. Ramasubramanian, R., Gnanappazham, L., Ravishankar, R and Navamuniyammal, M. 2006. Mangroves of Godavari – Analysis through Remote Sensing Approach. *Wetland Ecology and Management*, 14:29-37.
15. Saranathan, E., Chandrasekaran, R., Soosai Manickaraj, D and Kannan, M. 2011. Shoreline changes in Tharangampadi villages, Nagapattinam District, Tamil Nadu, India – A Case study. *Journal of Indian Society of Remote Sensing*, 39, 1:107-115.
16. To, D.V and Thao, P.T.P. 2008. A Shoreline Analysis using DSAS in Narn Dinh: Coastal Area. *International Journal of Geoinformatics*,4:1, 37-42.
17. Zhang, J., Wang, Y and Wang, Z. 2007. Change analysis of land surface temperature based on robust statistics in the estuarine area of Pearl River (China) from 1990 to 2000 by Landsat TM/ETM+ data. *International Journal of Remote Sensing*, 28, 10: 2383-2390.