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Instantaneous Shoreline Demarcation and Categorization using Remote Sensing and GIS Techniques

-A Case Study of Dynamic Nature of the Chennai Coast

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***Abstract*—The point of intersection of sea and land is called as shoreline and it is one of the rapidly changing landform. Due to volatile nature of the sea, coastal areas are submerging in stages creating history contributing to the continuous shoreline changes due to both anthropogenic and natural causes. The present study relates to an economically important Coastal city Chennai in India through remote sensing approach in which shoreline demarcation is done more precisely and quickly than conventional methods by employing shoreline derivation models and the obtained shoreline is further categorized using DSAS (Digital Shoreline Analysis System) module in ArcGIS according to its rate of erosion or accretion at local level. Remote sensed Landsat satellite data for various dates of pass over 38 years of period (1973 to 2009) of the Chennai stretch was processed and the shoreline changes due to various impacts is studied and presented. The present study has brought to light that Royapuram and the Port of Chennai stretch is in need of immediate relief measures to upkeep the coastal region and few stretches like Foreshore estate are still stable. Accretion of 276673.04sq.m was observed due to the wave action and other contributing factors along the coast in these 38 years. This study throws light on certain dynamic regions of the Chennai coast that are in need of effective and new remedial measures to protect the land which is being exposed to dynamic shoreline change and helps in the management process.**

Keywords— Shoreline Change, Demarcation, Categorization, Erosion,Accretion, Dynamic

I. INTRODUCTION

A coastline or a sea shore is the area where land meets the sea or ocean. A precise line that can be called a coastline cannot be determined due to the coastline paradox. The exploratory surveys of coastlines of India is carried out by mariners by sketches and notes prepared by the land travelers and sextant observations from the ships plying along the coastline which is time consuming. About 60 percent of the world population lives near the coast and in one way or the other depends directly or indirectly on the coastal zone and its resources. According to IPCC (Intergovernmental Panel on Climate Change) report, about 30% coastal wetlands are lost already and millions more people could experience coastal flooding each year based on an average rate of sea level rise of 4.2mm/year from 2000 to 2080. Important segments of low coastlines are receding, losing sand and there is a serious problem of beach recession. Tamil Nadu with nearly 44 villages engaged in fishing activity in and around the district (Coastal District profiles of Tamil Nadu) has a dynamic coast. There is an annual loss of 60.684crores along the coast of Tamil Nadu due to sea erosion (Public Works Department, Government of Tamil Nadu) and hence prioritizing the dynamic coast for relief measures becomes important.

Remote sensed data facilitates the decision makers in quantifying the amount of human settlement, land, properties, monuments etc., that were submerged into the sea and in the accurate demarcation and monitoring of shoreline for planning protective structures. The developments in the use of remote sensing data in India have proved the importance of remote sensing data in mapping and monitoring the coastal processes both in long term and short term and coastal environments with least time consumption for studying the dynamics of the coastline to protect the resources along the coast. Coastline extraction is done mostly by visual interpretation from optical imageries. One such extraction was done for the Urmia lake with the Landsat images resulted with an accuracy of 1.3 pixels (A. A. Alesheikh et al., 2007) and the same data was analyzed to quantify the rate of change due to erosion in Thailand coastline by color density slicing method (Absornsuda,2010). Accurate prediction of shoreline changes for Orissa was done cost effectively using multi- temporal Landsat data. (Pritam Chand et al., 2010) The band differencing was employed for Quantitative assessment of coastal changes between Narmada and Kim river of South Gujarat, India (Janak P Joshi et al., 2007). For the estimation of erosion and Accretion rates along gaza coastline, extracted coastlines by Band Ratio and First PCA demonstrated the best results (Khaldoun Abu Alhin and Irmgard Niemeyer, 2009). Thus, the accuracy of shoreline extraction required for confined studies can be improvised further by involving other methods.

Detailed studies related to coastal shoreline change are only carried out using remote sensing data that too in regional scale with reference to entire Tamil Nadu coastal plain. The erosion and accretion activities in Cuddalore district of Tamil Nadu for 41 years was estimated in GIS environment on the shoreline demarcated exactly by Edge detection technique (S. Kumaravel et al., 2013). Shoreline displacement was assessed along Tharangampadi village by superimposing Village maps with satellite images and a large-scale (E. Saranathan et al., 2011). Other studies involve archealogical explorations carried out since the state is of historical importance. Ancient literary sources exist that provide possible explanations for the loss of the littoral settlements: like the Sangam literature which refers to the submergence of Poompuhar. The "Manimekhalai" mentions that Poompuhar was swallowed up by the sea due to the wrath of goddess Manimekhalai .It may be taken as an echo of some actual sea erosion due to some high tidal wave surge that engulfed the city.

The false color composite imageries of the Landsat is used for visual interpretation and most of the time shoreline is digitized manually which cannot be taken into account as the shoreline. Thus the term instantaneous shoreline is used which refers to the shoreline obtained at the instant of time which is the time of acquisition of satellite imagery. In order to improvise the less accurate obtained unclear boundary by visual interpretation to be demarcated as shoreline, the usage of models which are predominantly used for classification is taken into account in this study. In this study remotely sensed temporal satellite data was used to delineate shoreline with improved accuracy from the imageries for the years 1973 to 2009 the coast is categorized into five classes according to the shoreline movement using EPR method and the stretches that are highly dynamic was identified which serves to be an information for providing immediate relief measures .

II. STUDY AREA

Chennai is an economically important coastal city, which is the capital of Tamil Nadu in India. The nature of the coastal belt is crystalline rocks overlaid by sedimentary and alluvial formation caused by wave action. The wave induced sediment transport; 'net littoral drift' that takes place along the coast as well as normal to the shore drift is approximately 1.2*106 m^3/ year which is directed towards North Chennai. The wave characteristics (wave height, its period and its direction) along the Chennai coast are influenced by the prevailing seasons, viz., South West monsoon (June to Sept), North East monsoon (Oct to Dec) and Non monsoon (Jan-May). Hourly wind speed data from the Indian Meteorological Department, Government of India for Chennai coast indicates the speed varies up to about 50kmph and much higher when cyclone cross the coast which also contributes to the wind erosion along the coast. The city is served by two major ports. The above mentioned are the climatic parameters that have a significant effect on the shoreline change in addition to the anthropogenic factors (non climatic).

"Fig. 1," shows the Location of Chennai district on the Coromandel Coast off the Bay of Bengal at 13° 5' 2.0040"N, 80° 16' 12"E and 6m above MSL in which remarkable proportion of the population lives along the coastal areas for their livelihood.

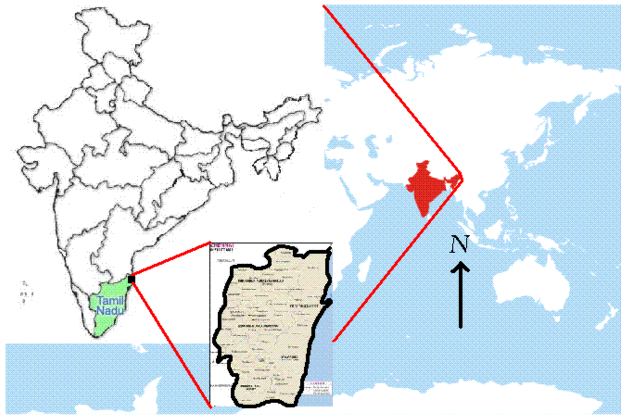

Fig. 1. Image showing the location of study area

The boundary of the study area as shown in *"Fig. 2,"* was obtained by overlaying the available shape file from the Institute of Remote sensing, over the satellite imagery obtained from USGS and digitizing it in the ArcGIS environment which was used as a baseline reference to know the shoreline deviation in the past decades.

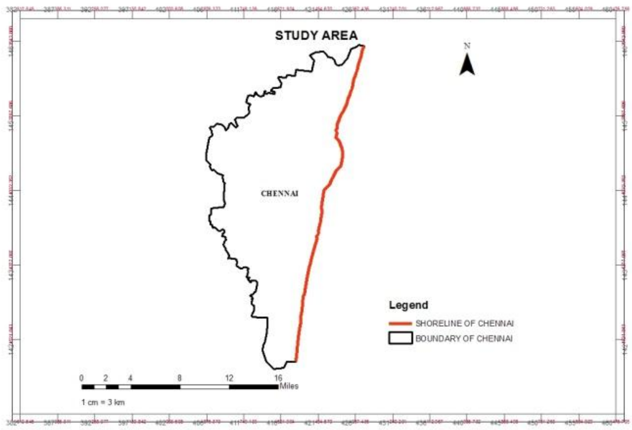

Fig. 2. Image showing the boundary of the study area

III. MATERIALS AND METHODS

Landsat data was collected from the open source USGS website. The spatial data Landsat 5 with 7 spectral bands, including a thermal band and Landsat 7 with 8 spectral bands, including a pan and thermal band used were of the following Dates of acquisition 06/02/1988, 15/03/1990, 16/01/1992, 28/10/2000, 28/06/2002, 18/08/2006, 15/02/2009. The resolution is 30 meters. The 1973 data was used to prepare the baseline from which the shoreline movement was found out.

Landsat spatial data pertaining various years are processed using models to improvise the accuracy of shorelines to be delineated which are further to be passed into DSAS module for categorization. The instantaneous shoreline was obtained from the available imageries by performing Tasseled Cap Transformation which is a common technique of data transformation for classification purposes and Normalized Difference Moisture Index which segregated the available imagery into land and sea. The shoreline obtained by this method is digitized carefully and it is passed as input vectors to DSAS module with suitable parameters for spacing and length of transects to be generated. Then the final clipped shoreline is categorized into five categories according to its dynamicity as given in "Table 1" by EPR (End Point Rate) method. The end point rate is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline so that the long term changes can be studied. By simple fish net analysis laying grids over the stretch, the area of land lost into sea and accreted is found out.

Table 1: Categorization criteria*

RANK	DYNAMICITY	RATE (m/yr)
1	Very High	(> -2 m /yr) – Erosion
2	High	(- 1.1 to - 2.0 m/yr)
3	Moderate	(- 1 to +1 m /yr)
4	Low	(1 to 2 m/yr)
5	Very low	(> +2 m/yr) - Accretion

*Source **:** Coastal Zones of India-Report published in 2012 by SAC

The overall methodology adopted from preliminary processing of the Landsat data to final categorization is as represented in *"Fig. 3,"*. In order to improve the accuracy of the shoreline delineation various classifications and transformations are done.

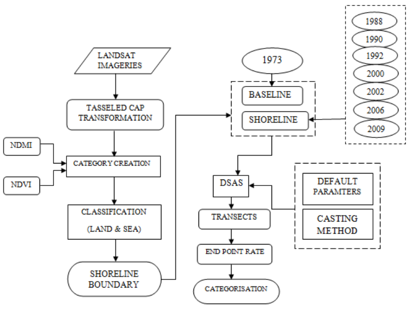

Fig. 3. Overall Methodology

Tasseled cap transformation with the advantage of reducing the amount of data from several multispectral bands to three primary components: brightness, greenness, and wetness and reduction in the atmospheric influences and noise components in imagery, enabling more accurate analysis is represented in *"Fig. 4,"*.

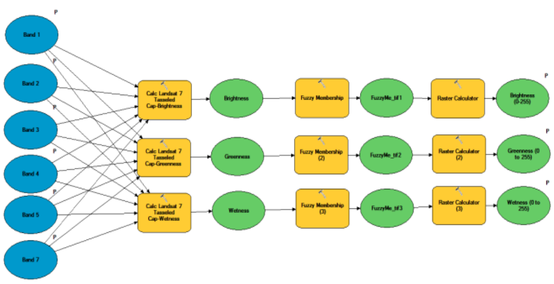

Fig. 4. TCT Transformation

Normalized difference moisture index in *"Fig. 5,"* enhances the land and sea classification using Near Infra Red (NIR) and Mid Infra Red Bands (MIR).

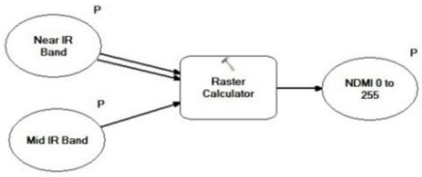

Fig. 5. NDMI model

"Fig. 6," the Category Creation Module takes Tasseled Cap and NDVI bands as input and creates a 10-class land cover data set.

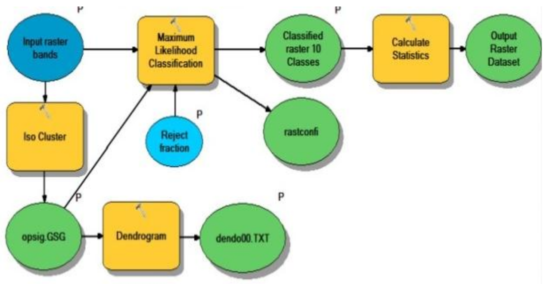

Fig. 6. Category creation module

Reclassification, as shown in *"Fig. 7,"* is done to reduce the land cover data set from 10 to 2 classes namely land and sea.

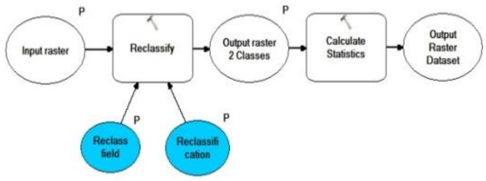

Fig. 7. Land & sea classifier

A shoreline is created from the 2-class land cover dataset using Majority filtering, Contour, and Smooth-line commands as represented in *"Fig. 8,"*

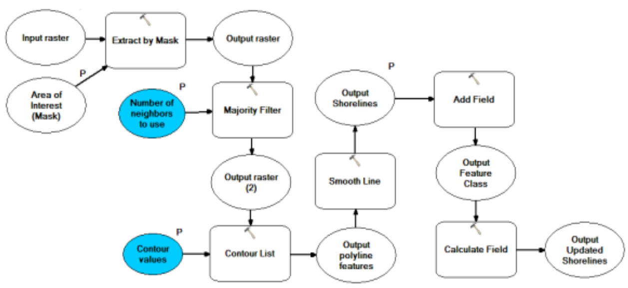

Figure 8 shoreline vector module

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IV. RESULT AND DISCUSSION

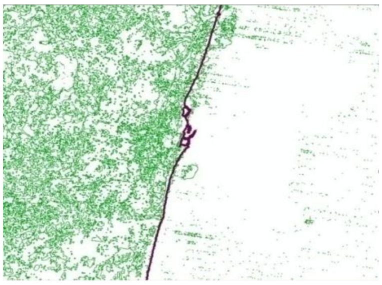

Figure 9 Shoreline (1988)

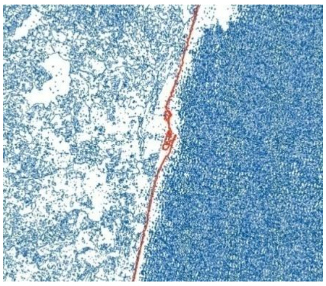

Figure 10 Shoreline (2003)

"Fig. 9," and *"Fig. 10,"* represents the shoreline for the year 1988 and 2003 as a result of the instantaneous shoreline derivation methodology followed.

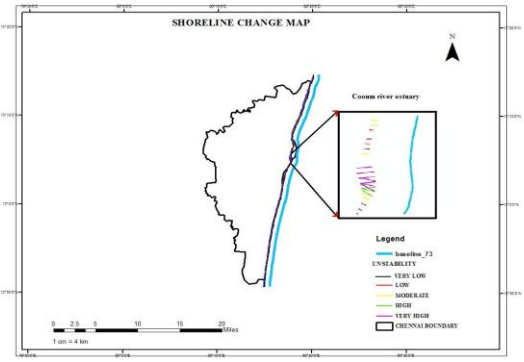

Figure 10: Shoreline categorization map

Table 2 : Coastal stretches and their dynamicity*

VERY LOW	1. Thiruchinnakuppam to Kasimedu Fishing Harbour 2. Triplicane 3. Besant Nagar
LOW	1. Thiruvotriyur Beach to Thiruchanankuppam 2. Cooum River Estuary 3. Marina Beach to Foreshore Estate Beach 4. Elliot's Beach to Thiruvanmiyur
MODERATE	1. Rajiv Gandhinagar to Thiruvotriyur Beach 2. Thiruchanankuppam to Tondiarpet 3. Pudumanikuppam to Royapuram
HIGH	• Royapuram
VERY HIGH	• Port Of Chennai

*Source : Computed by the author

By the methodology stated, Similarly obtained shoreline for various years are categorized with reference to table1 and the categorization map is obtained as shown in figure 9.From the categorization map obtained as shown in figure 9, the areas prone to dynamicity are tabulated in "Table 2". An interaction with the local people living along the coast was done at the villages so as to perform ground truth verification that lay on the stretches that were identified to be erosion prone. This field visit confirmed that the study area categorization as given in table 2 is perfect owing to dynamic change as experienced by people of that locality. The stretch of about 15km from Ennore towards its south to Royapuram comprise of a number of fishing hamlets. Most of the reaches have been protected by a seawall and combination of seawall and groins. By observation, even though, the stretch from Chinnakuppam (about 3 km from South of Ennore creek mouth) to Ennore mouth has been protected by a seawall, still it is highly eroding in nature.

To sum up it could be stated that Chennai coast has become highly volatile in nature because every short stretch is dynamic from the adjacent stretches. There is approximately 2mm rise in the global sea level every year. For a period of 38 years in the study undertaken, already approximately 5.319336 sq.km of land is lost into the sea due to natural and human factors. Considering this rise in the years to come there will be major amount of land area missing or in other words will be submerged inside the sea wherein creating history. The loss of shoreline causes capital damages to the human lives and their properties. There are continuous changes in the shoreline due to waves, storms, tides, tsunami, sea surface temperature etc. North Tamil Nadu coast comprising long sandy beaches and being magnificent owing to trade, tourism and fishing in the world is facing recession in recent times due to cyclic climatic factors, extreme weather events and anthropogenic activities. Hence there is an urgent need to protect the coastal environment which is under the threat due to dynamic shoreline change influenced by both climatic and non-climatic factors. Hence a necessity for effective and new remedial measures to protect the land along the Chennai coast where there is a trend for a greater proportion of people to live close to the sea has arouse, the economic activities on coastal environment are also increasing. Hence, apart from natural causes, the anthropogenic activities should be regulated by following coastal regulations to avoid losing land into the sea at a faster rate. The study suffers from drawbacks that higher the accuracy of the imagery used higher is the accuracy of the instantaneous shoreline demarcation. Also the shoreline demarcated is distinguishable when the extent varies over years and hence the seasonal pattern study pertaining to the same study cannot be performed.

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