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Assessment of Shoreline Changes Between Cuddalore and Nagapattinam Coast, East Coast of Tamil Nadu, India using Geospatial Techniques

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Key words: Shoreline, geospatial, erosion, accretion, DSAS, LRR

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Abstract: Coastal attrition is one of the most important problems in world seashore. Its impact has adversely affected the livelihood of the coastal community. The coastal zone of India is experiencing a wide range of natural and anthropogenic pressure. This study was carried out the shoreline changes between Cuddalore and Nagapattinam, East coast of Tamil Nadu, India using satellite images from 1980-2015. The long-standing coastal erosion and accretion rates have been calculated using the Digital Shoreline Analysis System (DSAS). Linear Regression Rate (LRR) statistical method is applied to estimate the shoreline change rate. The results of the analysis show that erosion is dominant in Devanampattinam to Cuddalore old town, Sothikuppam to Rajapettai, Chitrapettai to Nanjalingampettai, Kodiampalayam North side, Coleroon river mouth to Tandavankulam, Poompuhar to Kaveripattinam and Santirappadi.

INTRODUCTION

The boundary between land and sea, along with various land use and other effects of geological and hydrodynamic phenomena and their effects had made shoreline change one of the most common processes in coastal areas. These changes have happened different manifestations over short and long time periods. The recognition of sediment erosion, transport and depositions one of the most important and sensitive marine phenomena and develops direct impaction the design of ports and marine structures that indicate as a coastal management approach. Changes in erosion and sedimentation due to increasing precipitation have been observed in coastal areas, estuaries, canals and coastlines. Therefore, identifying the prevailing procedure to determine volatility and change in position of shoreline is the most important parameter required in managing in coastal areas. Therefore, it is important to determine measurements of the coastline at different times and it will support to compare and evaluate them for inclusion into the prognosis and decisions as future changes in the environment. Monitoring of coastline areas has needed over the time as shorelines are the most important and dynamic of the natural phenomenon and changes one and other parts of the land features. Failure of observing that may facts caused many coastal environment projects to be unsuccessful or to have a negative impact on the surrounding areas. These studies are an important priority while doing projects in management engineering studies. Krishnakumar *et al*. (2011) have studied change detection studies in coastal zone features of Nagapattinam, Tamil Nadu. Kumaravel *et al*. (2012), Quantitative estimation of shoreline changes using remote sensing and

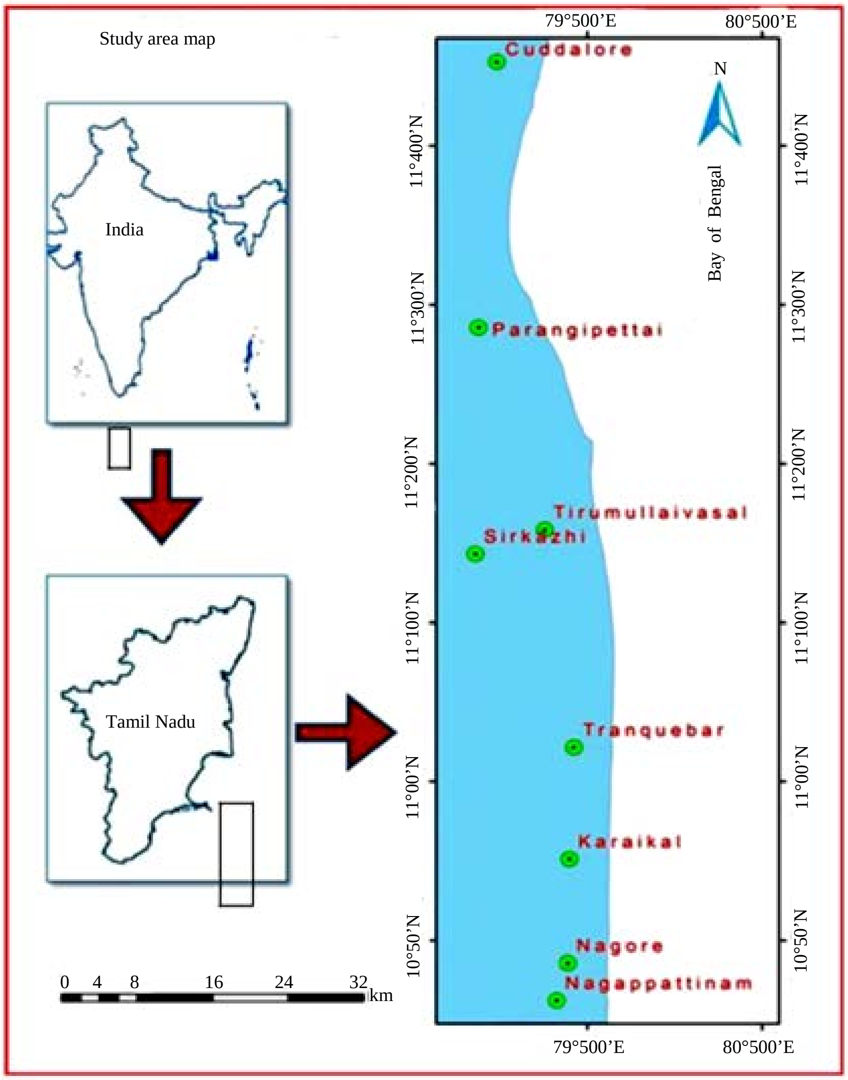

Fig. 1: Location map of the study area

GIS, a case study in the parts of Cuddalore district, East coast of Tamil Nadu. Salghuna and aravind Bharathvaj (2015) have analyzed shoreline change in Northern Part of the Coromandel Coast. Usha Natesan *et al*. (2015) have approached monitoring long-term shoreline changes along Tamil Nadu, India by applying geospatial techniques.

Scope of the study: This study has proposed to carry out shoreline changes with the comparison of Tsunami impacts over a length of 117 km from Cuddalore to Nagapattinam, Tamil Nadu, East Coast of India. Shoreline changes are main dynamic processes in the coastal area. The shoreline changes mostly associated with waves, tides, winds, storms, sea level change, erosion, accretion and human activities. In many coastal areas in the developing countries, the dense population being placed next to the shoreline creates the more vulnerable areas. It has become important to map the shoreline change as an input data for coastal hazard assessment). The different period of shoreline mapping is considered to be a valuable task for coastal monitoring and assessment.

Study area: The study area extends in between 11°77'N and 79°69'E-10°74'N and 79°92'E. The study area is represented by begins from Ponnaiyar river basin in the North of the region and Uppanar river basin in the Southern region (Fig. 1). The study area from Cuddalore New Town on the Western side and Eastern side represents Nagapattinam area. It falls under the survey of India Toposheets no of 58 M/10, 13, 14, 15, 16, 58 N/11, 13 and 15 in the scale of 1:50,000. The study area has consisted of Cuddalore, Chidambaram, Sirkazhi, Tarangambadi, Thiruvarur and Nagapattinam districts and part of Karaikal, Pondicherry state. The study region is well connected by roads and railways. In the study area have major economic revenue as Tourism, fishing and aquaculture.

MATERIALS AND METHODS

The methodology has utilized in satellite images were visually interpreted with field verification and implementation of observed data. The shoreline changes map of the overall scenario of task has discussed as result and discussion. The shorelines were drawn through on-screen digitaization using visual interpretation technique in Arc GIS software. The multi-date shorelines were given as input in Digital Shoreline Analysis System (DSAS) to calculate the shoreline change rate. Transects were generated using DSAS to 1 km length with 50 m spacing to study the changes occurred in between Cuddalore and Nagapattinam coast. Field verification is also carried out to check the current shoreline positions using hand held GPS in few locations and photographs was also documented. The above details were obtained from the interpretation of satellite images and also incorporated in it. The features delineated in the maps were checked, modified and corrected during the field work.

Data preparation: Acquired satellite data is reregistered using image to map registration technique. Then each image was cropped to study area using Area of Interest (AOI) of the cropping method. These six cropped images were re-projected to a common projection; Universal Transverse Mercator (UTM) with (World Geocoded System 84) WGS 84 datum and Zone 44 North.

Data products used: The data products for the study used both Satellite data and Survey of India Toposheets. Satellite data were obtained from the National Remote Sensing Centre (NRSC) and United States Geological Survey (USGS) websites. The most important technical details of the satellite data are given in Table 1. The long-standing coastal studies of Cuddalore to Nagapattinam coast is studied for a period of 35 years from 1980-2015. The Shoreline change evaluation are based on comparing six years of historical shorelines extracted from different satellite imageries. Multi-temporal satellite data of Landsat (MSS, TM&ETM+) and IRS-P6 LISS 3 data were downloaded freely from the websites are given in Table 1. The details regarding satellite data and their acquisition years are listed in Table 2.

Table 1: The satellite data and their acquisition years of the study area

Satellite data/sensor	Year of pass	Spatial resolution (m)	Producer	Product scale
Landsat (MSS)	1980	83.0	USGS	1:50,000
LANDSA (MSS&TM)	1990	30.0	USGS	
Landsat (MSS, TM&ETM+)	2000	30.0	USGS	
Landsat (MSS, TM&ETM+)	2005	30.0	USGS	
IRS-P6 LISS 3	2010	23.5	NRSC	
Landsat (MSS, TM&ETM+)	2015	30.0	USGS	

Coastal zone monitoring tools: The following are the widely used tools for coastal zone monitoring. Field survey, Global Positioning System (GPS), Remote Sensing, Geographical Information System (GIS) and scope of the shoreline changes study. The study area shoreline is a very important coastal stretch in Tamil Nadu as there are broad changes in the shoreline and river mouth geomorphology. This is for the reason that of erosion and accretion characteristics of shoreline. The valuation and changes of coastal dynamics of shoreline should be viewed as a combination of long term natural trends and short term alteration by man and disaster factors. The policy creator of this coastal stretch should therefore involve better understanding of the impact of coastal dynamics to avoid degradation in the coastal zone. In this background, this investigate gives complete particulars of geomorphologic changes in river mouth at meeting points, coastal erosion and accretion trend over a point of time (from 1980-2015) through geospatial approach. This study also visualizes the impact of sediment size, trend on coastal character and estimation the quantum of sediment movement in the study area.

Shorelines: This section provides strategy on collecting shoreline data and lists the necessary attribute fields users must create in the shoreline feature class. All shoreline data must be located in a single feature class within a personal geodatabase. If the shorelines are collected as shapefiles, they must be appending to a single file and then imported into a geodatabase within Arc Catalog. DSAS Software also need that the feature class be in meter units in a projected coordinate system (Fig. 2-4).

Shoreline data collection: Shoreline positions can reference many different features such as the vegetation line, high water line and low water line, wet or dry line. They can be digitized from a multiplicity of sources (such as, satellite imagery, digital orthophotos and historical coastal-survey maps), collected by Global Positioning System (GPS) field surveys or extracted from Lidar surveys. It is strongly suggested that initial data preparation steps be taken to reference all shoreline vectors to the same feature (example is mean high water)

Table 2: Long-term shoreline change detection from LRR for 35 years using various shorelines from 1980-2015

		Mean rate (m/year)			Erosion				Accretion		
Zones	No. of transects	Min.	Max.	Erosion transects	Min.	Max.	Percentage	Accretion transects	Min.	Max.	Percentage
1	233	-0.8	5.02	2	-0.8	-0.43	0.85	231	0.66	5.02	99.14
2	233	0.03	3.6	-	-	-	-	233	0.03	3.60	10.00
3	233	-2.31	2.88	37	-2.31	0	15.90	196	0.04	2.88	84.12
4	233	-0.11	5.49	3	-0.11	-0.02	1.28	230	0.02	5.49	98.71
5	233	-1.18	4.59	18	-1.18	-0.01	7.72	215	0.01	4.59	92.27
Total	1165	Total	60	Average	6.43	Total	11.05	Average	94.85		

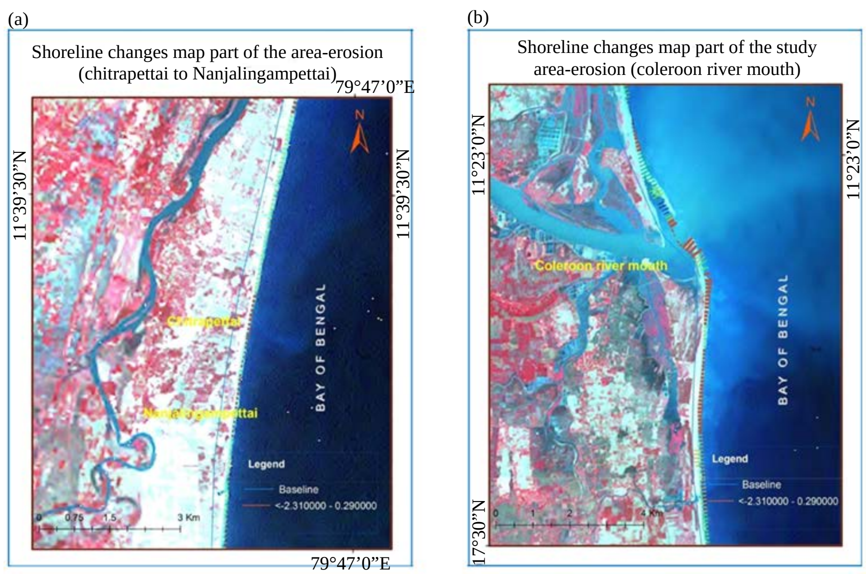

Fig. 2(a, b): FCC showing Shoreline erosion in Chitraipettai to Nanjalingampettai and Coleroon river mouth

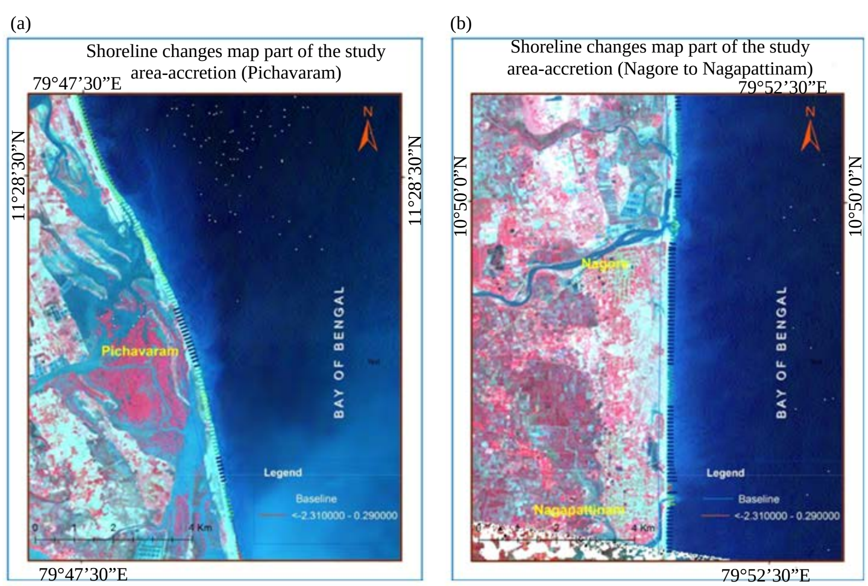

Fig. 3(a, b): FCC showing Shoreline Accretion in Pichavaram region and Nagore to Nagapattinam

before using DSAS to compute change statistics. Each shoreline vector represents a specific position in time and must be assigned a date in the shoreline feature-class attribute Table 3. The measurement transects that are cast

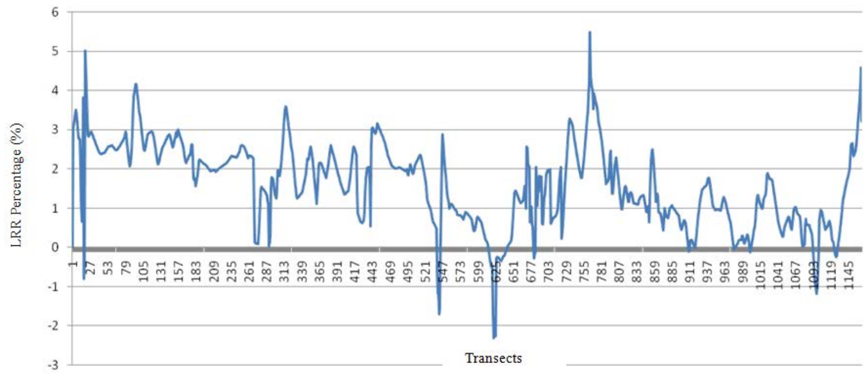

Fig. 4: Frequency curve shown the Shoreline changes over time in LRR method

Table 3: High erosional location spot in the study area (1980-2015)

High erosional places	Latitude/longitude	Changes (km)
Devanampattinam	79°79'10''E 11°74'50''N	5.43
To	To	
Cuddalore old town	79°79'10''E 11°77'80''N	3.38
Sothikuppam	79°77'50''E 11°68'60''N	
To	To	
Rajapettai	79°77'40''E 11°68'10''N	3.68
Chitrapettai	79°76'40''E 11°63'40''N	
To	To	
Nanjalingampettai	79°76'00''E 11°61'20''N	2.27
Kodiampalayam North side	79°81'70''E 11°40'00''N	
	To	
	79°82'20''E 11°38'20''N	6.57
Coleroon river mouth	79°82'30''E 11°38'00''N	
To	To	
Tandavankulam	79°83'60''E 11°32'20''N	1.12
Poompuhar	79°85'90''E 11°14'40''N	
To	To	
Kaveripattinam	79°86'60''E 11°12'70''N	0.52
Santirappadi	79°85'70''E 10°99'70''N	

by DSAS from the baseline will intersect the shoreline vectors. The points of intersection provide location and time information used to calculate rates of change. The distances from the baseline to each intersection point along transect are used to compute the selected statistics. The calculated rates of change provided by DSAS are only as reliable as the shoreline data. To better quantify the statistical reliability of the computed rates, users must account for measurement and 11 sampling errors when compiling each shoreline position. Users have the option of specifying for each shoreline an overall uncertainty value which should account for both positional and measurement uncertainties. Refer to Morton and etc, for examples, of how to calculate an overall shoreline uncertainty. The shoreline uncertainty will be incorporated into the calculations for the standard error, correlation coefficient and confidence intervals which are provided for the simple and weighted linear regression methods. For any shoreline vectors assigned a value of zero or null, DSAS will utilize the value specified by the user in the Set Default parameters window.

Baseline: This section gives guidelines on proper baseline construction and lists the necessary attribute fields users must create within the baseline feature class. DSAS uses a measurement baseline method to calculate rate-of-change statistics for a time series of shorelines. The baseline is constructed by the user and serves as the starting point for all transects cast by the DSAS application. Transects intersect each shoreline at the measurement points used to calculate shoreline-change rates.

DSAS Software workflow: Once the required geodatabase and input-feature classes have been created or imported from shapefiles and all necessary feature classes have been added and properly attributed, the DSAS Application can be utilized within Arc Map to establish transect locations and calculate change statistics.

Remote sensing techniques: The georeferenced satellite images were verified and corrected with the aid of GPS coordinates recorded from the selected locations with Global Positioning System (GPS) data and corrected wherever necessary. The shorelines were identified and delineated by processing the IRS LISS data and Landsat ETM data. In the present study, the exact land-water boundary was obtained by using a nonlinear edge-enhancement technique. These operations were applied to image data to produce an enhanced image output for subsequent visual interpretations. The enhancement techniques improve the feature exhibition and increases visual distinctions between features contained in a scene. This technique provides a clear demarcation of the land-water boundary. High resolution data are manually digitized using Arc GIS (10.2) software.

Shoreline change analysis: Multiple shoreline positions along with a fictitious baseline are the basic requirement for analyzing the shoreline. Continuous shoreline positions were digitized manually as per 1:50,000 scale

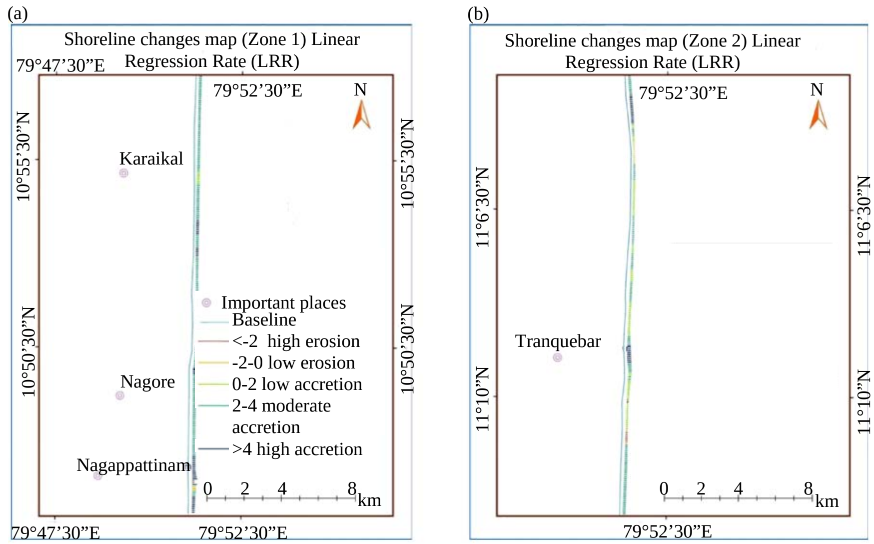

Fig. 5(a, b): Clipped shoreline changes map (LRR Zone 1 and LRR Zone 2)

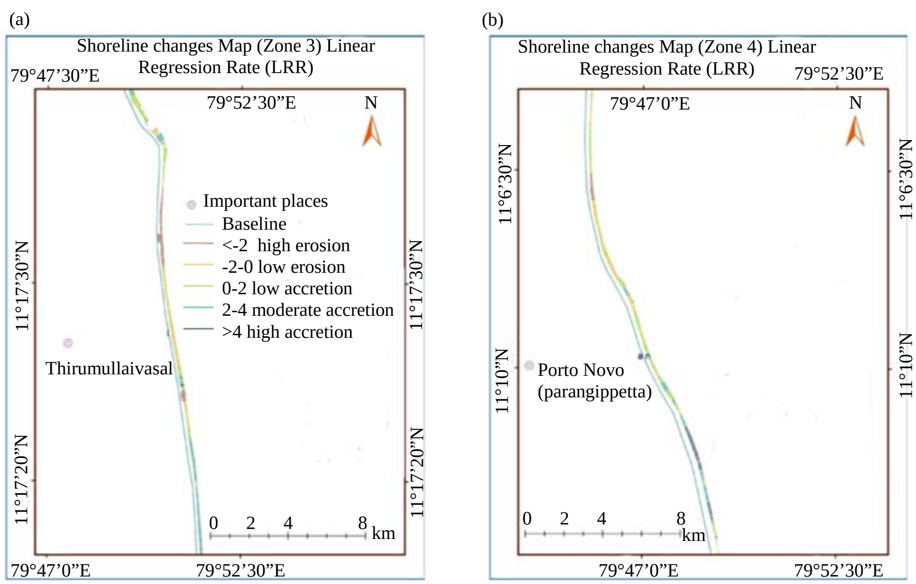

Fig. 6(a, b): Clipped shoreline changes map (LRR Zone 3 and 4)

requirement for six various periods, i.e., 1980, 1990, 2000, 2005, 2010 and 2015 with six attribute fields i.e., Object ID (a unique number assigned to each transect), shape, shape length, ID, date (original survey year) and uncertainty values for further analysis. All different shoreline features were then merged within a single line on the attribute Table 4 which enabled the multiple coastline files to be appended together into a single shape file for further analysis. Digital Shoreline Analysis System (DSAS), an extension of ESRI Arc GIS software was used to calculate the shoreline rate-of-change statistics from a time series of multiple shoreline positions. The 117 km of coastal stretch. The shoreline from Cuddalore to Nagapattinam is taken in to account for shoreline calculation. Totally 1165 transects were generated with 50 m and divided into five categories from zone 1-5 (Fig. 5-7).

Linear Regression Rate (LRR): Linear regression rate-of-change statistic can be determined by fitting least-squares regression lines to all shoreline points for a

Table 4: High accretional places in the study area (1980-2015)

High Accretional Places	Latitude/Longitude	Changes in km
Nagore	79° 85’40’’E 10°82’50’’N	3.15
To	To	
Samandampettai	79°85’30’’E 10°79’70’’N	
Nambiarkuppam	79°85’20’’E 10°28’00’’N	3.70
To	To	
Nagapattinam South	79°85’20’’E 10°25’10’’N	
Mariammankovil pettai	79°85’40’’E 10°86’90’’N	0.88
Kuttyandavar	79°85’50’’E 11°04’00’’N	0.70
Thirumullaivasal	79°84’80’’E 11°24’30’’N	0.60
Chinnavaikkal South	79°81’40’’E 11°42’20’’N	0.73
Chinnavaikkal North	79°81’20’’E 11°43’20’’N	1.54
Vellar river mouth	79°77’90’’E 11°50’00’’N	0.40
Ponnaiyar river mouth	79°79’60’’E 11°77’10’’N	0.35

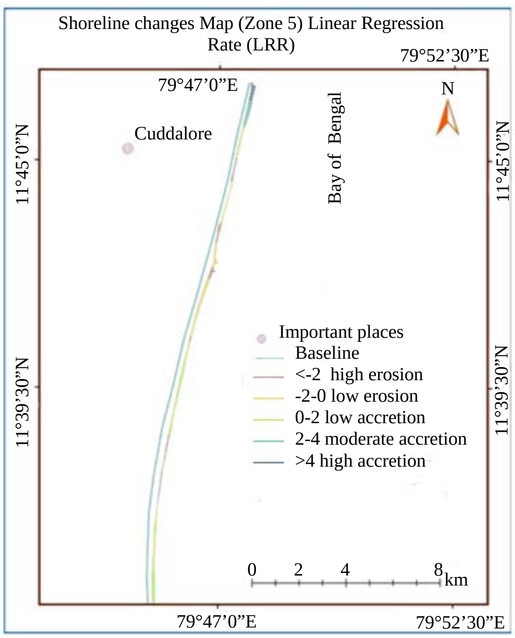

Fig. 7: Clipped map shown the shoreline changes in Cuddalore region (LRR Zone 5)

specific transect. The regression line is located so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. The method of linear regression includes these features: All the data are used, regardless of changes in trend or accuracy. The method is purely computational. The calculation is based on accepted statistical concepts and the method is easy to employ. However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics, like as EPR. The Linear Regression (LRR) erosional transects has totally 60 no’s and accretional transects has totally 1105 no’s. The shoreline analyzed, erosions are (-0.08 to -0.01 m/year) and a higher level of accretional are (0.66-4.59 m/year). The areas of high and very high accretion in almost all cases were human influenced.

Shoreline Changes: Satellite imageries of the study area for the years 1980, 1990, 2000, 2005, 2010 and 2015 data were used. The above mentioned year’s imageries from interpreted layers can utilize to find out the shoreline changes. The DSAS (Digital Shoreline Analysis System) software has utilized for georeferenced as in the case of Toposheets. Satellite imageries were obtained during low tide period as it is preferred for shoreline mapping . Using the geo-referenced satellite imageries, a shoreline of years 1980, 1990, 2000, 2005, 2010 and 2015 were extracted as a vector layer through on-screen digitization. These shoreline vectors of the respective years were superimposed over the base map and the shoreline changes were quantified. Shoreline Mapping, inventory and monitoring is essential information for characterization and management of coastal systems which required to be documented. In this study has analyzed the shoreline changes rate using Linear Regression Rate (LRR) methods to provide consistent and reliable information in complex coastal systems across different time and scales. Shoreline changes along the Cuddalore to Nagapattinam coast region were studied over the different period of intervals. In the study area has been founded high erosional places are Gadilam river mouth, Cuddalore-Old, Cuddalore-New, Rajapettai, Coleroon river mouth, Thirumullaivasl, Pumpuhar, Nandalar river mouth and Santrappadi.

The study areas of erosion or accretion in almost all cases were high tidal action influenced. The high erosion was noticed on from Cuddalore-New to Coleroon river mouth region and some places are low erosion were founded these places are near Thirumullaivasal, Pumpuhar, Nandalar river and Santrapadi regions. The Linear Regression Rate (LRR) of method results shown as about -2.31 m/year for high erosion happened in the study area. Whereas, high accretion was identified along the Southern part of Coleroon river mouth to Nagapattinam region mostly occurred with a rate of Linear Regression Rate (LRR) method showed 5.49 m/year. The results of the Linear Regression Rate (LRR) methods seem to be more systematic and reliable. The method considers the entire set of the data with additional options of weight to the quality of data at each intersecting transects individually. LRR approach is most ideal to compute the shoreline change rates were identified in the different period of satellite data. The shoreline may be defined using a pragmatic approach. In the coastline stretch from Coleroon river mouth to

Nagapattinam port, erosion occurred in Coleroon river mouth, Toduvaipattnacheri-Pumpukar-Tarangambadi-Mandapattur-stretch and Thirumalairajanpattinam, Nagore and Nagapattinam stretch at an insignificant level. It is found that a total shoreline length of 117 km. Devanampattinam to Cuddalore old town 5.43 km, Sothikuppam to Rajappettai 3.38 km, Chittiraippettai to Nanjalingam pettai, 3.68 km, Kodiyampalayam North side 2.27 km, Coleroon river mouth to Tandavankulam 6.57 km, Pumpukar to Kaverippattinam 1.12 km, Santirapadi 0.52 km were subjected to high erosional places. Nagore to Samandampettai 3.15 km, Nambiarkuppam to Nagapattinam South 3.70 km, Mariammankovil pettai 0.88 km, Kuttiyandavar 0.70 km, Tiirumullaivasal 0.60 km, Chinnavaikkal South 0.73 km, Chinnavaikkal North 1.54 km, Vellar river mouth 0.40 km, Ponnaiyar river mouth 0.35 km were highly accretional places. Land use pattern and other human activities like construction of ports and comparatively straight flatter shoreline might have caused by the erosion.

RESULTS AND DISCUSSION

The shoreline changes can identify by using Linear Regression Rate (LRR) method for the study of erosion or accretion in the high tidal action influenced area. The high erosion was noticed on from Cuddalore-New to Coleroon river mouth region and some places are low erosion were founded these places are near Thirumullaivasal, Pumpuhar, Nandalar river and Santrapadi regions. The Linear Regression Rate (LRR) of method inferred that -2.31 m/year for high erosion happened in the study area. Whereas, high accretion was identified along the Southern part of Coleroon river mouth to Nagapattinam region mostly occurred with a rate of Linear Regression Rate (LRR) method result shown as 5.49 m/year. The LRR results exhibit the evolution of coastline stretch from Coleroon river mouth to Nagapattinam port, erosion occurred in Coleroon river mouth, Toduvaipattnacheri-Pumpukar-Tarangambadi-Mandapattur-stretch and Thirumalairajanpattinam, Nagore and Nagapattinam stretch at an insignificant level. The study has found that a total shoreline length of 117 km. Devanampattinam to Cuddalore old town 5.43 km, Sothikuppam to Rajappettai 3.38 km, Chittiraippettai to Nanjalingampettai, 3.68 km, Kodiyampalayam North side 2.27 km, Coleroon river mouth to Tandavankulam 6.57 km, Pumpukar to Kaverippattinam 1.12 km, Santirapadi 0.52 km were subjected to high erosional places. Nagore to Samandampettai 3.15 km, Nambiarkuppam to Nagapattinam South 3.70 km, Mariammankovil pettai 0.88 km, Kuttiyandavar 0.70 km, Tiirumullaivasal 0.60 km, Chinnavaikkal South 0.73 km, Chinnavaikkal North 1.54 km, Vellar river mouth 0.40 km, Ponnaiyar river mouth 0.35 km were highly accretional places. Land use pattern and other human activities like construction of ports and comparatively straight flatter shoreline might have caused by the erosion.

The coastal geomorphic studies can improve and protect the coastal zone in the vulnerable areas. In the present study has brought out recent and full information on the vulnerability of coastal region, coastal geomorphology, Landuse/land cover and shoreline changes between several years (1980-2015). The coastal rural community and coastal population to the projected accelerated sea level rise in Nagapattinam region. The Coastal Geomorphology that has been controlled by tidal effect and winds. The tectonic upliftment will drive that causes of abrupt changes in the river direction. Transgression and regression happened in drastic changes in the sea due to several effects like sea level changes due to tectonic movement. The changing faces of the shoreline phenomena from Cuddalore to Nagapattinam. Major changes in the sea that happened for increasing and decreasing of beach ridges is due to impact of Tsunami appeared in 2004. The near shoreline areas are might have quick access to vulnerable zone but in the case of human settlement near to the shoreline that causes loss of life and property.

In 2004, Tsunami has modified the drastic changes in the shoreline such as change of soil profile, coastal morphology and Landuse/land cover in the study area. In fact that, there is a negative factor such as increased wasteland and reduced mangrove forest. The immediate attention is required towards the increasing of mangrove forest because of it has to be a natural protection of natural calamities.

CONCLUSION

High Accretional places in the study area such as Nagore to Samandampettai, Nambiarkuppam to Nagapattinam South, Mariammankovil pettai, Kuttyandavar, Thirumullaivasal, Chinnavaikkal South, Chinnavaikkal North, Vellar river mouth and Ponnaiyar river mouth. Both natural and anthropogenic processes along the coast control the erosion and accretion activities of the coastal zones. The present study demonstrates that the combined use of satellite imagery and statistical methods can be a reliable method for shoreline change analysis.

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