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Geospatial analysis of shoreline changes along the Pondicherry and Vedaranyam coast, east coast of Tamil Nadu, India

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Abstract

Shoreline change study was carried out for the 243km long stretch of Pondicherry and Vedaranyam coast. IRS-1C Liss-III (2012), STRM (2000) Satellite images and Survey of India toposheets for the years 1970 input dataset. A field survey was also carried out using GPS instrument for 2014. One method i.e. Linear Regression Rate (LRR), were working to calculate shoreline change rate for 1970 to2012. While Linear Regression Rate method is used to work out the Long-term analysis for 1970-2012. Totally 45 transects were generated with 50m spacing and the length of each transect was 200m. From the Long-term analysis, the overall erosion change was -2.80 m/yr and accretion 1.88 m/yr during the period of 1970 to 2012. From the analysis, it clearly shows that the assessment of shoreline change rates showed a trend of shoreline erosion and accretion. Most of the beach underwent erosion while some part of the beach accretion through the study period. The observed patterns of the erosion and accretion along the central Tamil Nadu coast resulted from both natural and human impacts. Most of the shoreline was exposed to natural shoreline phenomena such as waves, tides and periodic storm surges apart from the coastal tectonics activities.

Keywords: Erosion, Accretion, Satellite imagery, Linear Regression Rate.

Introduction

The shoreline is defined as the fringe of land at the edge of the large water body. The shoreline comprises a major element of the earth's landscape and the procedures that shape it is exceptionally complex[1]. The actual definition of shoreline, mapping and using them is a complicated task[2]. Reported that the shoreline is a unique feature of the earth surface[3]. It is one among the twenty-seven features recognized by the international geographic data committee (IGDC) and a rapidly changing landform in the coastal area.

It exposes a more detailed picture of shoreline change through time and of how adjacent shore types evolve in concern with the associated coastal landforms. Shoreline changes are the significant features in the coastal region and provide more information on coastal landform dynamics. Hence, precise recognition and regular monitoring of shorelines are vital to comprehending the coastal processes and understand the dynamics of various coastal landform.

Geology: The geology of the area includes metamorphic complex, metasediments and younger intrusive of Archaean formations on the western portion and the overlying sedimentaries of upper Cretaceous, Tertiary on the central part and Quaternary formations of the eastern part (Figure-1).

The contacts between the crystalline and sedimentary are separated by boundary fault.

Methodology

Study area: The study area is located on the East coast o India, bounded on the East by Bay of Bengal (Figure-2). It is extending between Pondicherry in the North and Vedaranyam in the South and lies between the latitudes 11° 54' N to 10° 16' N and longitudes 79° 49' E to 79° 49' E and form part of the Coromandel Coast which encompasses the coast of Andhra Pradesh and Tamil Nadu in India. The length of the coastline of the study area is 243km.

Satellite imageries: The survey of India toposheet 57 P 16, 58 M / 10, 13, 15, 16, and 58 N 4, 7, 8, 11, 13, 14, and 15 are utilized as secondary data source. The satellite imageries used for different time period for obtaining landforms and shoreline profiles were given below in the (Table-1).

Table-1: List of Satellite Imageries used.

S.No	Satellite	Sensor	Path / row / Area	Date of Acquisition
1	IRS-1C	LISS-III	Path 180 Row 100	18th Mar 2012
2	Space Shuttle Endeavor	SRTM	1degree X 1degree	22nd Nov 2000

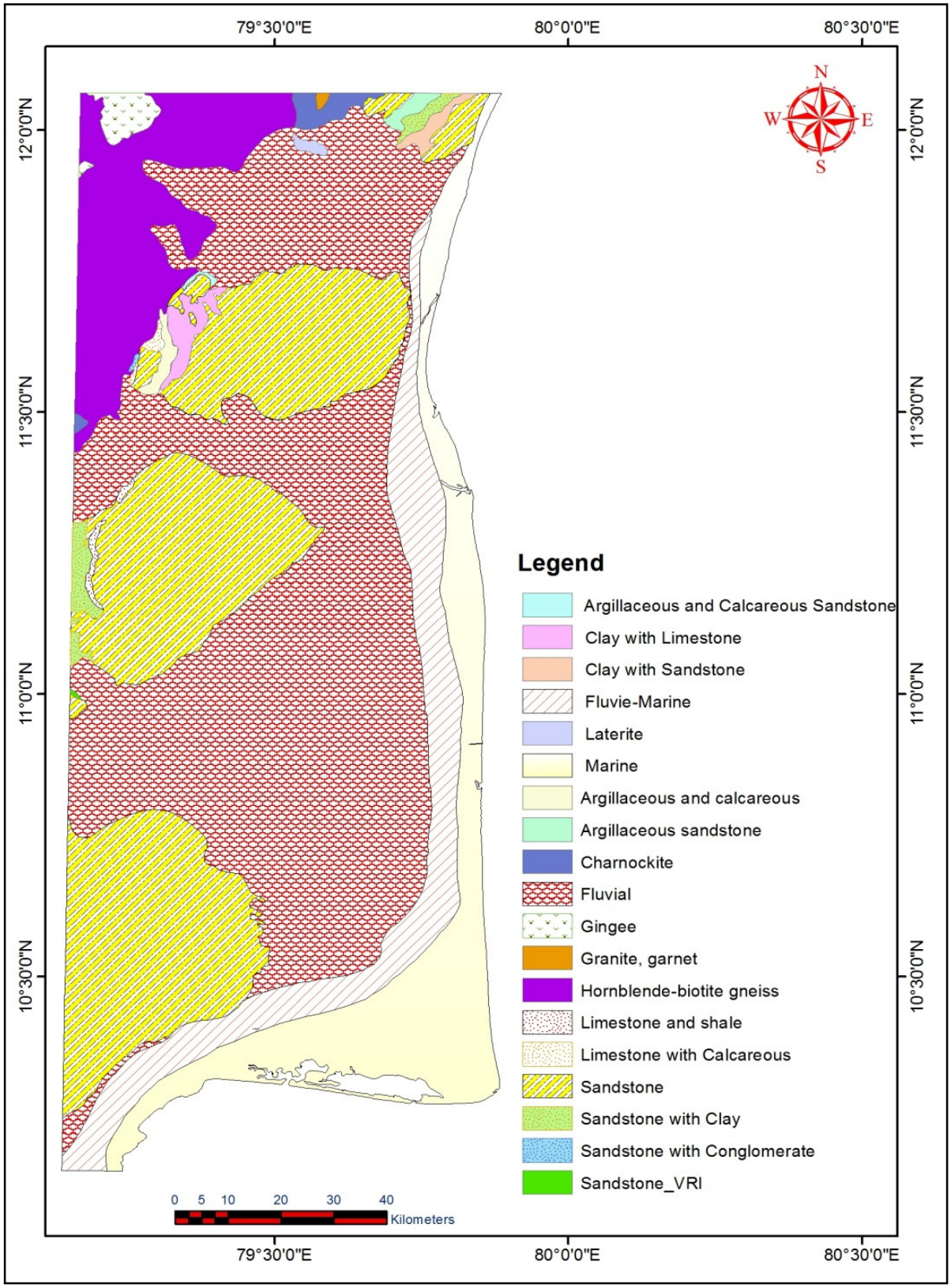

Figure-1: Geology Map of Study area.

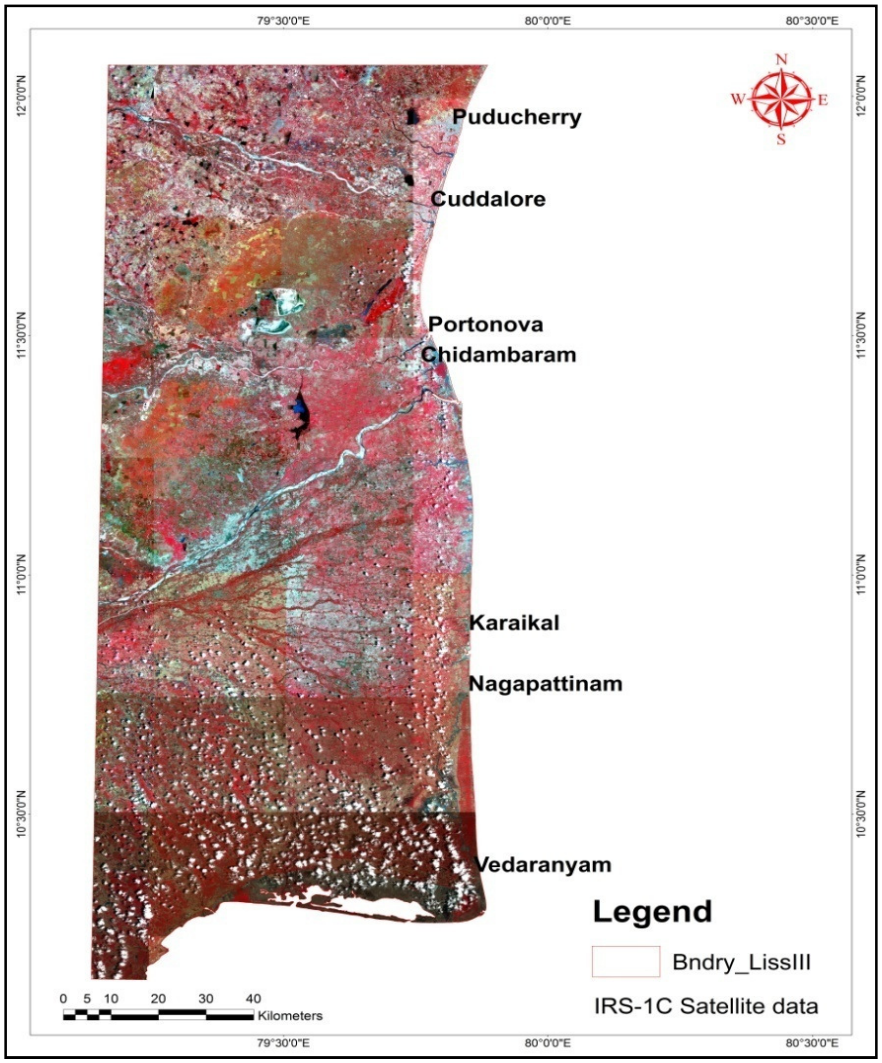

Figure-2: Location map of the Study area.

Coastal landform mapping: The coastal landform mapping between Pondicherry and Vedaranyam coast has been prepared based on classification, shoreline change detection. Presently the issue of shoreline changes due to sea-level rise which caused by Globe warming has increasingly become a major issue in terms of its impact on the population along the coastal area. Changes in mean sea level as measured by coastal tide gauges are called relative sea- level changes[4]. Sea- level has been raising 1.7–1.8 mm/year above the last century and the rate has bigger to 3 mm/year in the last decade[5-7]. Sea- level increase is causal to coastal erosion in various places of the earth[8].

Modify in the sea level appear to be superior on eastern coastline compare to the western coastline. The regular sea level increase for India has been report as 2.5 mm/year since 1950ʺs[9]. The current study which is motivated by above declaration demonstrate the possible of Geospatial and statistics method for monitor the shoreline changes along the coast of Tamil Nadu, India since such kind of change stands as a indication to the past and a there coastal atmosphere. In the present study, SRTM images, LISS-III and Toposheet include been utilize to separate shoreline position through different period in the past.

Analysis: The Digital Shoreline Analysis System (DSAS) as defined by the USGS (2005) was used to establish the rate of change for the shoreline in the Coastal part of Tamil Nadu. This way computes rate-of-change statistics from multiple historic shoreline positions inherent in a GIS environment. The created layers of multi-date Shorelines will be used as an input for the DSAS model for calculating the rate of change since 1970 for a period of 42 years.

Baselines will be created at ~1 km landward of the 1972 shoreline excluding the smaller creeks and areas such as river mouths and spits. With reference to the baseline, a seaward shift of the shoreline along transect was considered as accretion (deposition), while landward shift was considered as erosion. The rate of long-term shoreline variations has been calculated

using Linear Regression Rate (LRR), the method in the ARC-GIS environment to identify erosion and accretion areas along the coasts of the study area. The shoreline change analysis is done by using the USGS provided DSAS 4.3 (Digital Shoreline Analysis System) which is an additional "Extension" used for ArcGIS (v10.0).

Results and discussion

Coastal Erosion and Accretion: Scientists have developed the shoreline studies and classified the coast based on the extent of shoreline erosion and deposition. Johnson Douglas W.[10] and Shepard Francis P.[11] have classified the shoreline based upon a thought of the following factors.

Major or young coasts with configurations due to mostly non marine agency: i. Shaped by terrestrial erosion agency and drown by deglaciation or down warp and persons shaped by terrestrial depositional agency such as river, glaciers, and the wind. ii. Shaped by volcanic explosion or volcanic emission flow. iii. Shaped by diazotrophic action.

Secondary or older coasts with configurations primarily the effect of marine agency: i. Shaped by sea erosion and deposition Most of the countries suffering from increased rate of coastal erosion along their shoreline stretch, which threatens the living conditions and livelihood of people. ii. Devastating of global warming results in the increase in sea level, which is a persistent problem in the coastal stretch. In the modern world developing coastal structures are found very much necessary for economic development and at the same time, such structures should be sustainable against coastal erosion and accretion. The shoreline is said to be eroding, when the loss of sediments due to various reasons exceeds the sediments supplied to it similarly when the sediment loss is lower than that of sediment supply, makes the coast accreting.

Shoreline change analysis of study area: i. Coast erosion is a major problem along most open ocean shore of the India. ii. Shoreline of years 1970, 2000 and 2012 were extracted as vector layer through on screen digitization. iii. The rates of erosion/accretion perpendicular to the shoreline were computed for the study area and the results are furnished in (Table-2).

Table-2: Overall shoreline change rates from 1970 to 2012.

Shoreline statistics	Shoreline change (m/year and m/period)	
	Erosion	Accretion
Linear regression rate (LRR) (m/year)	-2.805	1.884

Linear Regression (long-term) Rate (LRR): The Long-term rate of shoreline change was calculated at each transect as the angle of the linear regression through all shoreline position from 1970 to 2012. The linear regression rate (LRR) shoreline analysis for the beach front showed a mean of -2.80m/year (Table-2) where 84% of transects fall under erosion and 16% accretion (Table-3). This analysis gives emphasis on data points for which the location uncertainty was lesser. The linear regression method of determining shoreline change rate does assume a linear trend of change between the earliest (1970) and latest (2012) shoreline dates. However, there is clearly an area where such a linear trend does not exist that is shoreline change rates have not remain stable through time (Figure-3, A, B, C).

Accretion and Erosion in the study area: Assessment of shoreline change rates showed a trend of shoreline erosion and accretion. Most of the beach underwent erosion while some part of the beach accretion through the study time. The observed patterns of the erosion and accretion along the central Tamil Nadu coast resulted from both natural and human impacts. Most of the shoreline was exposed to natural shoreline phenomena such as waves, tides and periodic storm surges apart from the coastal tectonics activities.

Accretion in the Study Area: In the coastline stretch from Pondicherry to Pointcalimer, accretion has occurred in Periyapattu to Ariyakoshti stretch, Kattur to Vettangudy stretch and Prathabaramapuram to Muthupet stretch at the significant level.

The long-term rates of accretion were found maximum as 13.54 m/year at Muthupet and minimum as 0.765 m/year at Nalavedapathi (Table-4). The long-term rate of accretion in this stretch was worked out to be 5.34 m/year at Ariyakoshti as maximum and 1.44 m/year at Periyapattu as a minimum (Table 4), in this stretch. The Kattur to Thirumullaivasal stretch shows the maximum value of 60.8m in Vettangudy and the minimum value of 8.34m in Pudupattinam with the 8.59 m/year (Kattur) and 0.29 m/year (Vettangudy) as maximum and minimum rate of long-term accretion respectively (Table-4).

As a whole, it is found that a total shoreline length of 52 km was subjected to accretion. The Presence of Mangrove swamp and vegetative barrier like Casuarinas, bamboos etc along with low coastal processes (tide and wave height) are responsible for the accretion nature of the coast in different part of the study area.

Erosion in the Study Area: In the coastline stretch from Pondicherry to Pointcalimer, erosion occurred significant level.

The long-term rate of erosion in this stretch was worked out to be -4.44 m/year as maximum and -0.43 m/year as a minimum (Table-4). The second coastal stretch underwent erosion was Ariyakoshti – Thirumullaivasal – Nagapattinam - Vedaranyam coastal stretch with a maximum erosion of -340.06 m at Nagore and that of minimum as -23.95m at Vellapallam and its maximum and minimum long-term rate of erosion of this stretch were -8.12 m/year at Ariyakoshti and 0.47 m/year at Vizhunthamavadi respectively (Table-4). It is found that a total shoreline length of 191 km of shoreline subjected to erosion. Land use pattern and other human activities like construction of ports and comparatively straight flatter shoreline might have caused the erosion.

Table-3: Long-term of shoreline Accretion/Erosion in the study area (LRR).

S. No.	Location	Reference Latitude	Rate of shoreline Accretion/Erosion in m/Year		
			1970 to 1990	1970 to 2000	1970 to 2012
1	Pondicherry	11°54'49.44"	-3.873	-4.213	-4.160
			4.674	4.024	4.745
2	Madalpattu	11°50'34.78"	-4.5325	-4.3225	-4.4825
			0	0	0
3	Cuddalore	11°44'40.78"	-4.360	-4.075	-4.055
			0	0	0
4	Pachchyankuppam	11°41'47.14"	-3.863	-3.73	-3.806
			0	0	0
5	Kudikkadu	11°41'3.02"	-3.576	-3.563	-3.614
			0	0	0
6	Tiyagavelli	11°37'16.33"	-4.0877	-4.106	-4.037
			0	0	0
7	Tiruchchepuram	11°36'23.58"	-2.7375	-2.8125	-2.77
			0	0	0
8	Kayalpattu	11°35'21.52"	-2.383	-2.483	-2.5166
			0	0	0
9	Andarmullippallam	11°34'23.61"	-1.493	-1.395	-1.343
			0	0	0
10	Periyapattu	11°33'17.42"	0	-0.43	0
			1.13	1.78	1.495
11	Silambimangalam	11°32'39.89"	0	0	0
			3.49	3.425	3.705
12	Villiyanallur	11°31'55.91"	0	0	0
			4.475	4.005	3.71
13	Kothattai	11°30'34.35"	0	0	0
			7.695	7.44	7.765
14	Ariyakoshti	11°29'17.25"	-7.85	-7.32	-9.21
			5.8466	5.825	4.51
15	Parangipettai	11°30'30.41"	-4.147	-4.758	-3.67
			0	0	0

S. No.	Location	Reference Latitude	Rate of shoreline Accretion/Erosion in m/Year		
			1970 to 1990	1970 to 2000	1970 to 2012
16	Killai	11°27'11.38"	-5.823	-6.255	-5.913
			0	0	0
17	Pichavaram	11°25'52.08"	-4.016	-4.3137	-4.257
			0	0	0
18	Kattur	11°21'24.66"	-3.07	-1.6325	-2.203
			7.93	10.69	7.15
19	Pudupattinam	11°19'56.68"	-4.53	-3.645	-4.49
			5.655	5.14	1.103
20	Thandavankulam	11°19'11.56"	0	0	0
			1.996	2.028	1.902
21	Vettangudy	11°16'6.63"	-0.6725	-0.776	-0.58
			0.37	0.32	0.09
22	Thirumullaivasal	11°14'41.83"	-2.057	-1.985	-2.145
			0	0	0
23	Thennampattinam	11°12'41.13"	-4.196	-4.1675	-4.296
			0	0	0
24	Perunthottam	11°11'54.93"	-5.095	-5.155	-5.255
			0	0	0
25	Melulyar	11° 9'8.74"	-4.38	-4.335	-4.42
			0	0	0
26	Vanagiri	11° 7'10.77"	-4.358	-4.67	-4.38
			0	0	0
27	Marudampallam	11° 5'59.36"	-4.805	-4.776	-4.76
			0	0	0
28	Karaikal	10°55'31.60"	-4.109	-4.591	-4.371
			5.498	4.2275	5.305
29	Tarangambadi	11° 1'44.54"	-4.15	-4.124	-4.005
			0	0	0
30	Nagapattinam	10°45'56.02"	-3.823	-3.849	-3.882
			0	0	0

S. No.	Location	Reference Latitude	Rate of shoreline Accretion/Erosion in m/Year		
			1970 to 1990	1970 to 2000	1970 to 2012
31	Vadakkupoigainallur	10°43'35.16"	-3.771	-3.655	-3.798
			0	0	0
32	Therkupoigainallur	10°42'15.08"	-3.8025	-3.915	-3.8725
			0	0	0
33	Velankanni	10°40'55.09"	-3.956	-3.9	-4.035
			0	0	0
34	Prathabaramapuram	10°39'43.34"	-1.668	-1.684	-1.581
			1.24	1.04	1.243
35	Thiruppoondi	10°37'36.36"	0	0	0
			1.93	1.986	1.93
36	Vizhunthamavadi	10°35'43.86"	-0.45	-0.49	-0.46
			1.276	1.25	1.405
37	Vettaikkaraniruppu	10°34'23.74"	-0.735	-0.79	-0.85
			2.68	2.533	1.98
38	Vellapallam	10°30'54.80"	-0.45	-0.86	-0.16
			1.673	1.7925	1.343
39	Nalavedapathi	10°29'35.55"	-1.03	-1.08	-0.81
			0.7	0.915	0.673
40	Pushpavanam	10°27'45.31"	-3.255	-3.3	-3.318
			0	0	0
41	Periyakuthagai	10°25'37.38"	-3.432	-3.0575	-3.3525
			3.3575	2.84	2.31
42	Kadinevayal(Vedaranyam)	10°21'52.14"	0	0	0
			5.1	5.205	5.148
43	Vedaraniyapuram	10°22'27.10"	-1.37	-0.73	0
			4.6	4.6625	4.186
44	Kodiyakkari	10°17'4.21"	-3.882	-4.7525	-4.036
			2.53	2.345	2.158
45	Muthupet	10°23'44.48"	0	0	0
			13.410	13.64	13.596

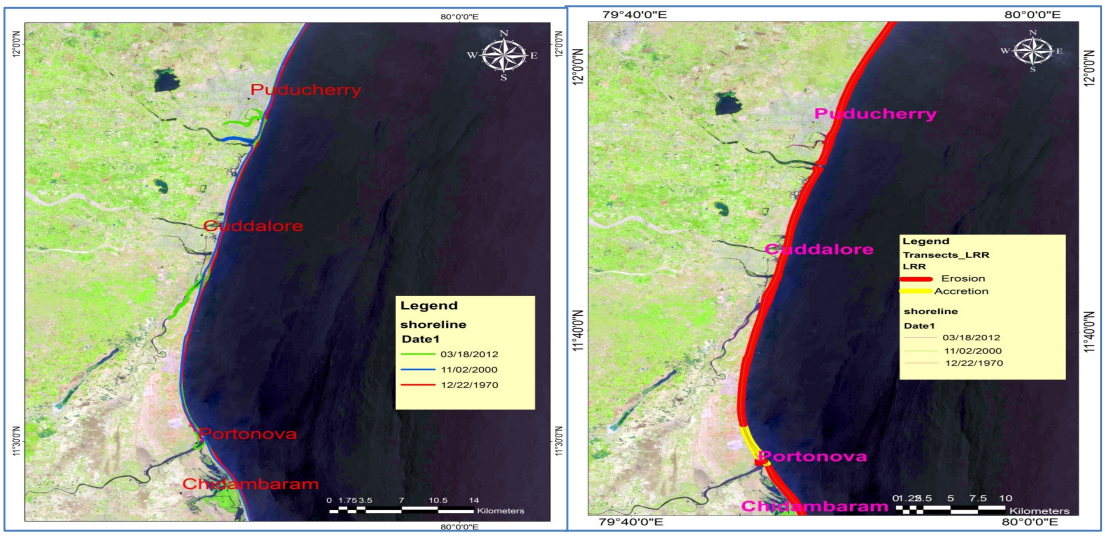

Figure-3(A): Long-term rate of Shoreline change (LRR m/year) along the shore from 1970 to 2012.

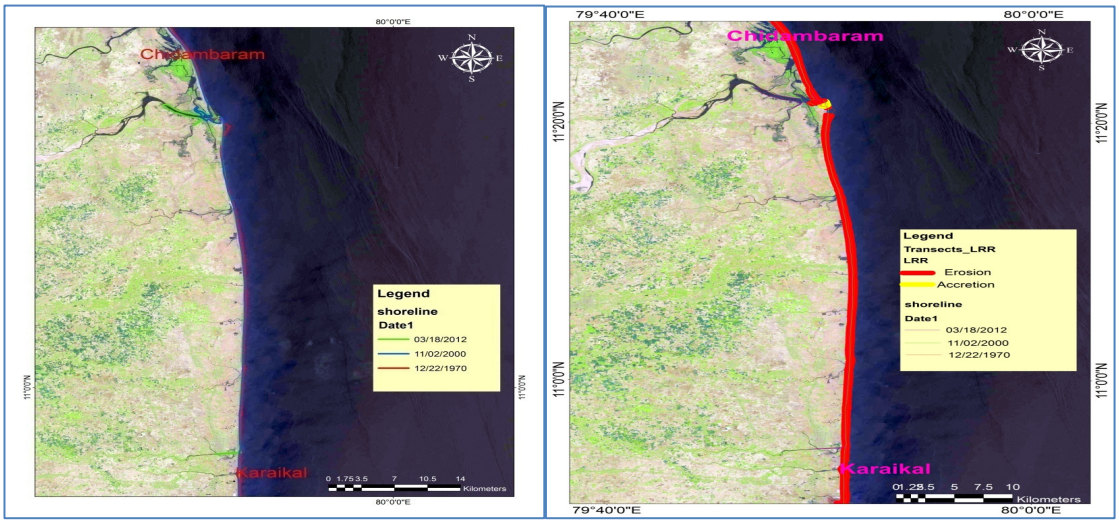

Figure-3(B): Long-term rate of Shoreline change (LRR m/year) along the shore from 1970 to 2012.

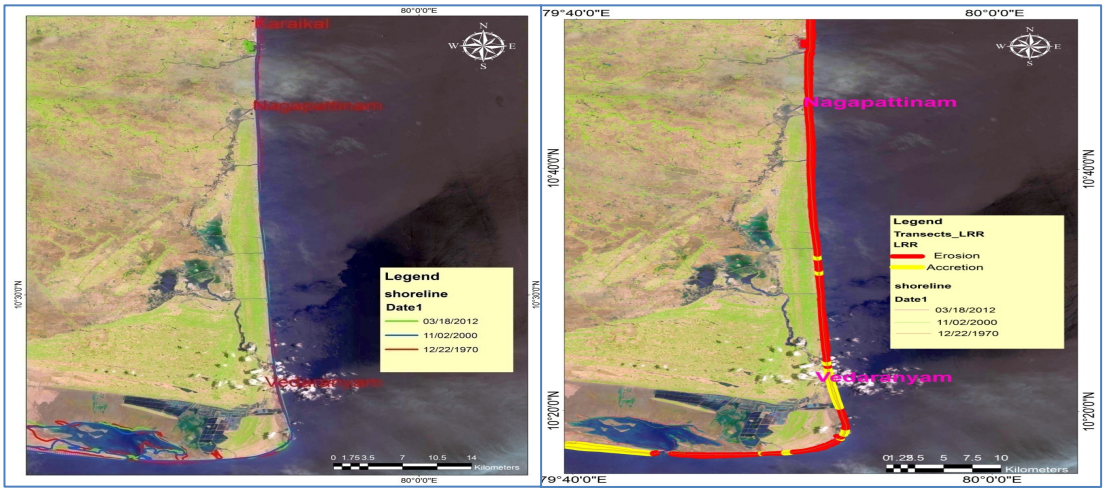

Figure-3(C): Long-term rate of Shoreline change (LRR m/year) along the shore from 1970 to 2012.

Conclusion

The coastline of the study area is more or less smooth and straight in its direction and having the regular geomorphic features. The shoreline is straight due to the predominance of the erosion related activities in the study area. As a whole, it is found that a total shoreline length of 52 km was subjected to accretion. It is found that a total shoreline length of 191 km of shoreline subjected to erosion. Land use pattern and other human activities like construction of ports and comparatively straight flatter shoreline might have caused the erosion.

Table-4: Long term shoreline change rates from 1970 to 2012.

S. No.	Location	Shoreline Change from 1970 to 2012 (LRR) m/year	
		Erosion	Accretion
1	Pondicherry	-4.08	4.351316
2	Madalpattu	-4.44583	0
3	Cuddalore	-4.16361	0
4	Pachchyankuppam	-3.80875	0
5	Kudikkadu	-3.58632	0
6	Tiyagavelli	-4.07571	0
7	Tiruchchepuram	-2.77364	0
8	Kayalpattu	-2.46	0
9	Andarmullippallam	-1.4125	0
10	Periyapattu	-0.43	1.445714
11	Silambimangalam	0	3.505
12	Villiyanallur	0	3.97125
13	Kothattai	0	7.555714
14	Ariyakoshti	-8.12667	5.34
15	Parangipettai	-4.405	0
16	Killai	-5.965	0
17	Pichavaram	-4.19304	0
18	Kattur	-2.31091	8.59
19	Pudupattinam	-4.341	3.557143
20	Thandavankulam	0	1.975333
21	Vettangudy	-0.66	0.298333
22	Thirumullaivasal	-2.0585	0
23	Thennampattinam	-4.215	0
24	Perunthottam	-5.16474	0
25	Melulyar	-4.37818	0
26	Vanagiri	-4.46933	0
27	Marudampallam	-4.78091	0
28	Karaikal	-4.35058	4.810909
29	Tarangambadi	-4.09115	0
30	Nagapattinam	-3.851	0
31	Vadakkupoigainallur	-3.74455	0
32	Therkupoigainallur	-3.86333	0
33	Velankanni	-3.955	
34	Prathabaramapuram	-1.64063	1.168182
35	Thiruppoondi	0	1.948667
36	Vizhunthamavadi	-0.47	1.305714
37	Vettaikkaraniruppu	-0.786	2.3625
38	Vellapallam	-0.49	1.622
39	Nalavedapathi	-0.908	0.765
40	Pushpavanam	-3.29158	0
41	Periyakuthagai	-3.29231	2.835833
42	Kadinevayal (Vedaranyam)	0	5.151111
43	Vedaraniyapuram	-1.05	4.47
44	Kodiyakkari	-4.176	2.354
45	Muthupet	0	13.54753

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