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A Study on Shoreline Changes in Parts of Pondicherry and Tamil Nadu Using Remote Sensing and GIS Techniques

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ABSTRACT

Coastal areas, the place where the water of the sea meet the land are indeed unique places in our global geography. Coastal zones are dynamic interfaces between land and water and are common locations of high-density development. Monitoring shoreline changes help to identify the nature and processes that caused these changes in any specific area, to assess the human impact and to plan management strategies. Remote sensing data could be used effectively to monitor the changes along the coastal zone, including shoreline with reasonable accuracy it has been taken up. The study area is the district of Pondicherry, which is the first largest among the four regions ,and it has an area of 293 km2.The study area falls in the Survey of India Topographic Map nos. of 58M/13 and 58P/16 on 1:50,000 scale. Detailed geomorphological was done based on mapping has been done using IRS P5 (2011) data and Survey of India Topographic map. In the present study, detailed coastal geomorphologic landforms of fluvial, coastal and uplands were studied.

Keywords: Remote sensing, GIS, Shoreline, Geomorphology, landforms.

I. INTRODUCTION

Coastal areas, the places where the water of the sea meets the land are indeed unique places in our global geography. They are endowed with a wide range of coastal ecosystems like mangroves, coral reefs, lagoons, sea grass, salt marsh, estuary, etc. They are unique in a very really economic sense as sites for port and harbour facilities that capture the large monetary benefits associated with waterborne commerce and are highly valued and greatly attractive as sites for resorts and as vacation destinations. The combination of freshwater and salt water in coastal estuaries creates some of the most productive and richest habitats on earth; the resulting bounty in fishes and other marine life adds great value to the coastal nations. In many locations, the coastal topography formed over the millennia provides significant protection from hurricanes, typhoons, and other ocean related disturbances. Inappropriate development and accompanying despoilment can reduce the attractiveness of the coastal environment, greatly affecting tourism potential. Coastal ecosystem management is thus immensely important for the sustainable use, development and protection of the coastal and marine areas and resources.

Coastal zones are dynamic interfaces between land and water and are common locations of high-density development. Coasts are subjected to frequent natural hazards, including flooding, storm impacts, coastal erosion, and tsunami inundation. Coastal erosion is a constant problem along the most open ocean shores of India. As coastal populations continue to grow, and infrastructures are threatened by erosion, there is an increasing demand for accurate information regarding the past and present shoreline changes. It is a known fast that the coast, especially the beaches, are facing severe erosion and the shorelines are changing. These are primarily due to natural and manmade activities such as construction of ports, harbors, groynes, shore protection measures, etc

Study Area

The Union Territory of Pondicherry comprises of four interspersed geographical entities namely Pondicherry, Karaikkal, Mahe and Yanam having a total area of 492 km2 and parts of Tamil Nadu located in southern India. The study area is the district of Pondicherry, which is the first largest among the four regions, and it has an area of 293 km2. The study area is located on the East coast between 77° 45’ and 77° 50’ E longitudes and 11° 45’ and 12° 03’ N latitudes. It is limited on the east by the Bay of Bengal and on the other three sides by the Villupuram and Cuddalore districts of Tamil Nadu State as shown in Fig.II.1. The study area is well connected by road transport network namely East Coast Road and Chennai – Vedaranyam National highways and by rail to Villupuram – Chennai.

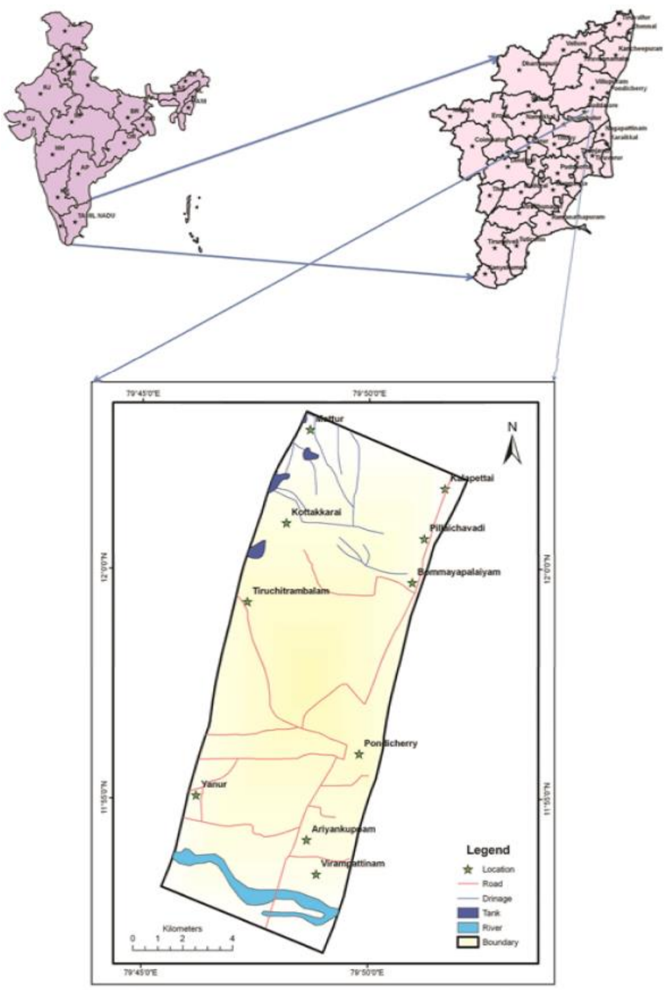

Figure 1: Location Map of the Study Area

II. METHODS AND MATERIAL

A. Image Pre-processing

Image pre-processing may include the detection and restoration of bad lines, geometric rectification, image registration, radiometric calibration, atmospheric correction, and topographic correction. Accurate geometric rectification of remotely sensed data is a prerequisite for a combination of different source data for a classification process. Many textbooks and articles have described this image preprocessing (Jensen 1996, Toutin 2004). In the present study digital image processing was done using ERDAS image processing software and co-registration are made to normalize data from various sources used for these studies.

Radiometric correction was made as the study involves analysis of the same area with different dates obtained for different years. The geometric correction (or registration) of satellite images was done to avoid an error in terms of the overall area. The registration process transforms each pixel of a raw satellite data into a new coordinate system in a specified map projection, chosen to be the India Nepal Grid for this study. The location of the pixel in the rectified image is derived from ground control points (GCPs). The satellite data were geo-registered in ERDAS image-processing software with the base map using 50 corresponding ground control points like bridges, road crossing and other permanent significant features, using Survey of India Toposheet.

One can use three basic methods of re-sampling (nearest neighbor, bilinear interpolation and cubic convolution). Cubic convolution is an advanced image restoration method that determines pixel values by evaluating the block of 16 pixels surrounding each output pixel (Lillesand & Kiefer, 1994). Although the cubic convolution is more complicated than both the nearest neighbor and the bilinear methods, it produces an image that does not contain blockiness and avoids the disjointed appearance of the nearest neighbor method. In addition, the output images do not exhibit the over-smoothing of the bilinear method and provide a slightly sharper image, making the method appropriate to use for discriminating between land and sea (Mather, 1999). Re-sampling in each case was performed using cubic interpolation technique to keep the spatial distortions at the minimum. Therefore, the cubic convolution method was selected to register the data in the study area.

The digital images were then registered using the re-sampled output of the toposheet to its corresponding geographic coordinates. One way of assessing the registration accuracy is to use the root mean square (RMS) error data generated by the software. Accuracy of the geometrically corrected image was checked by overlaying the rectified toposheet over the digital data and swiping horizontally and vertically to check for a shift in the corresponding field. The geo corrected data is through the Arc-GIS environment for digitization of shoreline. High waterline shown in the topographic sheets and different periods of IRS satellite data in the year 2000, 2005 and 2011 are digitized as the line feature.

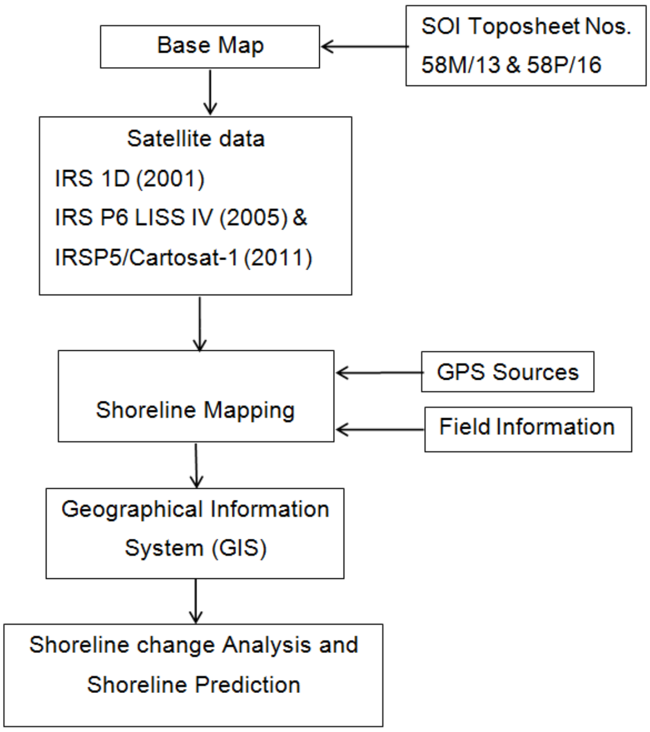

Figure 2 : Flowchart of Methodology

B. Shoreline Changes

Shoreline or coastline, the boundary between land and sea keeps changing its position and shape continuously due to dynamic environmental conditions. The change in shoreline is mainly associated with waves, tides, winds, periodic storms, littoral currents, sea level change, the geomorphic processes of erosion and accretion and human activities. Shoreline also depicts the recent formations and destructions that have happened along the shore. The beach profile is an important, in that it can be viewed as an effective natural mechanism, which causes waves to break and dissipate their energy. A wave changes the coastline morphology and forms the distinctive coastal landforms. Monitoring changes in shoreline help to identify the nature and processes that caused these changes in any specific area, to assess the natural and human impact and to plan management strategies. In this regard, remote sensing data could be used effectively to monitor the changes along the coastal zone, including shoreline with reasonable accuracy.

III. RESULT AND DISCUSSION

A. Shoreline Mapping

In the present study, extract and demarcate the shoreline from Survey of India Topographic map (1973) and different periods of satellite data in the year 2000. 2005 and 2011. The total length of the coastline is 20km. Shoreline accretion noticed in the north from Kalapettai to Pillaichavadi and from Veerampatnam to the southern part of the study area as shown in Fig.V.2 in the year 2000. The remaining areas of Bommayapalayam, Periya Mudaliyarchavadi, Chinna Mudaliyarchavadi, Kottakuppam, Muttaiyalpettai is noticed at erosion. During the period of 2005, shoreline accretion noticed from Kalapettai to Pillaichavadi whereas recession noticed from Pillaichavadi to Thengathittu, and the remaining areas are noticed accretion as shown in Fig.5.4. Accretion activities are noticed in the northern part of the study area from Kalapettai to Pillaichavadi, and the remaining areas are noticed at recession in the year 2011 (Fig.V.4).

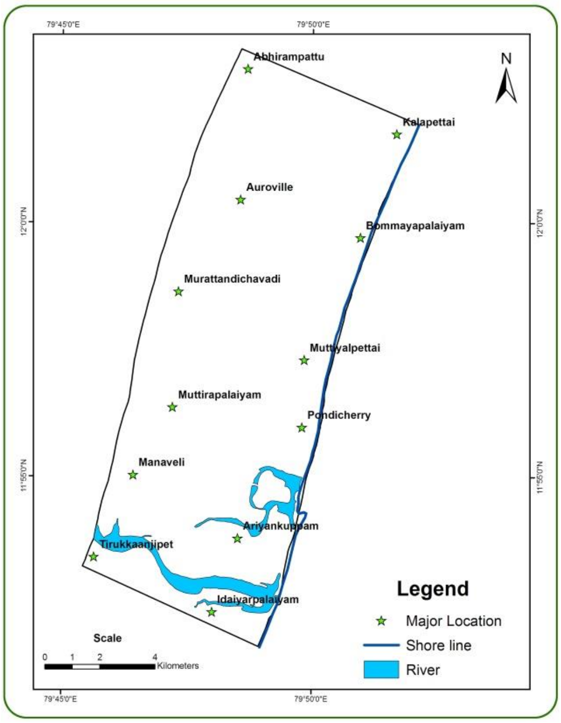

Figure 3 : Shoreline Map of 1973

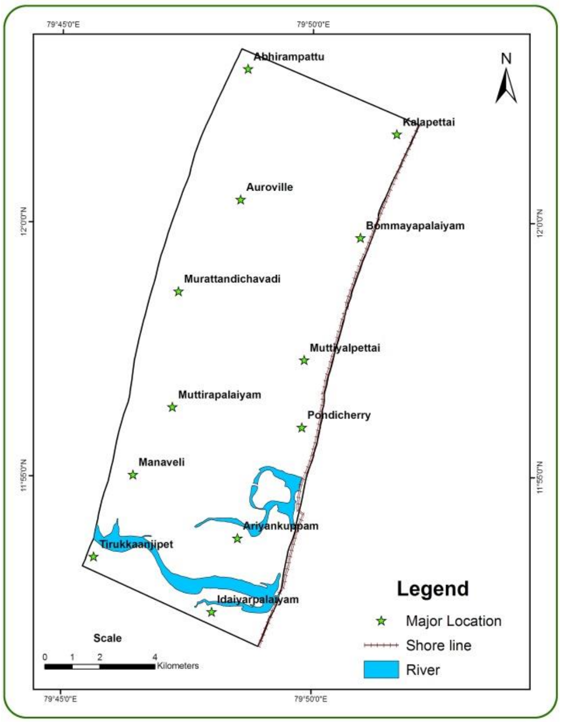

Figure 4 : Shoreline Map of 2000

B. Shoreline Change Analysis

The shoreline is one of the important dynamic coastal features where the land, air and sea meet. In any open coast, when man-made structures such as harbor or breakwaters interfere with the littoral current shoreline changes drastically. In India, Chauhan and Nayak (1995) have studied the shoreline changes using the satellite data along the Indian coast. During the low tide condition, maximum land is exposed and even low water line/land water boundary and high water line are distinctly visible. This enables better mapping of the shoreline. In this study, the shoreline positions and changes in the last 38 years and periodical changes during 1973 to 2011 reveal that the shoreline positions of either accretion or recession (Plate 3). The demarcation and areal extent of the sites of erosion and accretion are queried and estimated through Arc GIS software. The shoreline change status for the periods of 1973, 2000, 2005, 2011and overall period of 1973 - 2011 was analyzed in the study area. The study area has a shoreline length of 20 km.

Shoreline change analysis has done both map overlay techniques and transect wise identified the erosion and accretion activities in the study area. The map overlay analysis techniques in GIS for the period of 1973 - 2000, 2000 - 2005, 2005 - 2011 and the overall study period of 1973 - 2011. By using statistical methods, the study area has equally divided into 80 transect lines, and each transects have 250m length of the coastline. The analysis results are discussed in transects wise and location specific Shoreline positions are often defined from various sources (e.g. topographic surveys, coastal monument, and beach profiles and aerial photographs) each with its own measurement uncertainty. Several methods are available for calculating the shoreline position namely, End Point Rate (EPR), Average of Rates (AOR), Linear Regression (LR), Minimum Description Length, Ordinary Least Squares and jack-knifing are being widely used to estimate and forecast the rate of change in shoreline. However, they are always subjected to uncertainty because of inherent errors and deficiencies in the model used to evaluate the historical shoreline position, but apply the only one method in used shoreline changes that model is end point rate (EPR). The EPR method uses only two data points to delineate a change rate - the earliest and most-recent shoreline positions. Calculations of accurate shoreline change rates are frequently employed to summarize historical shoreline movements and to predict the future shoreline positions through different modeling procedures (Li et al. 2001; Appeaning Addo et al. 2008). The accuracy of shoreline change rate estimation reflects actual changes and prediction of future changes depends on several factors, such as the accuracy in shoreline position data, variability of the shoreline movement, number of measured shoreline data points (Kumar et al. 2010b), total time span of the shoreline data acquisition (Douglas et al. 1998), temporal and spatial bias in the estimation of shoreline rate-of-change statistics (Eliot and Clarke 1989), and the method used to calculate the rate (Dolan et al. 1991). In addition, causes for variation in rate of change include geomorphic features such as inlets, wave energy, engineering changes, etc. (Douglas and Crowell 2000).

C. Shoreline Changes During 1973 and 2000

During the period of 1973 and 2000, the accretion activities are noticed in the north and southern part of the study area as shown in Fig.V.5. Accretions are noticed in the north from Kalapettai to Pillaichavadi and Veerampattinam to Pudukuppam in the southern part of the study area. Remaining areas are noticed as shoreline erosion from Bommayarpalayam in the north to Veerampattinam in the south. The maximum amount of recession was noticed at Ariyankuppam river mouth and Thengathittu in the southern part of the study area.

To measure the amount of shoreline change, the shoreline position from SOI toposheet of 1973 has been chosen as a baseline or zero (0) position. Concerning this baseline, advance of the shoreline is considered as a positive value, while retreat as a negative value. The baseline distance of shoreline from 1973 to 2000 is shown in FigV.6 indicates that both the shoreline advance and retreat are noticed. The rate of change in shoreline position is calculated by the end point rate (EPR) method. It is calculated by dividing the distance of shoreline changes by the time elapsed between the earliest image and the most-recent shoreline. Thus, the shoreline erosion and accretion are indicated by negative and positive values respectively.

The advance's activities are noticed from transect number 1 to 21 in the south and 66 to 80 in the northern part of the study area. The maximum extent of accretion from baseline noticed at transaction number 21 (111.02m nearby Ariyankuppam river) in the southern part and the minimum was noticed at 79 (1.33m Kalapettai). The average amount of accretion was 40.44m. During this period, neither erosion nor accretion was noticed in the transect number 80. However, the minimum and maximum amount of erosion was noticed in the southern part of the study area at transect no. 19 (0.60m) and 24 (129.12m) respectively. No erosion activities are noticed in the south and northern part of the study area. Overall, accretion activities are dominant in the south than the northern part of the study area. The average distance of recession activities are noticed at 49.03m.

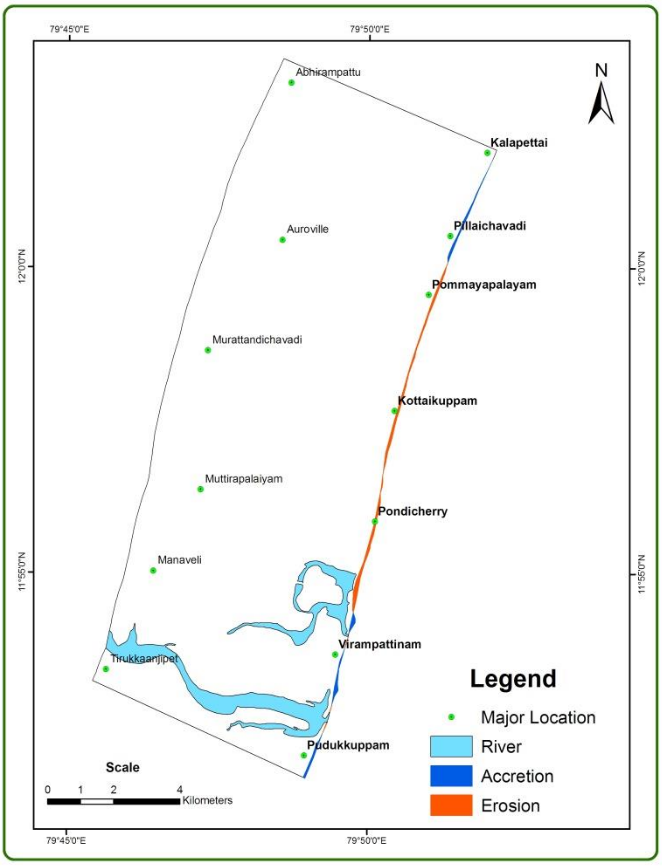

Figure 5 : Shoreline Changes during 1973 – 2000

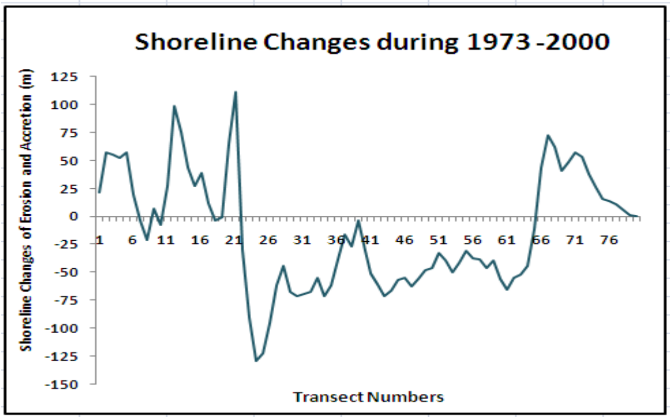

Figure 6 : Transect Number wise Shoreline Changes during 1973 – 2000

D. Shoreline Changes During 2000 and 2005

During this period, advances activities are noticed at northern part of the study area from Kalapettai to Chinna Kalapettai as shown in Fig. V.6. From Chinna Kalapettai to Secretariat, erosion was dominant and after that both the actions are noticed in less significant amount. Similarly, Thengathittu to Pudukuppam, erosion activities are noticed and of which predominantly noticed at Veerampattinam. The accretion activities are noticed and their areal extent was 0.26km2 respectively. The minimum and maximum distance of accretion was noticed at near Bommayarpalayam and Ariyankuppam river mouth noticed at 0.94m and 144.99m respectively. The lowest and highest distance of erosion was noticed at Bommayarpalayam (-0.05m) and Veerampattinam (-87.19m) in the study area.

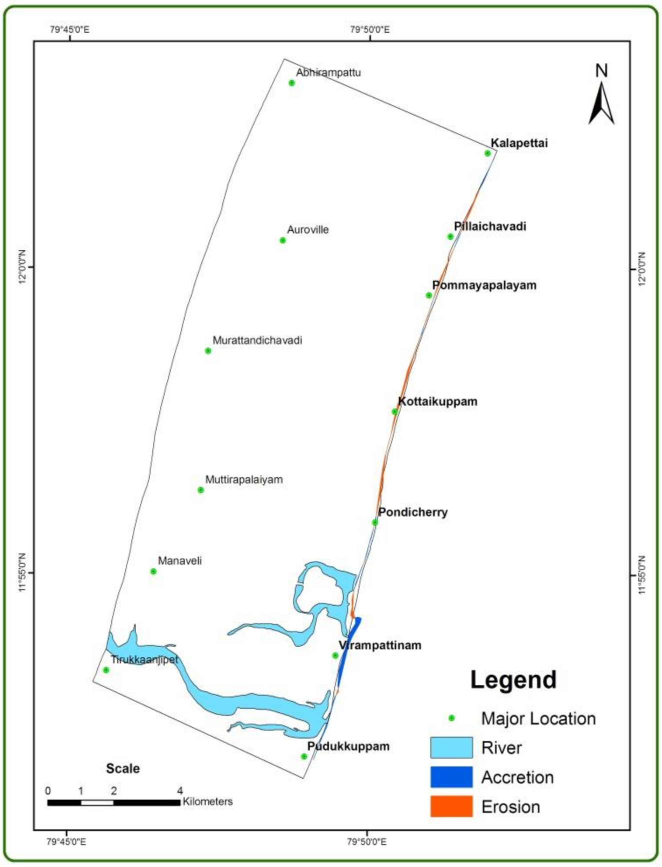

Figure 7 : Shoreline Changes during 2000 and 2005

The accretion activities are noticed from 2000 to 2005 in the study area of which north is the lowest and south is the highest as shown in Fig V.7. The minimum amount of accretion noticed at transect number 33 is nearby Secretariat (0.22m) in the middle part and the maximum noticed at 21 nearby Ariyankuppam river mouth (153.16) in the southern part of the study area. The average accretion activities are noticed at 37m distance during this period. Similarly, the minimum and maximum amount of erosion noticed at transect number 60 and 22 is nearby Bommayarpalayam (-0.02m) in the northern part and Ariyankuppam river mouth (-50.67m) in the southern part of the study area. The average erosion activities are noticed at -21.67m distance during this period. Transect numbers 1, 2, 3 in the south and 79, 80 in the northern part are noticed no significant changes of shoreline. Compared to previous period, higher amount of accretion was noticed in the northern part during this short span of time. Overall, erosion actions are dominant than advances during this period.

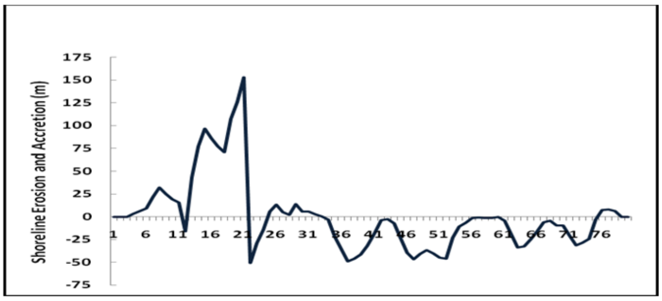

Figure 8 : Transect Number wise Shoreline Changes during 2000 and 2005

E. Shoreline Changes During 2005 And 2011

During the period of 2005 and 2011 erosion and accretion map (Fig. V.9) shows that both the shoreline changes are noticed. However, erosion activities are dominant than accretion throughout the coastline of the study area. The maximum amount of erosion was noticed at Tandiriyaarkuppam in the central part of the study area. Compared to previous periods, southern part of the study area is noticed at erosion than accretion. However, both the changes of accretion and erosion were noticed during this period.

Fig. V.10 shows that transect wise baseline distance from 2005 to 2011. Erosion activities are dominantly noticed in the south than the northern part of the study area. However, erosion was noticed in the central and northern part as selected locations. The central and northern part of the study area has noticed accretion activities are dominant than erosion. The minimum and maximum amount of accretion was noticed at transaction number 33 (Secretariat) is 0.39m and 89.26m at transaction number 52 (Tandiriyaarkuppam) respectively. The average amount of accretion is noticed during this period is 21.22m. Similarly, the minimum amount of erosion was noticed at transaction number 18 (in between Ariyankuppam River and Veerampattinam) is -0.62m and maximum was -96.01m at transaction number 21 nearby Ariyankuppam river mouth. The average amount of erosion is noticed during this period is -24.34m. Compared to previous periods of

1973 - 2000, 2000 - 2005 accretion activities are dominant in the central to northern part of the study area.

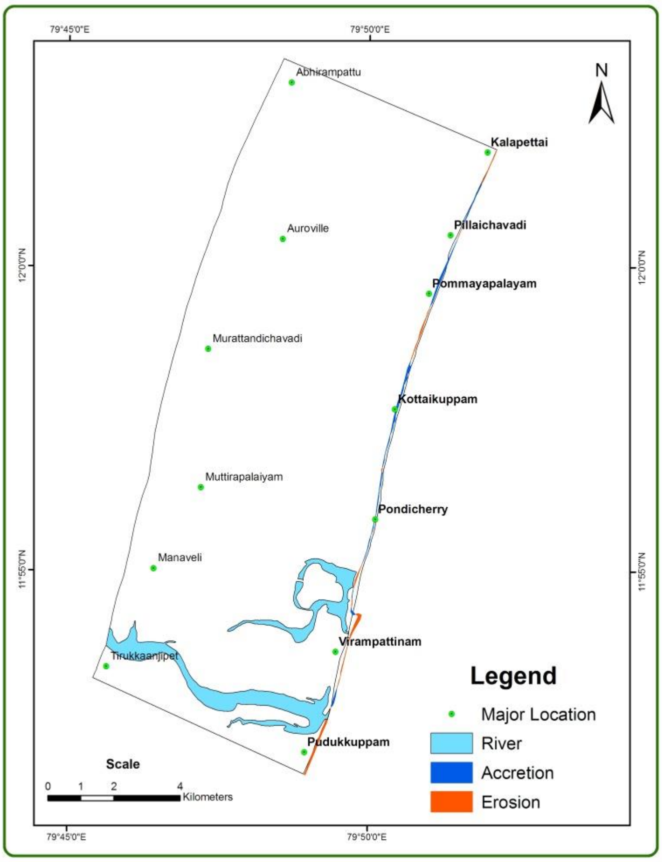

Figure 9 : Shoreline Changes during 2005 and 2011

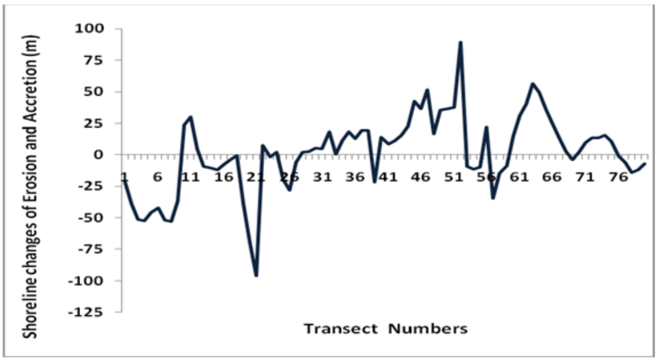

Figure 10 : Transect Number wise Shoreline Changes during 2005 and 2011

F. Shoreline Changes During 1973 And 2011

Overall the study period of 1973 to 2011 shows that, accretion activities are noticed in the north from Kalapettai to Bommayarpalayam and river mouths of Ariyankuppam to Chunnambar in the southern part of the study area as shown in Fig. 5.12. The maximum amount of erosion and accretion noticed at Thengathittu and Veerampattinam in the southern part of the study area. Overall, recession was dominant than the advances of the shoreline during the study period.

Transect wise baseline distance from 1973 to 2011 shown in Fig. V.11. Shoreline changes of accretion and erosion activities are noticed in the south in which accretion is dominant than erosion in the study area. The maximum amount of accretion and erosion was noticed at transect number 16 is 117.08m and 25 is 136.15m. However, erosion was noticed in the middle of the study area and northern part as selected locations. The northern part of the study area has noticed accretion activities are dominant than erosion. The minimum (0.78m) and maximum amount (79.07m) of accretion was noticed at transaction number 65 and 67 in the north. The average amount of accretion is noticed during this period was 21.22m. Similarly, the minimum amount of erosion (-0.62m) was noticed at transaction number 18 (in between Ariyankuppam river and Veerampattinam) and maximum (-96.01m) at transaction number 21 located nearby Ariyankuppam river mouth. During this period, the average amount of erosion was noticed at -24.34m. Compared to previous periods of 1973 - 2000, 2000 - 2005 accretion activities are dominant in the central to northern part of the study area.

Different year periods of shorelines of 1973, 2000, 2005 and 2011are overlay with satellite data as shown in Fig. V.13. From 1973 to 2000 shows that accretion has dominant in the south and northern part of the study area and the central part have erosion dominant. However, it has reversed in the subsequent period of 2000 to 2005. During this period, erosion alone noticed in the north and central part of the study area. The maximum amount of accretion was noticed at southern part of the study area. From 2005 to 2011, accretion activities are noticed in the southern part as less significant amount compared to previous periods. Similarly, higher amount of accretion was noticed in the central and northern part of the study area. Compared to previous periods erosion alone noticed in the central as well as northern part of the area. The study period of past four decades shows that, both erosion and accretion activities are equally noticed and it is similar to 1973 - 2000.

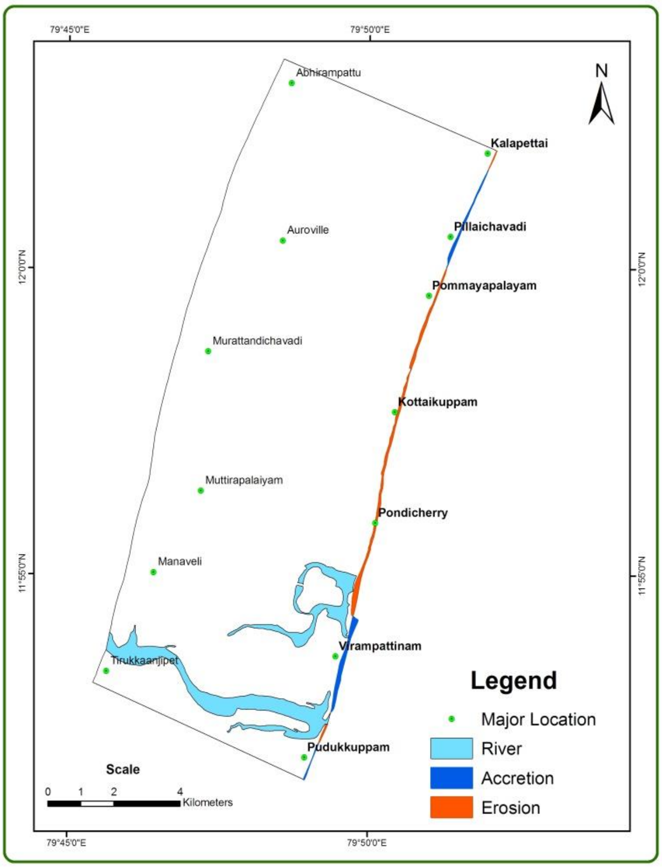

Figure 11 : Shoreline Changes during 1973 and 2011

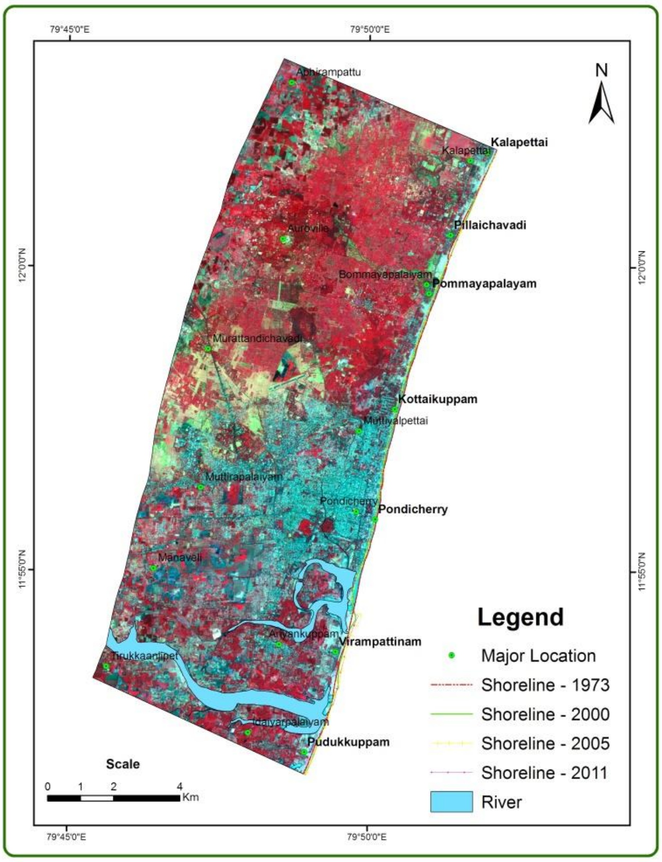

Figure 13 : Shoreline Changes during 1973, 2000, 2005 and 2011

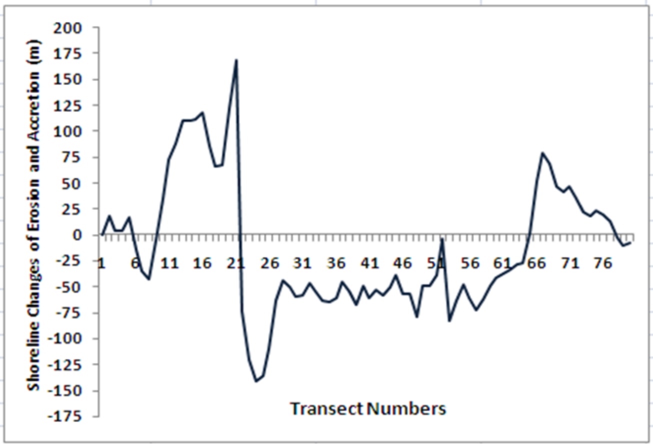

Figure 12 : Shoreline Changes during 1973 and 2011

G. Prediction Of Future

A. Shoreline Positions

Predictions of future shoreline positions were made by the study area using current rates of change and the end point rate (EPR) method are presented in Table VI.1 The future predicted shoreline positions exhibit accretion noticed at southern part of the study area vide transect nos. 1 to 5 and 10 to 21. Erosion noticed the remaining transects numbers of 6 to 9 in the south and 22 to 64 in the middle and northern parts of the study area. Similarly, shoreline changes are noticed the transect nos. 65 to 77 (accretion) and 78 to 80 (erosion) in the northern part of the study area. The 10 year shoreline prediction of accretion and erosion is 14.55m and -14.37m respectively.

Table VI.1 Transects wise Future Shoreline Position

Transect Number	Shoreline Changes of Erosion and Accretion (1973 - 2011)	Shoreline Prediction for 10 Years (m)	Shoreline Prediction for 25 Years (m)	Shoreline Prediction for 50 Years (m)
1	0.00	0	0	0
2	18.10	4.76	3.13	4.12
3	4.22	1.11	0.73	0.96
4	3.25	0.86	0.56	0.74
5	17.14	4.51	2.97	3.90
6	-14.06	-3.70	-2.43	-3.20
7	-34.45	-9.07	-5.96	-7.85
8	-42.67	-11.23	-7.39	-9.72
9	-4.75	-1.25	-0.82	-1.08
10	34.53	9.09	5.98	7.86
11	73.02	19.22	12.64	16.64
12	87.72	23.08	15.19	19.98
13	109.86	28.91	19.02	25.03
14	110.12	28.98	19.07	25.09
15	111.42	29.32	19.29	25.38
16	117.08	30.81	20.27	26.67
17	85.63	22.53	14.83	19.51
18	66.24	17.43	11.47	15.09
19	67.81	17.84	11.74	15.45
20	121.45	31.96	21.03	27.67
21	168.17	44.26	29.12	38.31
22	-73.60	-19.37	-12.74	-16.77
23	-120.87	-31.81	-20.93	-27.53
24	-141.15	-37.15	-24.44	-32.16
25	-136.16	-35.83	-23.57	-31.02
26	-110.11	-28.98	-19.06	-25.08
27	-62.88	-16.55	-10.89	-14.32
28	-44.60	-11.74	-7.72	-10.16
29	-50.67	-13.33	-8.77	-11.54
30	-60.17	-15.83	-10.42	-13.71
31	-58.45	-15.38	-10.12	-13.31
32	-46.60	-12.26	-8.07	-10.62
33	-54.55	-14.36	-9.44	-12.43
34	-63.09	-16.60	-10.92	-14.37
35	-65.02	-17.11	-11.26	-14.81
36	-60.60	-15.95	-10.49	-13.80
37	-45.66	-12.02	-7.91	-10.40
38	-53.94	-14.19	-9.34	-12.29
39	-67.03	-17.64	-11.60	-15.27
40	-49.35	-12.99	-8.54	-11.24
41	-60.32	-15.87	-10.44	-13.74
42	-52.74	-13.88	-9.13	-12.01
43	-58.77	-15.47	-10.17	-13.39
44	-50.83	-13.38	-8.80	-11.58
45	-38.32	-10.08	-6.63	-8.73
46	-57.60	-15.16	-9.97	-13.12
47	-57.06	-15.02	-9.88	-13.00
48	-79.30	-20.87	-13.73	-18.07
49	-49.33	-12.98	-8.54	-11.24
50	-49.87	-13.12	-8.63	-11.36
51	-39.50	-10.40	-6.84	-9.00
52	-4.37	-1.15	-0.76	-1.00
53	-82.37	-21.68	-14.26	-18.76
54	-64.04	-16.85	-11.09	-14.59
55	-47.35	-12.46	-8.20	-10.79
56	-60.62	-15.95	-10.49	-13.81
57	-72.08	-18.97	-12.48	-16.42
58	-62.10	-16.34	-10.75	-14.15
59	-49.72	-13.08	-8.61	-11.33
60	-41.29	-10.87	-7.15	-9.41
61	-38.13	-10.03	-6.60	-8.69
62	-33.91	-8.92	-5.87	-7.72
63	-28.71	-7.56	-4.97	-6.54
64	-26.96	-7.09	-4.67	-6.14
65	0.78	0.20	0.13	0.18
66	52.23	13.74	9.04	11.90
67	79.08	20.81	13.69	18.01
68	68.53	18.03	11.86	15.61
69	46.01	12.11	7.97	10.48
70	40.74	10.72	7.05	9.28
71	45.96	12.10	7.96	10.47
72	35.41	9.32	6.13	8.07
73	22.36	5.88	3.87	5.09
74	17.57	4.62	3.04	4.00
75	23.14	6.09	4.01	5.27
76	19.36	5.09	3.35	4.41
77	12.60	3.31	2.18	2.87
78	-2.37	-0.62	-0.41	-0.54
79	-10.59	-2.79	-1.83	-2.41
80	-7.30	-1.92	-1.26	-1.66

IV. CONCLUSION

The integrated approach using Topographic map, Remote Sensing data and GIS illustrates that shoreline changes in the study area. Both natural and anthropogenic processes active along the coast modify the shoreline configuration. During the period of nearly three decades (1973 to 2000), both erosion and accretion activities are noticed whereas erosion was the dominant. The short period of 2000 to 2005, the erosion activities are dominant than accretion compared to previous periods. From 2005 to 2011, accretion activities are dominant than erosion. Overall, the study period of 1973 to 2011, the study area experienced more erosion than accretion due to both natural and man-induced activities. The future shoreline positions exhibit possibility that the above average erosion and accretion of -14.37m and 14.55m for the 10 year is expected.

V. REFERENCES

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