Original Research Paper Geology

COASTAL GEOMORPHOLOGICAL AND SHORELINE CHANGE ANALYSIS OF RAMNATHAPURAM DISTRICT TAMILNADU USING REMOTE SENSING AND GIS TECHNIQUES

S.Venkateswaran	Department of Geology, Periyar University, Salem-11, Tamil Nadu,India - Corresponding author
G.Panneer Selvam	Department of Geology, Periyar University, Salem-11, Tamil Nadu,India
M.Vijay Prabhu	Department of Geology, Periyar University, Salem-11, Tamil Nadu,India
G.Prithiviraj	Department of Geology, Periyar University, Salem-11, Tamil Nadu,India
R.Kannan	Department of Geology, Periyar University, Salem-11, Tamil Nadu,India

ABSTRACT Shoreline changes are important linear feature on the Earth surface and it presents dynamic in nature. Coastal region has geomorphologically complex processes, such as erosion, accretion, landslides, subsidence and tidal inundation hazard. Shoreline changes are considered a valuable task for coastal monitoring and assessment. Coastal vulnerability is defined as the occurrence of a phenomenon, which has the potential for causing damage to or loss of buildings under natural ecosystems and the other infrastructure man made. The assessment of the coastal erosion hazard and mitigation is an estimation of a coastal area susceptible to erosion, based on a number of factors such as shoreline changes, geomorphology, human impact on coast etc. Many researchers have successfully investigated long-term shoreline changes and geomorphological changes in the coastal landforms based on remote sensing and GIS techniques. The present study is aimed to investigate the coastal changes based on two parameters namely; geomorphological changes, Shoreline changes over the years, rate of erosion and accretion, using remote sensing and GIS techniques.

KEYWORDS : Coastal morphology, Coastal vulnerability index, Risk assessment, Remote sensing, Shoreline changes and Geographic Information System.

Introduction

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. Coastal zones are facing intensified natural and anthropogenic disturbances including sea level rise, coastal erosion, over exploitation of resources among others. Over 70% of the world's beaches are experiencing coastal erosion and this presents a serious hazard to many coastal regions (Appeaning Addo et al., 2008). According to Zhang (2010), awareness of the quality of global coastal ecosystems being adversely impacted by multiple driving forces has accelerated efforts to assess, monitor and mitigate coastal stressors. Monitoring temporal spatial changes of coastal environments can help understand among others, the spatial distribution of erosion hazards, predicting their development trend and supporting the mechanism research on coastal erosion and its countermeasures. The shoreline, which is defined as the position of the land water interface at one instant in time (Gens, 2010) is a highly dynamic feature and is an indicator for coastal erosion and accretion. The processes of erosion and accretion affect human life, cultivation and natural resources along the coast. Rapid shoreline changes can create catastrophic social and economic problems along populated strands. Design of viable land-use and protection strategies to reduce potential loss is necessary and this requires comprehension of regional shoreline dynamics (Blodget et al., 1991; Chu et al., 2006).

Many researchers have successfully investigated long-term shoreline changes and morphological changes in the coastal landforms based on remote sensing and GIS techniques (Meijerink 1971; Nayak and Sahai 1985; Prabhakar Rao et.al. 1985; Shaikh et.al. 1989; Vinodkumar et. al. 1994; Capobiance et. al. 1999; Loveson et.al. 1990; Chandrasekar et. al. 2002; Amaro et. al. 2002 a,b; Vital 2003a, Vital et. al. 2003b; Rajamanikam 2006). They have been described the correlation between the rates of shoreline erosion to the heavy mineral groups and grain sizes of the beach sediment. Chockalingam (1993) have studied the impact of shoreline changes in Nile delta using the combination of remote sensing data near shore bathymetric surveys, heavy minerals and grain size.

Remote sensing techniques provide a synoptic vision of the Earth that is not possible to obtain other than by exhaustive and expensive field evaluations. Data from remote sensors allow analysis of a region with sufficient accuracy in an efficient, rapid and low cost way (Berlanga-Robles and Ruiz-Luna, 2002). It also helps in analysing areas that are poorly accessible or rapidly changing (Chu et al., 2006). The use of remote sensing data is therefore increasingly becoming a more effective option for monitoring shorelines. Over the years, geomorphologists, oceanographers and geologist have developed interpretation keys for mapping coastline geomorphic features using aerial photographs; however, few studies of this type have used images generated by remote sensing orbital instruments (Kawakubo, 2011). Though the use of aerial photographs tends to be effective in this case, the frequency of acquisition, cost and coverage presents a challenge (Appeaning Addo et. al., 2008). Furthermore, the spectral range of these sources is minimal and may introduce errors in shoreline interpretation (Alesheikh et al., 2007).

On the other hand, multispectral remote sensing satellites provide digital imagery in various spectral bands, including the near infrared where the land water interface is well defined. Furthermore this approach has advantages less time consuming, inexpensive to implement, large ground coverage, and the capability for repeat data acquisition and monitoring (Van and Bihn, 2008). The principal limitation of satellite images is arguably their low spatial resolution when compared to photographs taken from aircraft (Kawakubo, 2011).

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 (Kalaranjini 2016). The studied identified and assessed the impact of shorelines changes on Victoria Island in Eti-Osa Local Government Area, Lagos State, Nigeria. Data were collected through the instrumentality of structured questionnaires Michael Ajide Oyinloye et al., (2016).

The research deals with a combination of the Digital Shoreline Analysis System (DSAS) and remote sensing, studying historical mangrove shoreline changes and mangrove zoning in the Giao Thuy coastal area of the Nam Dinh province,Vietnam. The results show an over-all mangrove area increase of 2,487 hectares during the years 2005-2014. This dynamics results from both degradation and increase of the mangroves. The calculated degradation rate is 1.41m yr-1, and the growth rate is 1.26 m yr-1 on average (Nguyen An Thinh 2017). The presents an application of RS (remote sensing) and GIS (Geographic Information System) to analyze the spatial changes as well as quantify the shoreline change of Peat Soil Beach in Bengkalis Island, Riau Province, Indonesia. The area of Bengkalis Island is about 900 km^2, of which 665 km is covered by peat more than 1 m thick. Landsat satellite images were used with a combination of histogram thresholding and band ratio method for shoreline change detection for last 26 years from 1988 to 2014 Sigit Sutikno et al (2017).

Study Area

Ramanathapuram is one of the coastal districts bounded on the north by Sivagangai and Pudukottai districts, on the east and south by the Bay of Bengal, and on the west by Thoothukudi and Virudhunagar districts. The district headquarters is located at Ramanathapuram. The district lies between 9° 05' and 9° 50' North Latitude and 78° 10' and 79° 27' East Longitude the study area detail shown in Fig.1. The general geographical information of the district is simple and flat. Vaigai river and Gundar river are flowing in the district and they will be dry during the summer season. The total geographical area of the district is 4,175 sq.km and has the total population of 11, 87,604 including 5, 83,376 males and 6, 04,228 females.

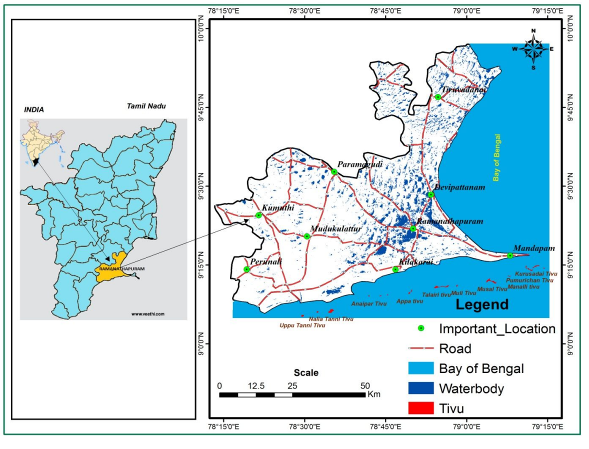


Fig.1 Location map of the Ramanathapuram district

Methodology

The study area base map was prepared using Survey of India toposheet on 1:50,000 scales. These toposheet were scanned and converted in GIS environment for geo referencing which is a process of stabilizing the relationship between map and the known real co-ordinates. Geo registration is a process of stabilizing the relationship between map, and the known real world coordinates. Re sampling in each case was performed using cubic interpolation technique to keep the spatial distortions at the minimum. Accuracy of the geo correction is tested by swiping one image of the other and confirmed by limited field check. The geo corrected data is through the ArcGIS environment for digitization of shoreline. High waterline shown in the topographic sheets 1973 and different periods of IRS satellite data in the year 2006 and 2016 are digitized as the line feature. Quantification of erosion/accretion rate is done by end point rate (EPR) method and digitization as a polygon features using Arc GIS.

RESULT AND DISCUSSION

Coastal geomorphological changes

Geomorphology is the science of studying the external landscape architecture of earth's crust, which stands as a testimony not only to the palaeo morphotectonic and morphodynamic activities but, for the present day geological processes as well. One of such commonly adopted scheme in India is proposed by Nayak (2002) which has used the scale of mapping as base to group the geomorphic forms in to the Level-I, Level-II and Level-III categories with increasing scale. Accordingly, the Level-I features include vegetated and non vegetated coastal areas, water bodies, shore land and other man made features whereas, the Level-II includes all major landforms in its descriptive sense like mangroves plantation, mudflats, sand, bays, lagoon, delta plain, back swamps, coastal dunes and ridges, etc. The Level-III specify the features at much higher scale like intertidal zone, high tide and low tide lines, spits, bar, tidal channel, dense and sparse vegetated areas, etc. For the present study author has largely used the descriptive terms which either depict the sediment nature or the style of geomorphic unit. The area comprises of an interesting assemblage of palaeo and neo coastal landforms which include alluvial plain, coastal plain, deltaic plain, eolian plain, flood plain, habitation mask, pediplain and upland etc. Geomorphology changes 2006 and 2016 shown in Table.1.

Table.1 Coastal Geomorphology Changes in 2006 to 2016

Geomorphology Change in 2006 to 2016						
S. No	Geomorphological class	Area (Km^2) in 2006	Area (%) n 2006	Area (Km^2) 2016	Area (%) 2016	Changes (%) n 2006 to 2016
1	Alluvial plain	2843.8	68.87	2343.8	56.79	-12.12
2	Coastal plain	640.47	15.51	1040.47	25.20	9.68
3	Deltaic plain	6.65	0.16	104.65	2.53	2.42
4	Eolian plain	157.25	3.81	157.25	3.81	0.00
5	Flood plain	81.51	1.97	83.51	2.02	0.05
6	Habitation mask	10.48	0.25	10.48	0.25	0.00
7	Pediplain	295.87	7.17	205.87	4.99	-2.18
8	Upland	93.09	2.25	183.09	4.43	2.18
Total Areas		4129.12	100.00	4129.12	100.00	

The alluvial plain has decreased from 2843.8 km^2 to 2343.8 km^2 it is almost -12% changes. The coastal plain has increased 640.47 km^2 to 1040.47 km^2 the change in 9% increased. The other feature some small change only occurred. The geomorphology map 2006 and 2016 shown in Fig.3 and Fig.4.

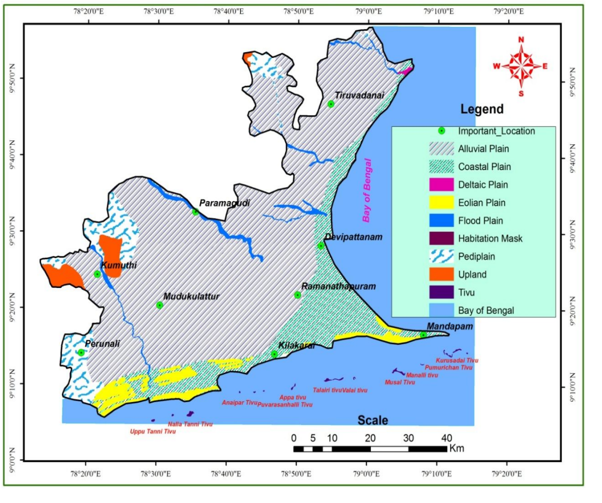


Fig.3 Geomorphology map of the Ramanathapuram district in the year of 2006

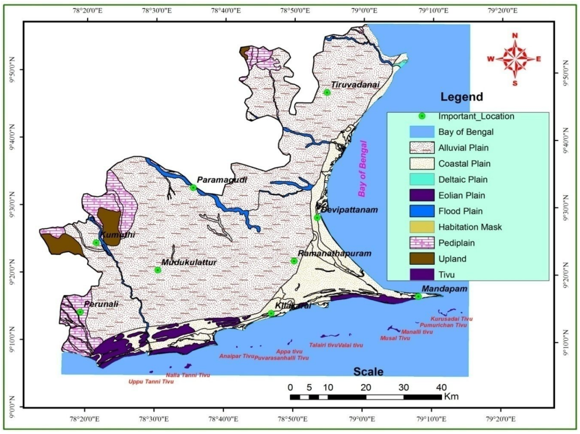


Fig.4 Geomorphology Map of the Ramanathapuram district in the year of 2016Shoreline extraction and delineation

Recent advancements in remote sensing and geographical information system (GIS) techniques have led to improvements in coastal Geo-morphological studies such as automatic and semiautomatic. The semi automatic techniques are attractive, due to their cost-effectiveness, time consuming etc. The dry wet/boundary which approximates the high waterline (HWL) was extracted using semiautomatic and manual methods. Automatic shoreline delineation is a complex process due to the presence of water saturated zone at the land water boundary Maiti, Bhattacharya AK (2009). In Arc Map, the extracted shorelines were overlaid on the satellite image. The high water line (HWL) was therefore adopted since it was relatively easy to distinguish it on all the images as a wet/dry line. The output vector however consisted of other water/land boundaries such as those of creeks and lagoons and could not be directly used for change detection. To extract the target sections, the extracted vector shoreline were overlaid on the colour composites and used as guide to digitize the target shoreline. In this present study, the exact land water boundary was obtained by using a nonlinear edge enhancement technique; these operations were applied to the 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.

Shoreline change analysis

From 1807 to 1927 all shoreline maps were generated through ground surveying, then aerial photographs played as only source for coastal mapping from 1927 to 1980 (Kumaravel. S et. al 2012). According to Howarth, (1981) remote sensing data can be used for environmental monitoring in the coastal region in over time. Dharanirajan. K (2006) has attempted to study the shoreline changes of South Andaman and its impacts on coastal geomorphology using Remote sensing and GIS. Remote sensing and geographical information system (GIS) have been widely used as another option than conventional method for monitoring shoreline position (Ryuet al., 2002; Yamano et al., 2006). Maizen et.al (1989) presented the coastal monitoring using visual interpretation of multi temporal images. Shoreline dynamic of lake Nasser was monitor by applied GIS and remote sensing technique (Mostafa and Soussa 2008). Marfai et.al., (2008) concluded multi temporal spatial data analysis considered good method regarding lack of homogeneous data source for long period. In this study, the shoreline positions and changes in the last 43 years and periodical changes during 1973 to 2016 reveal that the shoreline positions of either accretion or erosion. The demarcation and areal extent of the sites of erosion and accretion are queried and estimated through Arc GIS software. The shoreline position status for the periods of 1973, 2006, 2016 and overall period of 1973 - 2016 was analyzed in the study area Fig.5. The study area has a shoreline length of 271 km.

Shoreline Changes during 1973 and 2006

During the period of 1973 and 2006 shoreline changes are shown in Fig.6 the accretion activities are noticed at 3.11 km (1.53%) length of the coastline, and their areal extent was 3.69 km^2 respectively. The erosion was noticed at 22.35 km (11.01%) of the total coastline length over a period of 33 years and their areal coverage was 23.94km^2 during this period. The maximum extent of erosion was observed at Sattakonvalasai and maximum extent of accretion was observed at Mandapam with the length of 1619 and 568m the erosion and accretion Graphs 1 and 2. The accretion activities are increased from Chittirakottai to Mandapam, and it has reduced to Valinokkam (239.27m) and subsequently increased towards the north direction of the study area.

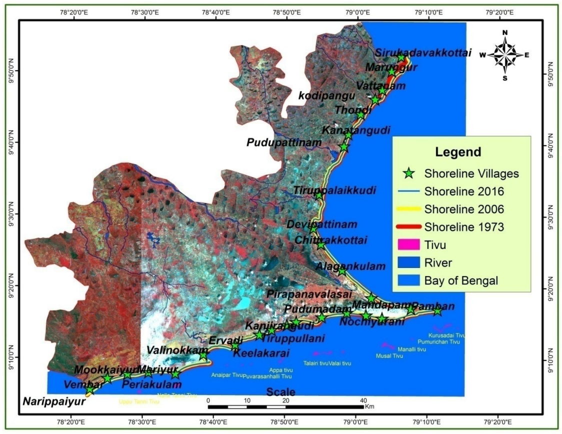


Fig.5 Shoreline Position Map of the Ramanathapuram district in the year of 1973, 2006 and 2016.

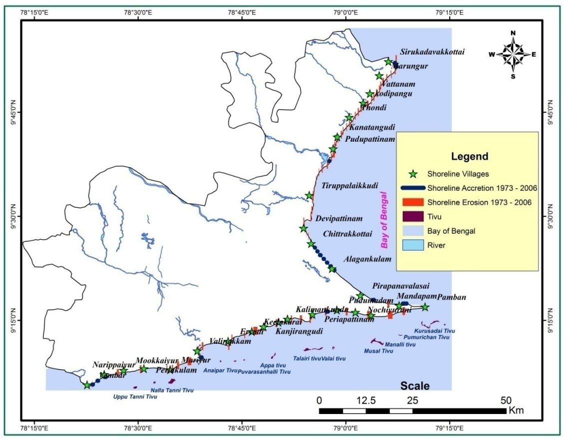
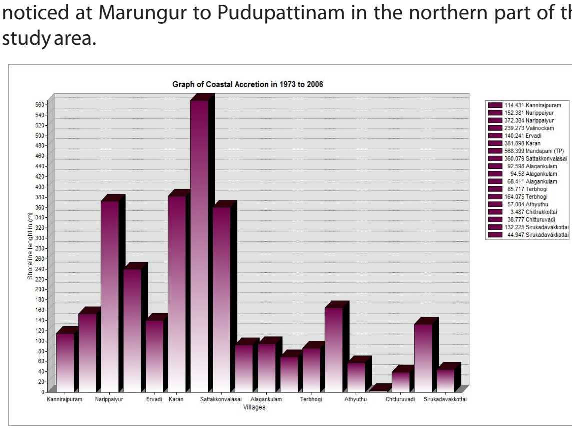
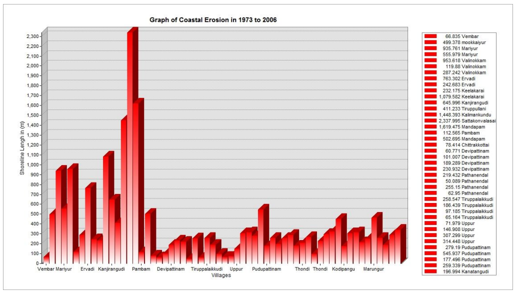


Fig.6 Shoreline change map of the of the Ramanathapuram district in the year 1973 – 2006

The average length of accretion was 172.82m. The erosion was high noticed at Marungur to Pudupattinam in the northern part of the study area.



Graph. 1 Coastal Accretion Distances during 1973 to 2006



Graph.2 Coastal Erosion Distances during 1973 to 2006

Shoreline Changes during 2006 and 2016

Shoreline observation during this decade is shown in Fig.7.The erosion and accretion was noticed in the entire coastline. The maximum length of erosion observed was 1329.75m noticed nearby the village of Mandapam in the center part of the study area. The length of erosion during 2006 and 2016 is shown in Graph.3. The lowest distance of erosion was noticed at Kandankudi 9.9m) and Uppur 16.63m). The maximum distance of accretion was noticed at Nochiyurani 1247.97m) in the centre art of the study area, the accretion Graph.4, the mean distance of accretion of 76.60m was measured during this period. More than the mean distance of erosion 252.13m) was noticed at Sattakonvalasai, Periyapattinam, and Keelakarai in the southern part of the study area. The shoreline erosion distance has alternate phases of increasing and decreasing, and the pattern was irregular during this period.

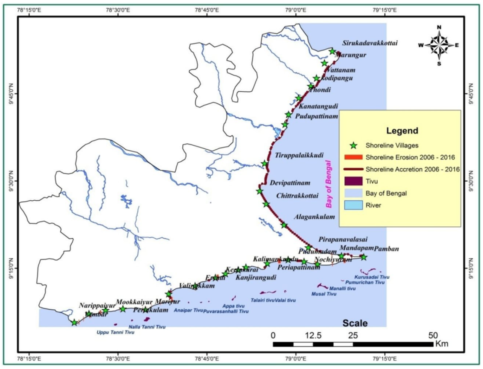
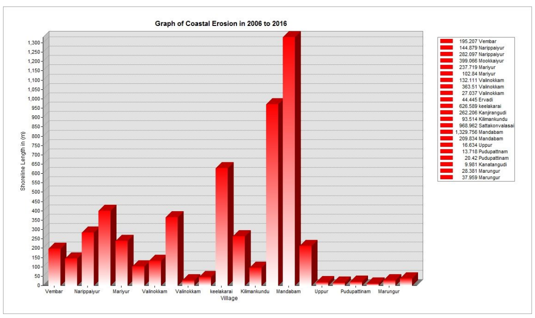
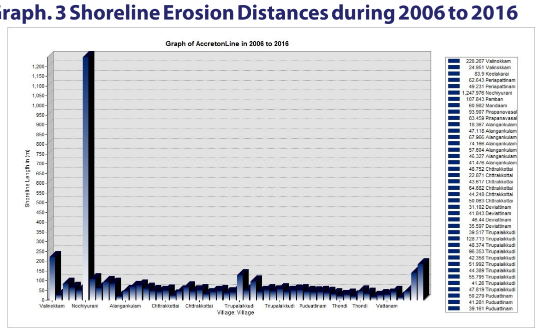


Fig.7 Shoreline changes during the year 2006 – 2016



Graph. 3 Shoreline Erosion Distances during 2006 to 2016



Graph.4 Shoreline Accretion Distances during 2006 to 2016

Shoreline Changes during 1973 and 2016

Between 1973 and 2016 shoreline erosion and accretion map (Fig. 8) shows that erosion activity was dominant than accretion in the study area. The data reveals that more than two third of the coastline length was noticed erosion and their areal extent was 23.94km^2. Erosion was noticed in the entire coastline except Sattakonvalasai, Mandapam, Kalimankundu, Keelakarai and Valinokkam Graph.5. The minimum was noticed at Sattakonvalasai (2337m) in the south. Shoreline changes due to accretion were noticed as less than one third of the coastline length (0.78km) and their areal coverage was 4.72km^2. The accretion activities are noticed at Alangulam, Piraanavalasai, and Mandapam Graph.6.

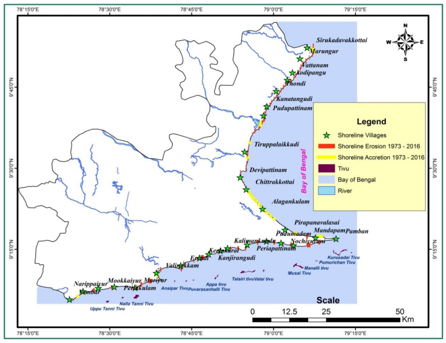
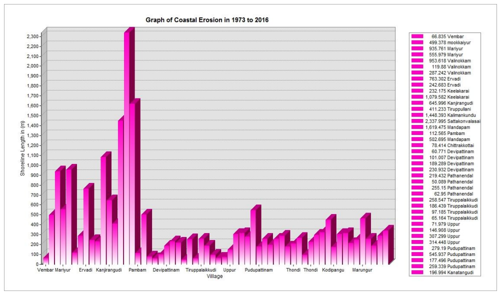
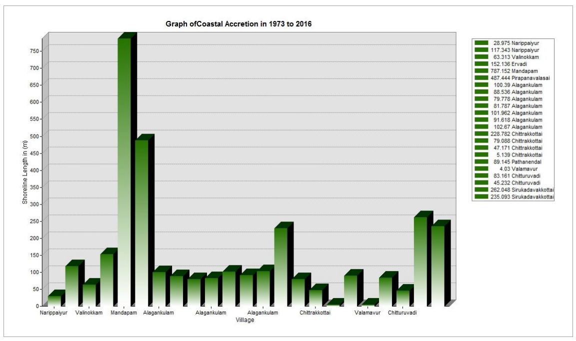


Fig.8 Shoreline changes during the year 1973 – 2016



Graph 5. Shoreline Changes of Erosion during 1973 to 2016



Graph.6 Shoreline Changes of Accretion during 1973 to 2016

Conclusion

A shoreline and geomorphology change is very valuable in regards to coastal hazard assessment. It is concluded that Remote sensing and GIS techniques is most effective tool to detection of shoreline. The geomorphology changes 2006 and 2016 the alluvial plain has decreased from 2843.8 km^2 to 2343.8 km^2 it is almost 12% changes. The coastal plain has increased 640.47 km^2 to 1040.47 km^2 the change in 9% increased. The other feature some small change only occurred. The shore line shifting or change landward or seaward caused erosion or accretion is studied by using multi-temporal satellite images of Resourcesate and LISS III images. The study has given an output stating that erosion or accretion is found in 1973 to 2006 erosion occurs in Sattankkonavalasai (2337.9m), Kalimankundu (1448.39m), Manadapam (1619.47m), Kelakkarai (1679m). Accretions Mandapam (568.39m), Naripaiyur (372m) Karan (381m), Sattankkonvalasai (360.7m). The year 2006 to 2016 the erosion occurs in Nochiyurani (1247.97m), Valinokkam (220m). Accretion Mandapam (1329.75m) Sattankonavalasai (968m), Kellakkarai (626m). The shoreline erosion and deposition changes calculated from 1973 to 2016 at Sattankonavalasai (2337.99m), Kalimankundu (1448.39m), Mandapam (1619.47m), Kilakkarai (1079.58m) and accretion at Mandapam (787.152m), Prapannavalasai (487.44m), Sittarakottai (228m) respectively. Overall, during the study periods, erosion activities are high compare to accretion in study area. However, erosion activities are not occurred in the southern side of the study area. Continuous monitoring of shoreline changes is very important need to the study area to understand changes taken place in the coast. Furthermore, studies that link land use patterns, hydrological data, human activities and other processes taking place in the coastal areas are recommended. It is concluded that remote sensing and GIS are useful tools for monitoring the shoreline changes in Ramanathapuram district.

Acknowledgement:
The authors thank people living around the Ramanathapuram district for their co-operation in the field studies. The second author is thankful to the Director of the State Mines and Geology for providing permission to carry out this research. The authors are also grateful to Professor and Head, Department of Geology, Periyar University, Salem for his kind support during the field work.

REFERENCES:

1. Alesheikh, A.A, Ghorbanali, A. and Nouri, N., (2007). Coastline Change Detection Using Remote Sensing. International Journal of Environmental Science and Technology, 4 (1), 61-66.
2. Amaro, A.C., Duesen, H. and Belchers, G. (2002 a) Slopes, boundary conditions, and the development of convexo-concave forms - some numerical experiments. Earth Surface Processes and Landforms, Vol. 12, pp. 17-30.
3. Amaro, A.C., Duesen, H. and Belchers, G. (2002 b) Modeling cliff development in South Wales: Savigear re-viewed. Z. Geomorph. N.F., Vol. 28, pp. 405-426
4. Appeaning Addo, K., Walkden, M., and Mills, J.P., (2008). Detection, Measurement and Prediction of Shoreline Recession in Accra, Ghana. Journal of Photogrammetry & Remote Sensing, 63, 543–558.
5. Berlanga-Robles, C. A. and Ruiz-Luna, A., (2002). Land Use Mapping and Change Detection in the Coastal Zone of Northwest Mexico Using Remote Sensing Techniques. Journal of Coastal Research, 18(3), 514-522.
6. Blodget, H.W., Taylor, P.T. and Roark, J.H., (1991). Shoreline Changes along the Rosetta-Nile Promontory: Monitoring with Satellite Observations. Marine Geology, 99, 67-77.
7. Capobianco, M., Devriend, H.J., Nicholls, R. J., Stive, M. J.(1999) Coastal Area Impact and Vulnerability Assessment: The point of view a morphodynamic modeler. Jour.Coastal Research., Vol.15, No.3, pp.701-716.
8. Chandrasekar,N., Anil Cherian, Rajamanickam,M. and Rajamanickam,G.V. (2002) Ilmenite and Magnetite ratio in the beaches between Kallar and Vembar Coast, Tamil Nadu : Implication on the accumulation of other heavy minerals, Jour. Ind. Assoc. Sed., Vol.22, No.1&2, pp.203-210.
9. Chockalingam M. (1993), Coastal geomorphological studies of the region subtended between Mandapam and Devipattinam, Tamilnadu, Thesis report, Tamil University, Tanjavur, 117p.
10. Chu, Z.X., Sun, X.G., Zhai, S.K. and Xu, K.H., (2006). Changing Patter of Accretion/Erosion of the Modern Yellow River (Huanghe) sub aerial delta, China: Based on Remote Sensing Images. International Journal of Marine Geology, Geochemistry and Geophysics, 227, 13-30.
11. Dharanirajan K, (2006), Coastal zone management of southern part of South Andaman Island using remote sensing and GIS, Institute for Ocean Management, Anna University.
12. Gens, R., (2010). Remote Sensing of Coastlines: Detection, Extraction and Monitoring. International Journal of Remote Sensing, 31(7), 1819-1836.
13. Howarth PJ, Wickware GM, (1981), Procedures for change detection using Landsat digital data. Int.J. Remote Sensing, 2 pp 277–291.
14. Kalaranjini V. S. Ramakrishnan S. S.(2016) Instantaneous Shoreline Demarcation and Categorization using Remote Sensing and GIS Techniques -A Case Study of Dynamic Nature of the Chennai Coast .International Journal of Engineering Research & Technology (IJERT),ISSN: 2278-0181.Vol. 5 Issue 03.
15. Kawakubo, F.S., Morato, R.G., Nader, R.S. and Luchiari, A., (2011). Mapping Changes in Coastline Geomorphic Features Using Landsat TM and ETM+ Imagery: Examples in South- eastern Brazil. International Journal of Remote Sensing, 32(9) 2547-2562.
16. Kumaravel S, Ramkumar T, Gurunanam B, Suresh M, (2012), Quantitative estimation of shoreline changes using remote sensing and GIS: A case study in the parts of Cuddalore district, East coast of Tamil Nadu, India, International journal of environmental sciences, 2(4).
17. Loveson, V.J., Rajamanickam,G.V. and Chandrasekar, N. (1990) Environmental impact of Micro deltas and swamps along the coast of Palk Bay, Tamil Nadu, India. In: Sea level Variation and its impact on coastal environment, (ed.)Rajamanickam, G.V., Tamil University Press, Thanjavur, pp.159-178.
18. Maiti, Bhattacharya AK (2009) "Shoreline change analysis and its application to prediction: A remote sensing and statistics based approach". Marine Geology 257: 11-23.
19. Mazian HI, Aziz I, Abdullah A, (1989), Preliminary evaluation of photogrammetric remote sensing approach in monitoring shoreline erosion. (The 10th Asian Conference on Remote Sensing Proceeding. November 1989, Kuala Lumpur).
20. Meijerink AMG (1971) Reconnaissance survey of the Quaternary Geology of the Cauvery delta. J Geological Society of India 12: 113–124 .
21. Michael Ajide Oyinloye,Gabriel Esan Ajayi, and Julius Adekunle Olanibi (2016) Assessment of Shoreline Changes on Victoria Island in Eti-Osa Local Government Area, Lagos State, Nigeria. Journal of Earth Sciences and Geotechnical Engineering, vol. 6, no.1, 2016, 47-62 ISSN: 1792-9040 (print), 1792-9660 (online) Scienpress Ltd, 2016.
22. Mostafa MM, Soussa HK, (2006), Monitoring of LakeNasser using remote sensing and GIS techniques. (ISPRS Mid-term Symposium Proceeding. May 2006, Enschede).
23. Muh Aris Marfai, Hussein Almohammad, Sudip Dey, Budi Susanto, Lorenz King, (2008), Coastal dynamic and shoreline mapping: multi-sources spatial data analysis in Semarang Indonesia, Environ Monit Assess, 142, pp 297–308.
24. Nayak S R (2002) Use of satellite data in coastal mapping [J]. Indian Cartographer, 5: 147-157
25. Nayak, S.R. and Sahai, B. (1985) Coastal geomorphology: a case study of the Gulf of Khambhat (Cambay). Int. Jour. Remote Sensing., Vol. 6, pp. 559-567.
26. Nguyen An Thinh and Luc Hens(2017) A Digital Shoreline Analysis System (DSAS) Applied on Mangrove Shoreline Changes along the Giao Thuy Coastal Area (Nam Dinh, Vietnam) During 2005-2014 . Vietnam Journal of Earth Sciences, 39(1), 87-96.
27. Prabhakar Rao, P., Nair, M., and Raju, D.V.(1985) Assessment of the role of Remote Sensing in monitoring shoreline changes, A case study of the Kerala Coast, Intl. Jour. Remote Sensing., Vol.6, No.3 & 4, pp.549-558.
28. Rajamanickam, M. (2006) Remote sensing and GIS applications on beach placer minerals evaluation along the coast between Kallar and Vember, unpublished Ph.D thesis, Tamil University.
29. Ryuet, (2002), waterline extraction from landsat TM data in tidal flat a case study in Gomso bay, Korea. Remote sensing of Enviroment , 83(3), pp 442-456.
30. Shaikh, M.G., Nayak, S. and Jambusaria, B.B. (1989) Effects of engineering Structures on the morphology of the Mahi estuary. In: Proc. National Seminar on Engineering Applications of Remote Sensing and Recent Advances, ISRS, Indore, pp.77-81.
31. Sigit Sutikno, Ari Sandhyavitri, Muhammad Haidar, and Koichi Yamamoto (2017) Shoreline Change Analysis of Peat Soil Beach in Bengkalis Island Based on GIS and RS International Journal of Engineering and Technology, Vol. 9, No. 3, pp223-238.
32. Van, T.T. and Binh, T.T., (2008). Shoreline Change Detection to Serve Sustainable Management of Coastal Zone in Cu Long Estuary. Proceedings of the International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences. Retrieved December 27, 2011 from http://wgrass.media.osaka-cu.ac.jp/gisideas08/viewpaper.php?id=247
33. Vinodkumar, K., Arup Palit, D., Chakraborti, A.K, Bhan, S.K., Chowdhury, B. and Sanyal,T.(1994) Change detection study of Islands in Hooghly Estuary using Multidata Satellite Images. Jour. Ind. Soc. Rem. Sensing., Vol. 22 , No.1, pp.1-7.
34. Vital, H. (2003 a) Applications of Remote Sensing for monitoring and evaluation of coastal morphodynamic on the north-eastern coast of Brazil. EOS Transactions, American Geophysical Union. ISSN 0096-394. pp. 67-89.
35. Vital, T.L., Isobe, M. Igarashi, H. Sasaki, T.O. and Horikawa, K. (2003 b) Discussion of Sand Bypassing Simulation Using Synthetic Longshore Transport Data; Second Series, CETA 82-4. U.S. Army Corps of Engineers, Waterways Experiment Station, Coastal Engineering research Centre, Vicksburg, Mississipi. pp. 56-67.
36. Yamano et al, (2006), Evaluation of various satellite sensors for waterline extraction in a coral reef environment: Majuro Atoll, Marshall Islands. Geomorphology, 82(3-4), pp 398-411.
37. Zhang, Y., (2010). Coastal Environmental Monitoring using Remotely Sensed Data and GIS Techniques in the Modern Yellow River Delta, China. Environmental Monitoring Assessment, DOI: 10.1007/s10661-010-1716-9