

Shoreline Change Monitoring in Nellore Coast at East Coast Andhra Pradesh District using Remote Sensing and GIS

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Abstract

The shoreline is one of the most important features on earth's surface. They are highly dynamic and ever changing. Changes are over time scales including minutes, hours, decades and Centuries. Spatial scales vary from local to regional to worldwide. Although change is continuously occurring, it doesn't occur in a constant manner. Many factors influence these changes including the type of shoreline (rocky, sandy), wave activity, tidal variations, storms and human impacts. The shoreline change study is necessary for updating the shoreline change maps and management of natural resources. Shorelines are the key element in coastal GIS and provide the most information on coastal landform dynamics. The frequently monitoring coast only to accesses variation of shoreline changes. In this paper investigate the shoreline changes of Nellore district in Andhra Pradesh coast, as well as find the quantity of the erosion and accretion rate. Using multi-temporal resolution satellite data (TM & LISS III, IV) and Geographic information system (GIS) for past 25 years' period i.e. from 1989 to 2015. Nellore having length of coast line is 167km for this study used. The resultant coastal maps were used to estimate the geomorphologic changes and shifting of the shoreline position. This integrated study is found useful for exploring accretion and erosion processes in the region. About 87.6km of coastline was found to be accreting nature with average of +1.40m/yr followed by 38.4km of coastal line eroding with average of -1.36m/yr and stable coastline of 41.4km was found. This study demonstrates that combined use of satellite imagery and statistical method such as linear regression for shoreline change analysis are helpful for erosion monitoring and preventive measure.

Keywords: ERDAS, LISS IV, Shoreline change, Erosion, Accretion, Linear Regression, DSAS

I. INTRODUCTION

The world's coastlines are dynamic. Even shorelines that are in equilibrium undergo advancement towards the Sea or recession towards the land which is very often due to Man's intervention through construction of structures as a part of different activities in coastal zone (Chen et al., 1998). The above said phenomena may also be due to nature. Either of the phenomena, like closing of river mouths and net coastal erosion poses a great challenge in its conservational and management (Kannan et al., 2013). Shoreline change is an issue of concern in coastal management. Shoreline is idealistically defined as the interface of land and water (Dolan et al., 1980), it is considered one of the most dynamic processes in the coastal area, beaches are among the most dynamic systems in nature, they show visible changes over hours, days, months and years. Coastline retreat has resulted in over 70% of the world's beaches experiencing coastal erosion (Anthony, 2005). Coastlines are dynamic in nature. Accurate mapping of the instantaneous coastline position has as a result been always associated with significant uncertainty (Crowell, 1999). Remote sensing data could be used effectively to monitor the changes along the coastal zone including shoreline with reasonable accuracy. Remote sensing data helps and replaces the conventional survey by its repetitive and less cost-effectiveness (Thieler et. al., 2009).

II. STUDY AREA

The State of Andhra Pradesh is strategically located in the Indian sub-continent. The length of Nellore coast line is 167km. It is located on the banks of the Penner River and is well known for its aquaculture and agricultural produce. Nellore is located at 14.43°N 79.97°E. Rainfall in Nellore occurs between the months of October and December due to the north-east monsoon. This period gives about 60% of the city's annual rainfall. Cyclones are common in the city during this period, causing floods.



Fig. 1: Study Area

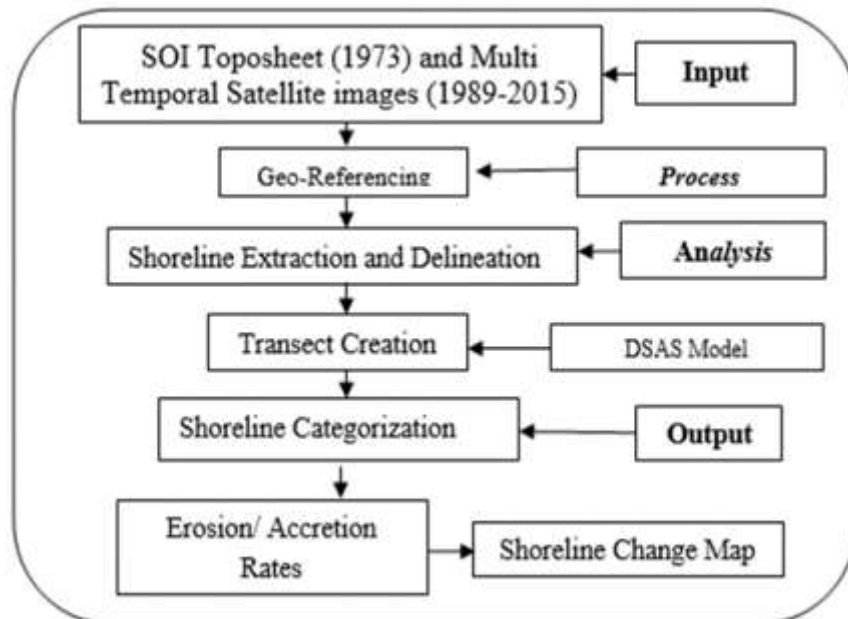
A. Materials

This study is carried out using Multi-Resolution satellite data of Landsat and IRS series such as, Landsat TM and IRS P6. These datasets were acquired on cloud free days of different dates over the chosen period (1989 to 2015). (As same resolution data is not available for the desired period) the multi temporal capabilities allow tracking of changes over time. Survey of India (Sol) toposheet (1:50,000 scale) are used for preparing base map.

Table - 1
Data Used

Sensor	Spatial Resolution	Year	Month	Source
Landsat 5TM	28.5	1989	November	USGS
IRS 1C - LISS III	23.5	1999	January	NRSC
IRS-P6 LISS III	23.5	2005	February	NRSC
IRS-P6 LISS III	23.5	2010	January	NRSC
IRS-P6 LISS IV	5.8	2012	March	NRSC
Landsat 8	28.5	2015	March	USGS

III. METHODOLOGY



B. Geo-Referencing

The SOI toposheets are converted into image format and are rectified in such a manner that the spatial co-ordinates correspond to its geographic co-ordinates will have less RMS error and then the toposheets are resembled using cubic convolution method. The projection applied in this study is Geographic Lat/Long with spheroid Everest and datum WGS 84. The digital image is then registered using the resembled output of the toposheet to its corresponding geographic coordination. Accuracy of the geometrically corrected image is checked by overlaying the rectified toposheet over the digital data and swiping horizontally and vertically to check for shift in the corresponding field. First base map are prepared on 1:25/50,000 scales from SOI toposheet. It has been

prepared on the basis of permanent control points such as transport network, forest boundary, tanks and settlements. The prepared base maps are overlaid and interpreted using the interpretation keys. The digital data are interpreted and classified by on-screen visual interpretation.

C. Shoreline Extraction and Delineation

Recent advancements in remote sensing and geographical information system (GIS) techniques have led to improvements in coastal Geomorphological studies such as automatic and semi-automatic. 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 semi-automatic and manual methods. Automatic shoreline delineation is a complex process due to the presence of water saturated zone at the land-water boundary [Maiti et al., 2009]. In ArcMap, 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 was 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.

D. Digital Shoreline Analysis System (DSAS)

The Digital Shoreline Analysis System (DSAS 4.2) developed by the USGS (Himmelstoss, 2009) was used for rate estimation. The DSAS uses measurement baseline method to calculate rate of change statistics for a time series of shorelines. The baseline is constructed to serve as the starting point for all transects cast by the DSAS application. The DSAS is computer software that computes the rate of change statistics from multiple historic shoreline positions residing in GIS (Thieler et al., 2005). DSAS generates transects that are cast perpendicular to the baseline at a user specified spacing alongshore. The transect shoreline intersections along this baseline are then used to calculate the rate-of-change statistics (Saranathan et al., 2011). Based on the settings DSAS, 1691 transects has been generated that are oriented perpendicular to the baseline at 100 m spacing and about 169.5 km along Nellore shoreline. DSAS 4.2 has 6 statistical approaches to compute changes. In this study, End Point Rate (EPR) and Linear Regression Rate (LRR) approaches were used. LRR uses all the available data to compute long term rate of changes. The EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. A LRR statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect (Thieler, et al., 2005 and Prabhakar Rao, et al., 1985).



Fig. 2: Shoreline with transect line

IV. RESULTS AND DISCUSSION

The shoreline change estimation was carried out for entire Nellore coast which is about 169 km in length. In this study, shorelines were extracted from satellite images for 1989, 1999, 2005, 2010, 2012 and 2015 by visually interpretation. The coastline rate of change was calculated using DSAS software and two different statistical techniques; End Point Rate (EPR) and Linear Regression Rate-of-Change (LRR). Base lines were constructed seaward and parallel to the general trend of the shorelines. Using DSAS transects were spaced 100m apart. Rates of shoreline change were calculated at each transect using linear regression. As a result of the analyses, the most significant changes were observed at Nellore Coast. Summary statistics for the rate of change is given in Table 2. and Table 3. Summarizes rates of shoreline classification Status and decadal changes, including both erosion and accretion.

Table - 2
Shoreline Status (1989-2015) along Nellore coast

Classification	Shoreline Status (1989-2015) Km
Total Coast	169
Erosion	38.4
Accretion	87.6
Stable Coast	41.4

The above table clearly shows the overall erosion and accretion status. The erosion and accretion was 87.6km and 38.4km noticed, Stable coast 41.4km acquired along the Nellore Coast. The erosion and accretion pattern observed along the coast is influenced mainly by coastal process and river inputs. The variation in river mouth morphology was quite significant and changing rate were more all along the river mouth.

Table - 3
Shoreline classification and status along Nellore coast

Shoreline Classification	Status (1989-99) Km	Status (1999-2005) Km	Status (2005-10) Km	Status (2010-12) Km	Status (2012-15) Km
High Erosion	2.9	32.1	17.9	83.2	55.6
Medium Erosion	17.2	44.1	15.9	7.8	22.4
Low Erosion	14.9	25.6	18.5	3.7	10.4
Stable Coast	13.2	14.6	13.1	2	7.9
Low Accretion	26.4	15.5	20.7	3.3	9.2
Medium Accretion	48.1	24.5	39	7.2	17.2
High Accretion	43.3	10.5	40.1	57.5	41

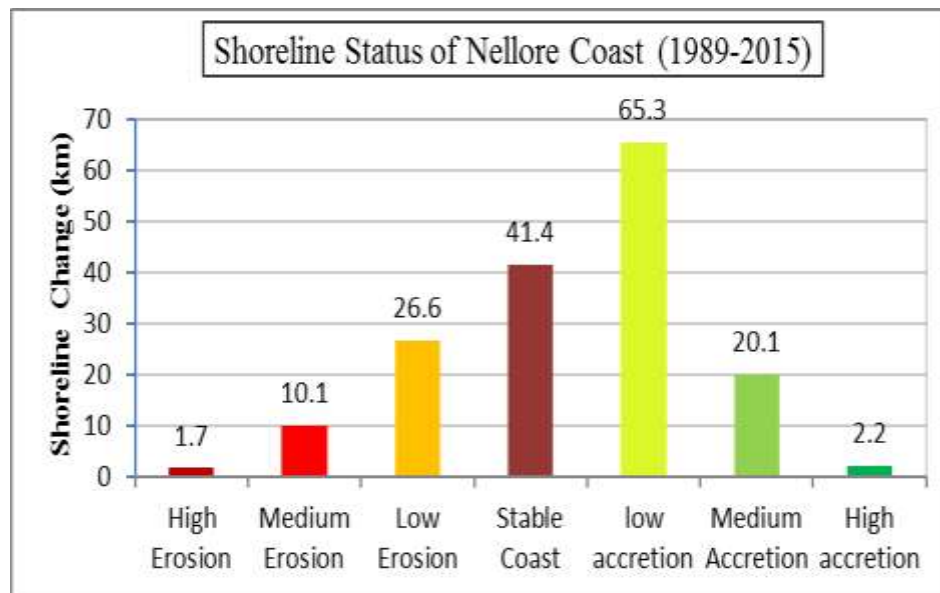


Fig. 3: Shoreline classification and status (1989-2015)

In the year of 1989 to 1999 average accretions rate is +4.29 m/yr and erosion rate -2.55m/yr acquired in the Nellore coast. In the another decade of 1999 to 2005 had severe erosion happened in all along the Nellore coast the average erosion had very high - 4.47m/yr absorbed and accretion rate is 3.18 m/yr. In 1989 to 2005 mostly erosion happened in northside of penner river mouth and upputuru river mouth areas.

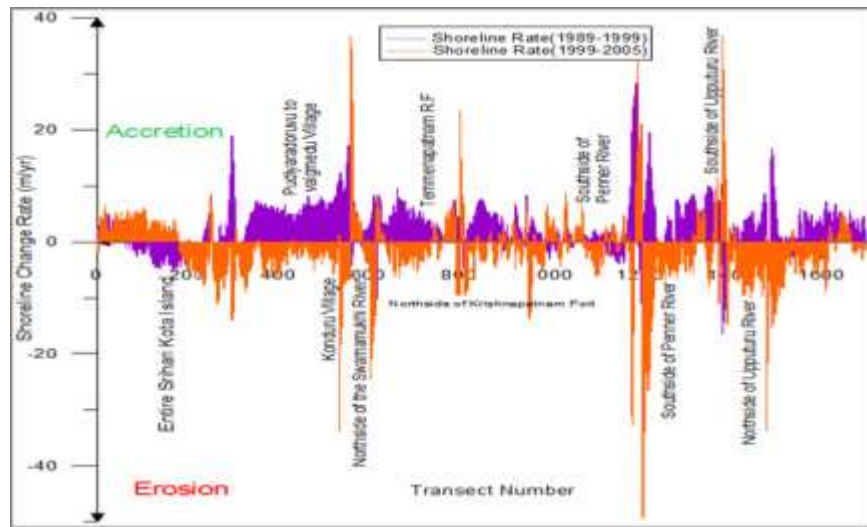


Fig. 4: Shoreline Change Rate 1989-1999 and 1999-2005

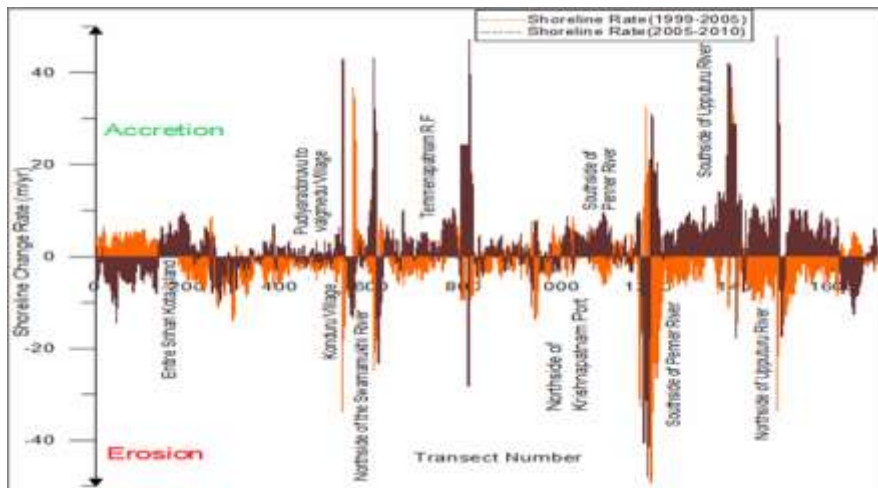


Fig.5: Shoreline Change Rate 1999-2005 and 2005-2010

In the decade of 2005 to 2010 the average accretion rate is +5.34 m/yr and erosion rate is -4.37m/yr acquired in the Nellore coast, same as of 2010 to 2012 had severe erosion happened in all along the Nellore coast the average erosion has identify -15.30 m/yr engrossed and accretion rate is +11.60 m/yr. In the above decade of 2005 to 2012 has huge erosion acquired many places, because of some event happened all along the Nellore coast. In the year of 2010 to 2012 highest erosion happened nearly +140 m/yr in the past 2 years mainly north side of krishnapattanam port , Northside of penner river and upputuru river mouth areas accretion had sriharikota .

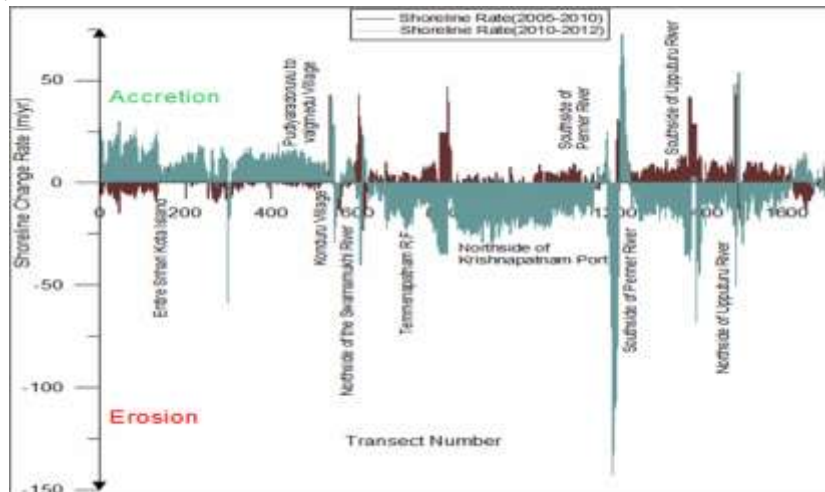


Fig. 6: Shoreline Change Rate 2005-2010 and 2010-2012

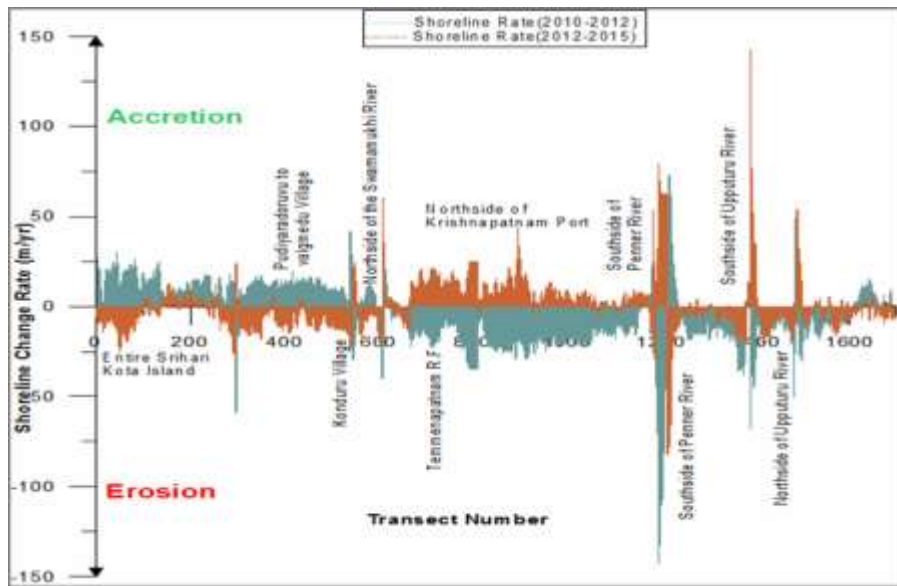


Fig. 7: Shoreline Change Rate 2010-2012 and 2012-2015

The Change rates were calculated for the period between 1989 and 1999, 1999 and 2005, 2005 and 2010, 2010 and 2012, 2012 and 2015 and then for 1989 to 2015. Overall rates ranges from -20 m/year to 10 m/year where negative values represent erosion and positive values represent accretion (Figure 9). Using the 1989 to 2015 results as a reference, about 24% of the entire shoreline experienced erosion and 18% has Stable coast ,while the remaining have mostly accreted. Accretion rates range from 0.1m/year to 10 m/year with an average 1.4 m/year while erosion rates were between 0.1 to 20m/year with an average of 1.36m/year. Both rates are significantly moderately high.

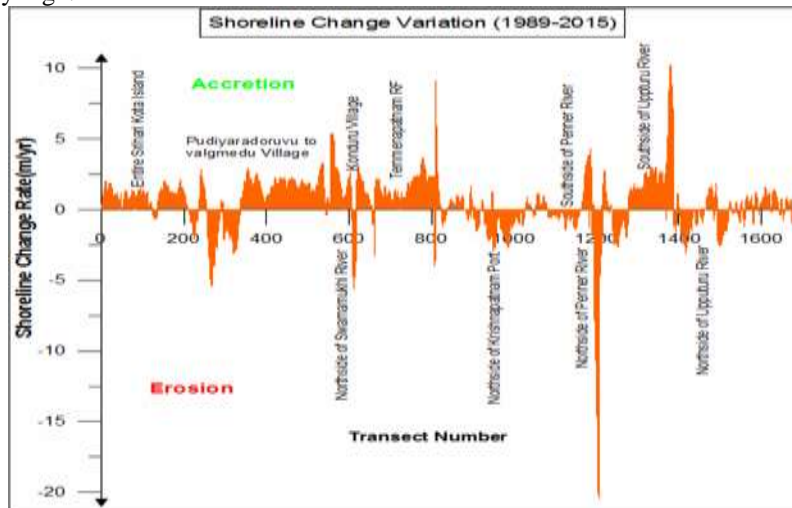


Fig. 8: Shoreline Change over all Rates 1989-2015

Table - 4
Long term shoreline change from EPR for 25 years using different interval of shoreline

Year	Erosion (m/Yr)	Accretion (m/yr)	Maximum (m/yr)	Minimum (m/yr)	Average (m/yr)
1989-1999	-2.59	4.3	28.19	-34.7	2.62
1999-2005	-4.47	3.79	36.8	-49.23	-1.68
2005-2010	-4.38	5.34	47.91	-48.11	1.83
2010-2012	-15.3	11.57	72.64	-142.48	-4.08
2012-2015	-7.01	13.43	143.35	-83.47	7.73

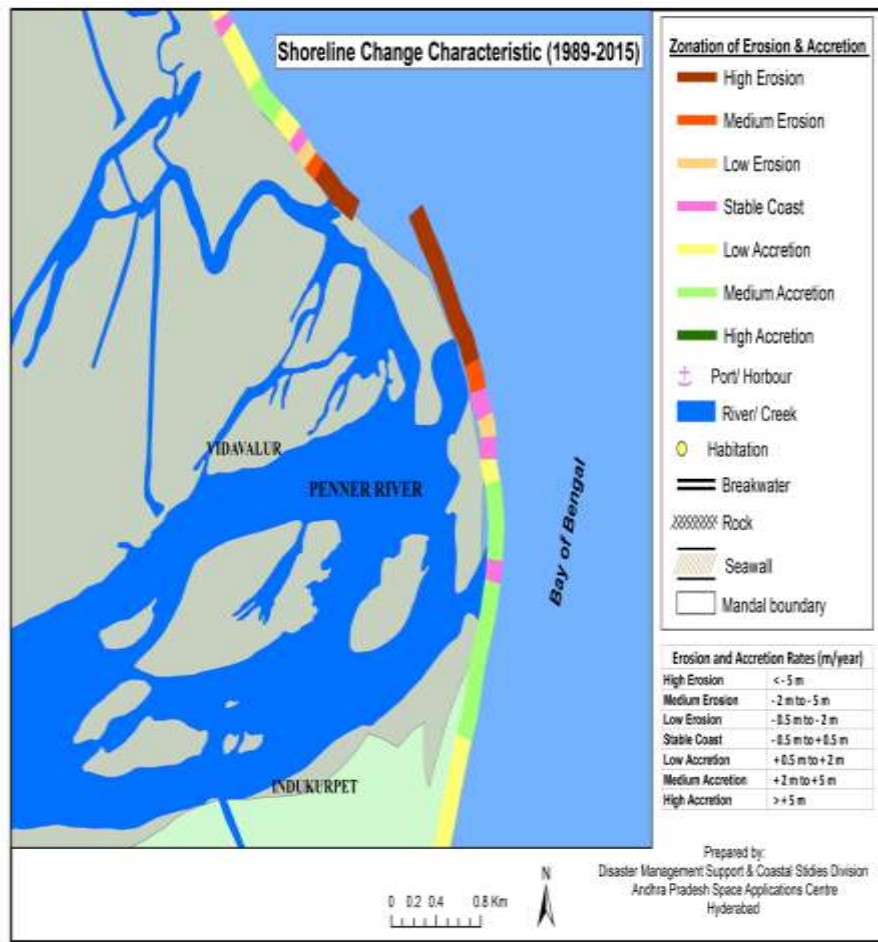


Fig. 9: Shoreline change map in Penner river mouth area along Nellore Coast



Photo: 1 North side of Iskappalli Village



Photo: 2 South of Iskappalli Village



Fig. 10: Shoreline change map along Nellore Coast

V. CONCLUSION

Shoreline position mapping is very valuable in regards to climate changes. Based on this study it can be concluded that remote sensing will be useful for long-term qualitative monitoring of shoreline erosion and accretion pattern in case lack of field data sources. The erosion and accretion pattern observed along the coast is influenced mainly by coastal process and riverine inputs. The variation in river mouth morphology was quite significant and changing rate were more all along the river mouth. In the year of 1989-2005 the average accretion rate is +2.46 m/yr and erosion rate acquired in the Nellore coast is -1.97 m/yr. It is same in the year of 2005 to 2015. The rate of accretion and erosion is derived as +2.74 m/yr and -2.8 m/yr. Overall, during the study periods, erosion activities are moderately high compare to accretion in study area. However, erosion activities are not occurred in the middle of the segment.

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REFERENCES

- [1] Alesheikh, A. A., Ghorbanali, A., and Nouri, N., (2007), "Coastline change detection using remote sensing" International Journal of Environment Science and Technology, 4, pp 61-66.
- [2] Anthony, E. J., (2005) "Beach Erosion. Encyclopaedia of Coastal Science" Springer. p140-144.
- [3] Bailey B. and Nowell D.(1996) "Techniques for monitoring coastal change: a review and case study" Ocean and Coastal Management, Vol. 2, pp. 85-95.
- [4] Bochicchio C., and Richmond B M, (2012) "National assessment of shoreline change: Historical shoreline change in the Hawaiian Islands" US Department of the Interior, US Geological Survey.
- [5] Boak E. H. and I. L. Turner (2005), "Shoreline Definition and Detection: A Review," Journal of Coastal Research, 214, pp. 688-703,
- [6] Blodget, H. W., Taylor, P. T., and Raork, J. H., (1991). "Shoreline changes along the rosetta Nile promontory - monitoring with satellite-observations" Marine Geology, 99: 67-77.

- [7] Crowell, M., Leatherman, S.P., (1999). "Coastal erosion mapping and management" *Journal of Coastal Research* 28 (special issue), 1–196.
- [8] Chen L.C. and J.Y. Rau (1998), "Detection of shoreline changes for tideland areas using multi- temporal satellite images," *International Journal of Remote Sensing*, 19, pp. 3383–339.
- [9] Dolan, R., Hayden, B., May, P. and May, S., (1980). "The reliability of shoreline change measurements from aerial photographs" *Journal of Shore and Beach*, p22-29
- [10] Dolan R., Hayden B.P. and May S. (1983). "Erosion of the US shorelines" *Journal of Remote Sensing*, Vol.6, pp.26-31.
- [11] Douglas B C and M Crowell, (2000) "Long-term shoreline position prediction and error propagation" *Journal of Coastal Research*, p. 145-152.
- [12] ICMAM (2005) "Shoreline Management Plan for Ennore Coast (Tamilnadu)", Report of Integrated Coastal and Marine Area Management Project Directorate, Ministry of Earth Sciences, India.
- [13] Fletcher C., Rooney J., Barbee M, and Lim S.C, (2003) "Mapping Shoreline Change Using Digital Orthophotogrammetry on Maui, Hawaii", *Journal of Coastal Research*,
- [14] Fletcher C .H., B M Romine, A S Genz, M M Barbee, M Dyer, T R Anderson, S C Lim, S Vitousek,
- [15] Gopinath G and Seralathan P. (2005). "Rapid erosion of the Coast of the Sagar Island, West Bengal India" *Environmental Geology* 48: 1058-1067.
- [16] Kannan R., Anand K.V., Sundar V., Sannasiraj S.A. and Rangarao V., (2013). Shoreline changes along the Northern coast of Chennai port, from field measurements. *ISH Journal of Hydraulic Engineering* Vol 66
- [17] Kaliraj, S., Chandrasekar, N., Magesh, N.S., (2013), "Impacts of wave energy and littoral currents on shoreline erosion/accretion along the south-west coast of Kanyakumari. Tamil Nadu using DSAS and geospatial technology" *Journal of Environmental Earth Science*.
- [18] Mani Murali, R., Shrivastava, D., Vethamony, P., (2009), "Monitoring shoreline environment of Paradip, East coast of India using remote sensing" *Current Science*, 97(1), pp 79-84.
- [19] Maiti and A K Bhattacharya., (2009) "Shoreline change analysis and its application to prediction: A remote sensing and statistics based approach" *Marine Geology*, 257(1–4): p. 11-23
- [20] Moufadal W, (2009) "Use of Satellite Imagery as Environmental Impact Assessment Tool: A Case Study from the New Egyptian Red Sea Coastal Zone," *Environmental Monitoring and Assessment*, Vol. 107, No. 1-3, pp. 427-452.
- [21] Moore, L. J. (2000) "Shoreline mapping techniques" *Journal of Coastal Research*, Vol. 16, p.111-124.
- [22] Nayak, S.R., (2002). "Use of satellite data in coastal mapping" *Indian Cartographer* 22, pp147–157
- [23] Pandian, P.K., Ramesh, S., Murthy, M.V.R., Ramachandran S., and Thayumanavan, S., (2004), "Shoreline changes and near-shore processes along Ennore Coast, East Coast of South India" *Journal of Coastal Research*. 20(3), pp 828-845.
- [24] 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" *International Journal of Remote Sensing.*, Vol.6, No.3 & 4, pp.549-558.
- [25] Saranathan, E., Chandrasekaran,R., Soosai Manickaraj, D., & Kannan, M., (2011), "Shoreline Changes in Tharangampadi Village, Nagapattinam District, Tamil Nadu, India-A Case Study" *Journal of Indian Society Remote Sensing*. 39(1), pp.107–115
- [26] Stauble, D. K., (2003). "The use of shoreline change mapping in coastal engineering project assessment" *Journal of Coastal Research*, 178- 206.
- [27] USGS (2005) User Guide and Tutorial for the Extension for ArcGIS v.9.0 (DSAS) version 3.2 Digital Shoreline Analysis System Part of USGS Open-File Report 2005-1304.
- [28] Thieler E R, Himmelstoss E A, Zichichi J L, et al., (2009), "Digital Shoreline Analysis System (DSAS) version 4.0. An ArcGIS extension for calculating shoreline change".
- [29] Thieler E R., E A Himmelstoss., J L Zichichi, and A Ergul., (2009) "The Digital Shoreline Analysis System (DSAS) version 4.0 an Arc GIS extension for calculating shoreline change", U.S. Geological Survey.