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Detection of Shoreline Changes Visakhapatnam Coast, Andhra Pradesh from Multi-Temporal Satellite Images

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Abstract

The shoreline is under several emotional threats for last few decades by some natural forces and human intervention. In this paper the beaches are analyzed to assessing their evolution (erosion/accretion) associated with human intervention and climatic condition. Coastal changes are attracting more focus since they are important environmental indicators that directly impact coastal economic development and land management. Both natural and anthropogenic processes along the coast control the erosion, and accretion activities of the coastal zones. In this study, high-resolution images taken from 1989-2015 at an interval of about 5/10 years and topographic maps were collected to determine coastline changes. The present shoreline maps illustrating the shoreline erosion accretion pattern in the coastal area of Visakhapatnam district by using different sources of remote sensing data. In the present study, Landsat 5 (1989), IRS-P6 LISS III (1999), IRS-P6 LISS III (2005, 2010), LISS IV (2012) and Landsat 8 (2015) satellite images were used. The shoreline change detection was conducted using the Digital Shoreline Analysis System (DSAS). The rate of shoreline change was assessed using Linear Regression (LRR) and End Point Rate (EPR) methods. In those methods End Point Rate (EPR) was calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements at each transect. Visakhapatnam having length of coast line is 135 km. 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 74.6 km of coastline was found to be accreting nature with average of +1.08 m/yr followed by 38.4 km of coastal line eroding with average of -1.40 m/yr and stable coastline of 41.4 km 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: Shoreline changes; Hudhud; Satellite images; DSAS; Coastal processes

Introduction

Coastline is a dynamic morphological entity, which responds to the external forces exerted by waves, tides, nearshore currents and the resultant sediment transport. When the resultant sediment transport entering a particular area is greater than the sediment going out from the area, accretion or beach development takes place [1]. On the other hand, when there is a deficit of the incoming sediment supply into a particular area with reference to the sediment going out of the same area, beach erosion takes place [2]. Beaches act as constant absorbers of the wave energy of water and though subject to small disturbances, remain in equilibrium. However, sometimes this equilibrium gets disturbed due to either natural phenomena or human intervention [3]. When shore structures are constructed, it is quite likely that equilibrium condition is destroyed. Since this can cause considerable damage and reduce the effectiveness of such structures, it is necessary to study the equilibrium condition of shores before constructing such structures [4].

Occasionally, coastal erosion processes could be very expansive and devastating to invaluable properties, human lives and even the natural environment. Globally, this has generated much concern; interests with regard to the scourge are also on the increase in academic discourse [5]. The natural action of winds and waves, together with the anthropogenic forces resulting from the continued desire for natural resources exploitation are constantly at work in this region. Although human actions may sometimes yield positive results, they cannot be completely exempted from facilitating and accelerating the extent of damage to the natural landscape [6]. For coastal zone monitoring, shoreline extraction in various times is a fundamental work. The shoreline, which is defined as the position of the land-water interface at one instant in time [7] 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 [8]. 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 [9].

Since coastal areas are regions of high economic value, the prediction of shoreline positions depends solely on having a clear understanding of the shoreline parameters [10]. Based on this argument therefore, an appreciable knowledge of the shoreline characteristics is of utmost importance and timely. This has become very essential and necessary to make informed decisions towards effective coastal management [11]. If such parameters are put in place, it is believed that any information relative to shoreline characteristics will be readily accessible at any point in time. In the light of the foregoing, taking into consideration the high economic potentials of the area, this study seeks to extract shoreline from the satellite imagery, determine the rate of shoreline change as well as the net shoreline movement in the area [12].

Study area

Visakhapatnam district is the 7th largest district in Andhra Pradesh

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which accommodates the second largest city of Andhra Pradesh. Visakhapatnam district occupies an area of approximately 11,161 square kilometers. The city was also called Vizag. As Visakhapatnam is an important port city in the eastern coast of India so it attracts many tertiary sectors to grow in its vicinity too. Visakhapatnam district is the central hub for industry and education in the state of Andhra Pradesh. Vizag is home to the Eastern Naval Command. Apart from Visakhapatnam, Gangavaram Port also serves as a gateway for contributing to the development of the petroleum, steel and fertilizer industries in the district. It is a hub for iron ore and other mineral exports which are exported through sea route to other countries (Figure 1).

The district was situated between 81°06′ and 83°31’E, of the eastern longitudes and 17°15′ and 18°32’N, of northern latitudes. The boundaries of this district are Bay of Bengal in the East, East Godavari district in the South, Orissa state in the West and North directions. The length of the coast line is 135 km .Headland bay and small beaches are seen in the Vishakhapatnam district. Fishing is a major sector of the district on which the economy of the district as well as the state of Andhra Pradesh depends. The district has one of the largest harbors in the country for the fishing industry and seafood exports. A number of fishermen have their livelihoods depend on Fishing in the district. The ice factories in and outside the Fishing Harbor, caters to the needs of the fishermen and provides employment as well.

Material and Methodology

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

Shoreline extraction and delineation

Recent advancements in remote sensing and geographical information system (GIS) techniques have led to improvements in coastal Geomophological studies such as automatic and semi-automatic [13]. The semi-automatic techniques are attractive, due to their cost-effectiveness, time consuming etc. Automatic shoreline delineation is a complex process due to the presence of water saturated zone at the land-water boundary [14]. The shorelines were identified and delineated by processing the NIR bands of Landsat TM using “Gray Level Thresholding” and “Edge Enhancement Technique”. In this present study, the exact land-water boundary was obtained by using a “non-linear edge-enhancement” technique; these operations were applied to the image data to produce an enhanced image output for subsequent “visual interpretations” [6]. The enhancement techniques improve the feature exhibition and increases visual distinctions between features contained in a scene.

To extract the shorelines from the satellite images, shape files were created in Arc catalog for each of the images [15]. For easy data handling, the images were spatially projected to Universal Transverse Mercator. This was followed by the determination of shoreline reference feature where measurements were based. The high-water

Sensor	Spatial Resolution	Year	Month	Source
Landsat 5TM	28.5	1989	November	USGS
IRS-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 8TM	28.5	2015	March	USGS

The images were processed to delineate the shorelines for 1989, 1999, 2005, 2010, 2012 and 2015 with a view to determining their rate of changes over the study period.

Table 1: Multi dataset used in this study.

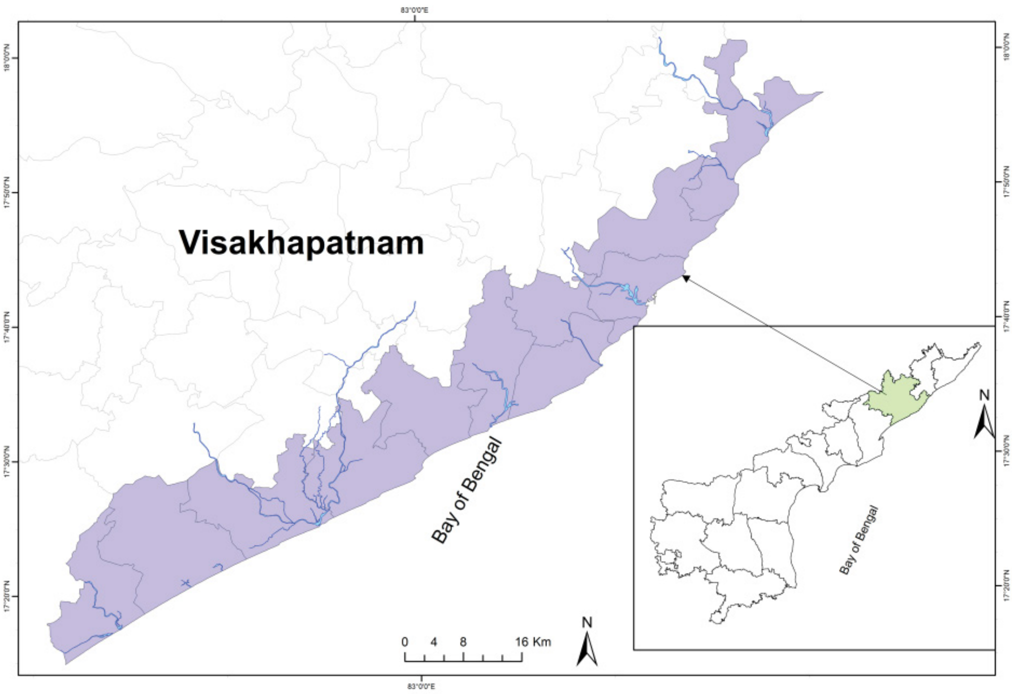

Figure 1: Study area.

line (HWL) was therefore adopted since it was relatively easy to distinguish it on all the images as a wet/dry line. The extraction was then carried out using the heads-up digitizing method. This manual method was adopted in an attempt to avoid the difficulties associated with the use of automated methods of extraction [16]. However, features from the landsat satellite imageries of 1989, 2015 and 1999, 2005, 2010, 2012 IRS image were digitized along the dry-wet sand boundaries which could be recognized from different tones in the sand beach. Usually, the tonal differences are caused by the variation in moisture in the sands as a result of being previously immersed or washed by high water level (Figure 2).

Digital shoreline analysis system (DSAS)

The technique calculates the rates of changes, such as erosion or accretion along shorelines based on the ArcGIS DSAS extension after the extraction of coastline from Landsat TM and IRS images [17]. The DSAS is computer software that computes the rate-of-change statistics from multiple historic shoreline positions residing in GIS. DSAS generates transects that are cast perpendicular to the baseline at a user-specified spacing along-shore [18]. The transect shoreline intersections along this baseline are then used to calculate the rate-of-change statistics. Based on the settings DSAS, 676 transects has been generated that are oriented perpendicular to the baseline at a 200 m spacing and about 135 km along Vizag 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 [19].

Results and Discussion

The shoreline change estimation was carried out for entire Visakhapatnam coast which is about 135 km in length. The shorelines were extracted from multi-temporal satellite images for 1989, 1999, 2005, 2010, 2012 and 2015 by Digital Image Processing and visually interpretation. The coast line rate of change was calculated using DSAS model with different statistical techniques; End Point Rate (EPR) and Linear Regression Rate-of-Change (LLR). Base lines were constructed seaward of and parallel to the general trend of the shorelines. The transects were spaced 200 m apart from each other and the rates of shoreline change were calculated at each transect using linear regression. As a result depicts that the most significant changes were observed at Visakhapatnam Coast (Table 2).

Shoreline status (Rate of change)

For the analysis of 1989 to 1999 shoreline data maximum places had eroded, because of due to severe cyclone hunted in Visakhapatnam coast in the year of 1998.The maximum erosion is -9.7 m/yr north side Gajuwaka area and maximum accretion is +17.3 m/yr south side Gangavaram port. The average erosion is -2.6 m/yr and accretion is +2.1 m/yr .The shoreline of 1999 to 2005 is mixture of accretion and erosion. In those periods Southside of Appikonda village to Annavaram

Classification of the Coast	Extend (Km)	Percent of the Coast	Cumulative (%)
Length of the coast including River and Port	135.2		
High Erosion	0.2	0.15	
Medium Erosion	9	6.66	
Low Erosion	22	16.27	23.08
Artificial coast: Seawall, Riprap	5.2	3.85	26.92
Stable Coast	24.2	17.90	17.90
Low Accretion	69.2	51.18	
Medium Accretion	5	3.70	
High Accretion	0.4	0.30	55.18
No. of port/Harbour	2		
No. of Groins	5		

Table 2: Shoreline Classification Status.

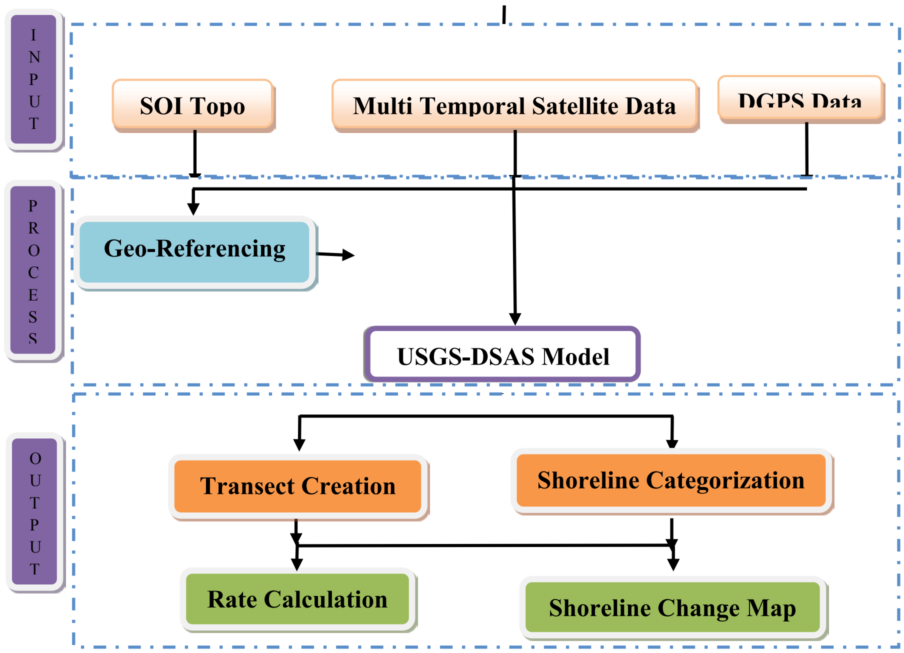

Figure 2: Methodology.

coast had fully eroded and at the same south side of Gangavaram port has fully Accretion coast. The maximum erosion is -20.62 m/yr and accretion is 11.76 m/yr. The average erosion and accretion is -2.97 m/yr, 3.30 m/yr acquired, for overall -136 m has eroded and 70.93 m accretion gained (Figure 3).

The decade of 2005 to 2010 the coast had eroded because of Tsunami happened in the 2004 December. The maximum erosion is -20.2 m/yr in the Annavaram areas and maximum accretion +10.2 m/yr in Payakaraopeta village. The average erosion in the above study period is -3.4 m/yr and accretion is +2.2 m/yr. The net shoreline movement has -99.96 m/yr eroded and accretion is 50.18 m. The analysis 2010-2012 periods mostly has been accretion. The maximum erosion had -29.4 m/yr in Rambilli area and accretion is +46.0 m/yr in North side of Visakhapatnam port area. The average erosion is -6.6 m/yr and accretion is 14.3 m/yr. The net shoreline movement of above periods is 100.77 m accretion and -64.37 m erosion (Figure 4).

In period 2012 to 2015 shoreline has mostly in accretion coast, but some places had eroded due to HUDHUD cyclone in 2014 October. The maximum erosion is -22.39 m/yr in north side of Bheemunipatnam and maximum accretion is 30.25 m/yr in Southside of Gangavaram and north side of Visakhapatnam port areas has identified. The overall erosion and accretion for above period -5.35 m/yr and accretion are 8.37 m/yr. The movement of net shoreline erosion and accretion is -66 m and 89 m (Figure 5).

Shoreline change using linear regression rate (LRR) method

A linear regression rate-of-change statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect [17]. The regression line is placed so that the sum of the squared residuals is minimized. The linear regression rate is the slope of the line. The method of linear regression includes these features: (1) All the data are used, regardless of changes in trend or accuracy, (2) The method is purely computational, (3) The calculation is based on accepted statistical concepts, and (4) The method is easy to employ [20]. However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics, such as EPR [17,21].

The Linear Regression Rata (LRR) of shoreline change were calculate at each transect. In the above study total transect has 576 and spacing of transect is 200 m. The highest erosion measured -5.02 m/yr measured in Bheemunipatnam coast and highest accretion is +10.31 m/yr in south side of Gangavaram port area [22]. The net shoreline movement of above period is -95 m has eroded, at same time 147 m has accretion gained (Figure 6).

Shoreline change statistics along Visakhapatnam coast

The total length of the Visakhapatnam coast is around 135 km. The analysis of the coast between year 1989 to 2015, accretion and erosion was 74.6 km, 31.2 km and 24.6 km stable has identified. The following table shows detail shoreline change static for decade wise (Figure 7 and Table 3).

Summary and Conclusions

The Visakhapatnam coast is one of the important public beaches along the Andhra Pradesh coast. In a natural environment erosion and accretion at a certain area are normally balance. If erosion occurs at a particular area, accretion would also be found. In this study this is not evident, proving that the sediment transport in the area has been disturbed. This study clearly demonstrates that the integration of remote sensing and GIS technology is very useful for long term shoreline change studies with reasonable accuracy. The result of shoreline change map will be more useful for coastal engineers and coastal zone management authorities to facilitate suitable management plans and regulation of coastal zones.

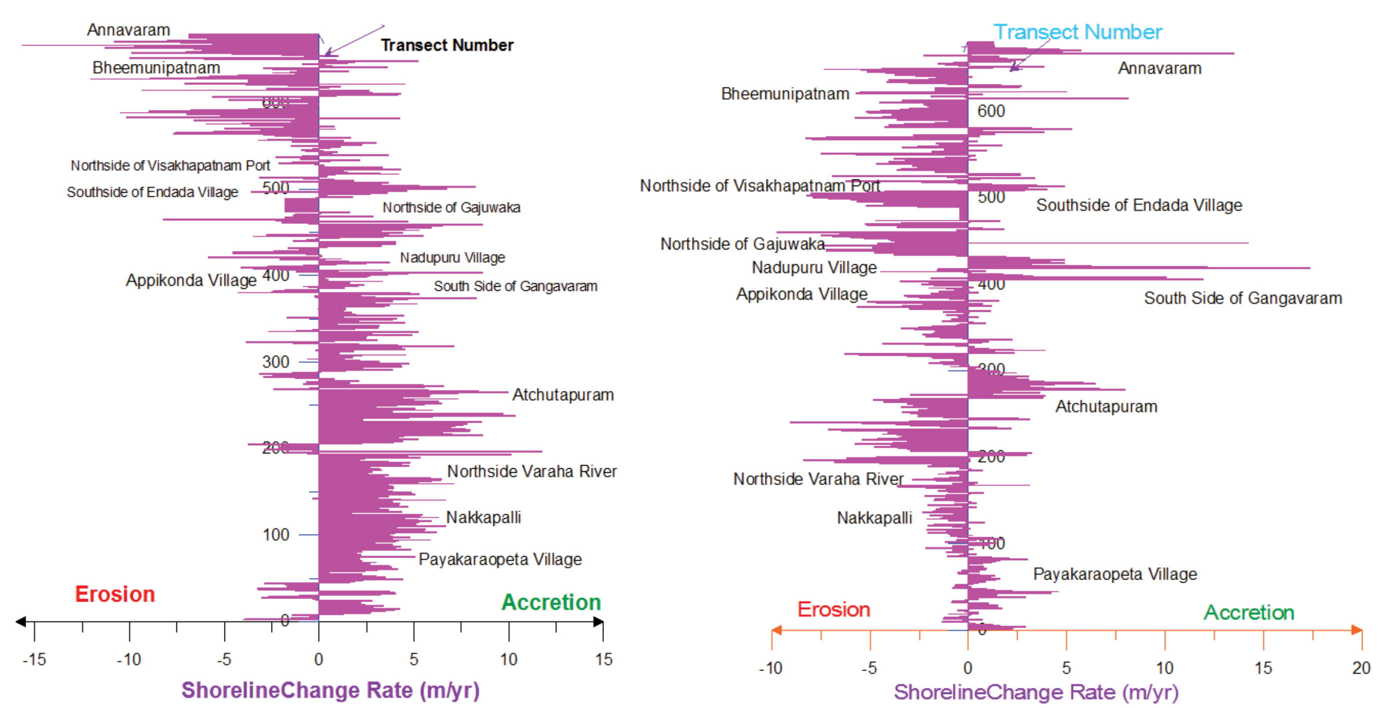

Figure 3: Shoreline change Status 1989-1999 and 1999-2005.

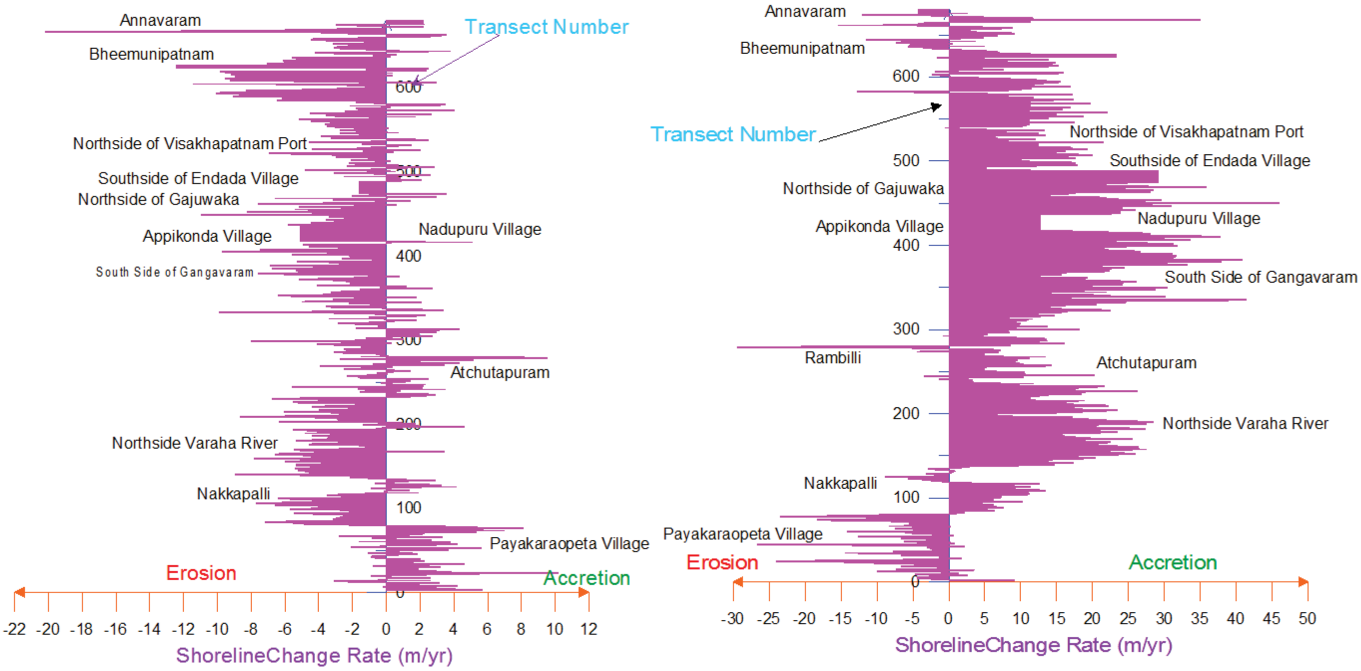

Figure 4: Shoreline change Status 2005-2010 and 2010-2012.

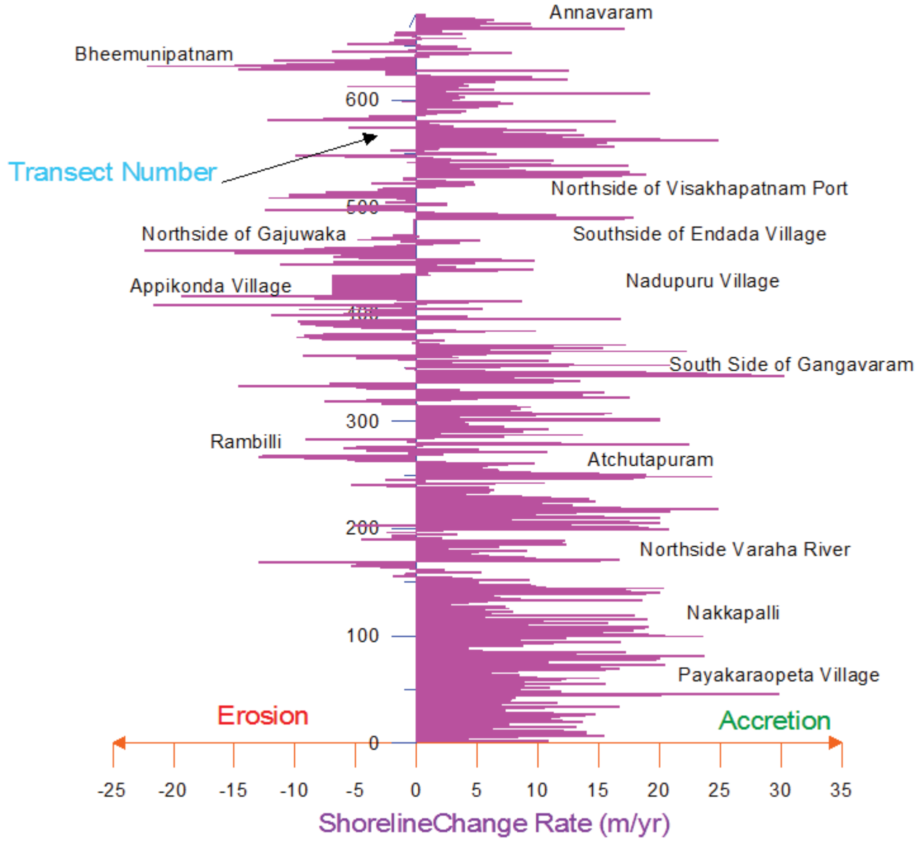

Figure 5: Shoreline change Status 2012-2015.

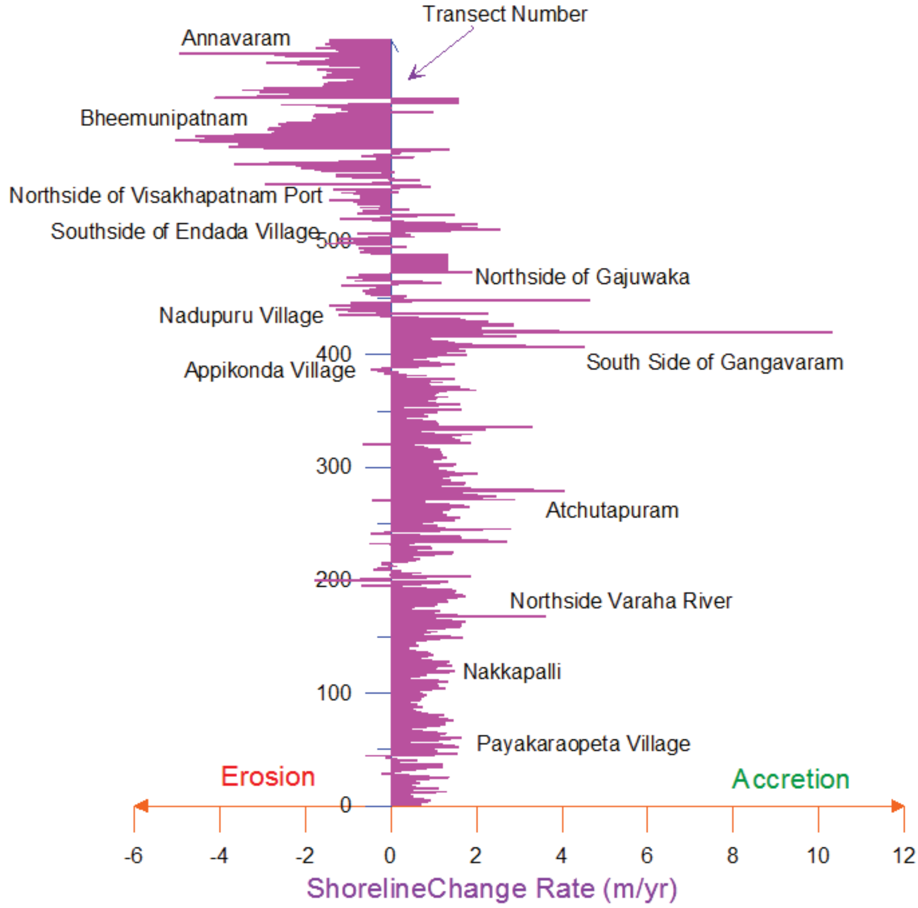

Figure 6: Shoreline change Status using LRR method (1989-2015).

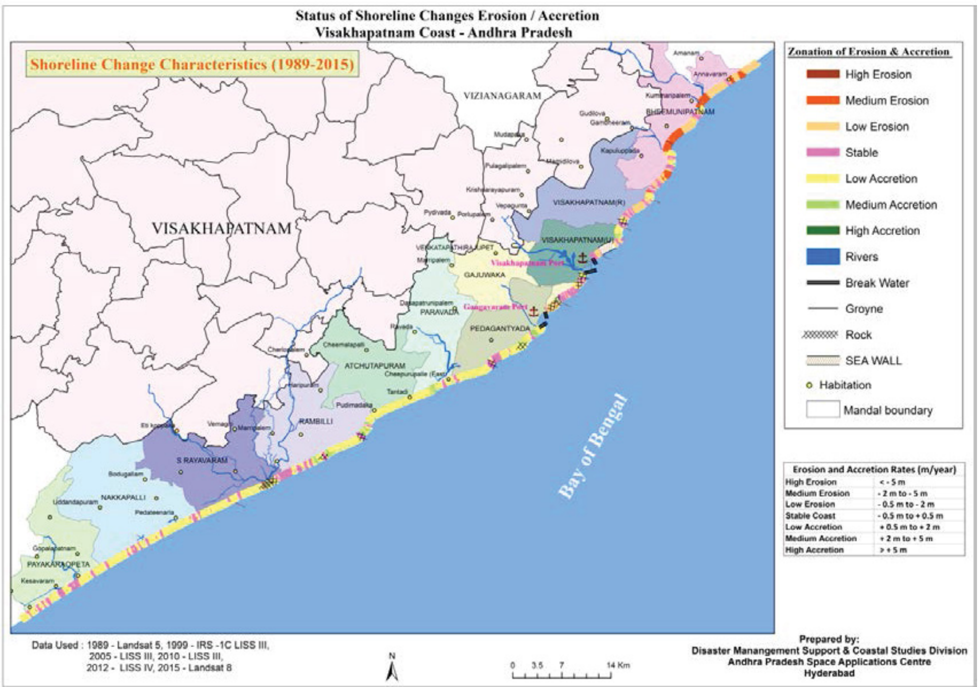

Figure 7: Shoreline classification along Andhra Pradesh coast.

Shoreline Classification	Shoreline Length (1989-99) Km	Shoreline Length (1999-2005) Km	Shoreline Length (2005-10) Km	Shoreline Length (2010-12) Km	Shoreline Length (2012-15) Km
High Erosion	11	8	21	10.8	14.8
Medium Erosion	32.6	13.4	38.6	7.4	9
Low Erosion	29.2	14.4	23	4.2	7
Stable Coast	21.4	11.8	12.6	1.6	5.8
Low Accretion	19	22	13.2	4.4	9.2
Medium Accretion	14.2	44	16	9.6	21.6
High Accretion	3.2	16.6	2.8	89.4	60

Table 3: Classification along Andhra Pradesh coast.

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