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Comparison of Shoreline Change Analysis using EPR and LRR methods along the Coastal Region

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Abstract

The shoreline is one of the coastline landforms that changes continuously concerning time and natural as well as man-made phenomena. It becomes essential to monitor such changes in the coastline to study the hydrological impact. This study focuses on analysing coastal change from 1991 to 2021 in a gap of 10 years. Post-monsoon season analysis has been carried out in this study. Coastline statistical analysis over the period has been carried out using the DSAS tool which is available as a plugin in ESRI ArcGIS software. Landsat sensor imagery provided by USGS is used in this research. DSAS uses three statistical methods to analyse shoreline change: 1. Endpoint rate (EPR), 2. Linear regression rate (LRR). Initially, coastline extraction has been carried out. The results are used as the base shoreline for the DSAS model and further extraction and analysis have been carried out to monitor long-term changes in the Gulf of Khambhat coastline from 1991 to 2021. The processing is carried out for the post-monsoon season to understand the environmental impact on coastal hydrodynamics. Results show the comparison of maximum accretion and erosion found using End Point Rate, and Linear Regression Rate, respectively.

Keywords: Landsat, Shoreline, Remote sensing, DSASv5.0,EPR,LRR

1. Introduction

The coast is a special environment where land, ocean, and air continuously interact, influencing a strip of abstraction zone known as the "Coastal Zone." In other words, both marine and terrestrial processes have an impact on the coastal zones. The importance of monitoring such areas with time to time is very important in terms of safety, ecology, and recreation. Indeed, over 80% of the world's beaches are experiencing coastal erosion with the rates ranging from 1.0 cm/year to 30m/year, and this presents a serious hazard to many coastal regions. [1]Monitoring, temporal-spatial changes of coastal environments can help understanding the spatial distribution of erosion hazards and predicting the development trend. Coastline can be defined as the position of the land-water interface at one instant in time and is a highly dynamic feature which gives an indicator for the coastal erosion and accretion. The shoreline changes occur over the wide range of time scale. Such changes occur due to tides, winds, storms, sea level change and other hydrodynamic changes. Subsequently, [2] described the shoreline change along the Northern coast of Sinai from an aerial photograph taken in 1955, a topographic map surveyed in 1992 and an admiralty chart of 1922. Earlier many research has been carried out using remote sensing and GIS techniques. [3] [4] [5] Recently, many research have carried out shoreline analysis study using Digital Shoreline Analysis System (DSAS) tool available on ArcGIS platform. DSAS becomes very handy to simulate results as it offers

many statistical methods to calculate rate of change in shorelines. The DSAS generate orthogonal transects along the coast and then it calculates changes in statistics according to the six distinct approaches. The methods used in this research are End Point Rate (EPR), and Linear Regression Rate (LRR).
The LRR method calculates the least square regression line for historical shorelines. It measures the distance between the shoreline and transects intersections points. [6]Linear regressions are common statistical analysis for determining shoreline change rate which is the rate of accretion along the shore. [5] Time period considered for this research to carry out long term coastal analysis is from 1991 to 2021. Shorelines are extracted for every tenth years i.e., for 1991, 2001,2011, and 2021. Landsat 4-5, Landsat 7, and Landsat 8 are used to extract coastlines.

1.1. Study Area

The Gulf of Khambhat is a south-to-north penetration of the Arabian Sea on the western side of India between the Saurashtra peninsula and mainland Gujarat. (Shown in Figure) It is located around between latitude 20°30'30" N and 22°20'00" N and longitude 71°45'00" E and 72° 53'30" E. At its northern end between the mouths of Sabarmati and Mahi, the Gulf region is barely 5 kilometers wide and opens out southward like a shape of a funnel, reaches its maximum breadth, and its north-south length is approximately 115 km. All the major river form estuaries and their inflow carry heavy load of sediments into the gulf.

Figure 1 (a) Gulf of Khambhat (b) Georeferenced toposheets

2. Data and Methods

Multitemporal satellite data of Landsat ETM+, TM and operational land imager sensor have been used in this study to cover the Gulf of Khambhat region in the years 1991,2001,2011, and 2021. Images have been downloaded after checking the cloud coverage and for both the periods of pre and post monsoon season. The satellite images are pre-processed in ERDAS IMAGINE software by checking orthorectification and geometric corrections are applied. OTSU algorithm is used to extract shorelines and then corrected by manual approach to increase its accuracy. Table 1 indicates the data acquired information.
After the pre-processing of the images, Landsat 7 sensor images were corrected differently from the rest sensors. Landsat 7 images contained slack lines which was needed to be corrected to generate suitable results. Hence, such images were processed in ERDAS IMAGINE by using Focal Analysis tool to remove such slack lines from the imagery.

Table 1 Details of satellite dataset (acquired via https://earthexplorer.usgs.gov/)

Year	Satellite	Date of Acquisition	Spatial Resolution
1992 (Post-Monsoon)	LANDSAT 4-5 TM	18th Feb 1992	30M
2001 (Post-Monsoon)	LANDSAT 7 ETM+	10th November 2001	30M
2011 (Post-Monsoon)	LANDSAT 7 ETM+	28th November 2011	30M

2021 (Post-Monsoon)	LANDSAT 8 OLI	25th November 2021	30M

DSAS tool takes shorelines as input to carry out the statistical analysis. For such purpose, digitizing shoreline for the Gulf of Khambhat region would be tedious and time consuming. Hence, remote sensing techniques has been used to automate the coastline extraction process. Initially, NDVI images have been generated by applying band combination and then OTSU algorithm has been applied which uses binary thresholding to divide the satellite image in binary format. Converting that image into vector format results into coastline which can be used as input in DSAS tool.

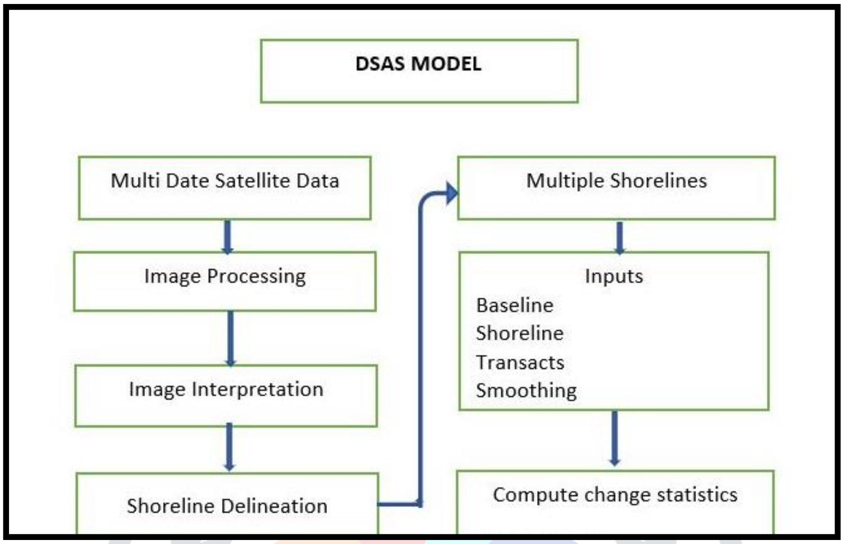

Figure 2 Work Flow Chart of Methodology Adopted for Long-Term Change Statistics

2.1. DSAS Tool- An overview

Digital Shoreline Analysis System (DSAS) tool available on the ArcGIS platform. It is valid to carry out the analysis of shorelines. The DSAS becomes very handy for simulating the results as it offers many statistical methods to calculate the rate of change in shorelines. The DSAS generates orthogonal transects along the coast, then calculates changes in statistics according to the six distinct approaches.

The digital shoreline analysis system (DSAS) software is an add-in to the ESRI ArcGIS desktop. It enables users to calculate rate-of-change statistics from multiple historical shoreline positions. [6] It automatically establishes measurement locations, performs rate calculations, and provides the statistical data required to assess the robustness of shoreline changes over the period. Along with the reports, it delivers a significant user-friendly interface for the visualization of various parameters in shoreline statistics calculations. It generates transects that are cast perpendicular to the reference baseline to intersect the shoreline at a user-specified spacing.

In this research study, the following three methods - Net Shoreline Movement (NSM), End Point Rate (EPR), and Linear Regression Rate (LRR) have been used to calculate shoreline rates of change based on measured differences between shoreline positions through time by use of DSAS version 5.1 and Arc GIS.DSAS measures the distance between the baseline and each shoreline intersection along with the transect. It combines date information, and positional uncertainty for each shoreline, to generate the change metrics. The Figure gives a brief explanation of the components of DSAS-generated results.Net Shoreline Movement

The net shoreline movement (NSM) is the distance between the oldest and the youngest shorelines for each transect which results in meter [6]. By dividing the distance of shoreline movement by the period between the oldest and most recent coastline, the End Point Rate is derived. Linear Regression Rate can be determined by fitting a least-squares regression line to all shoreline points for a transect. The offset distance of each data point from the regression line is squared, and the squared residuals are added to find the sum of the squared residuals, which is minimized. Here, the gradient of the line is considered the linear regression rate.

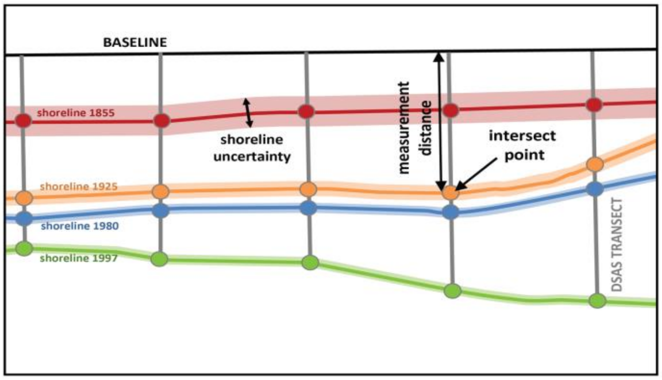

Figure 3 Components of DSAS tool

3. Results and Discussions

Shorelines are extracted by calculating NDWI and applying OTSU algorithm on all the imageries. Figure shows the shorelines extracted and are merged into single feature class. Manual corrections are applied after the extraction of results by overlaying toposheet base map to improve the results accuracy. The process is followed by using digitization tool in ArcMap.

The coastline changes over the period 1991 to 2021 were measured using the Net Shoreline Movement method (NSM), End Point Rate (ERR), and Linear Regression Rate (LRR) and developed change analysis statistics. In the results values, the coastline progradation shows positive values whereas, the negative values have linked to erosion of the coastline of the study area. The LRR, EPR, and NSM positive and negative value shows the seaward and landward movement of the coastline, respectively. Baseline, historical seashores, and coastline uncertainty are input data delivered in the model during the simulation phase. The spaces among transects alongside the baseline and transects length were demarcated based on the Coastline pattern. The reported rates are expressed as meters of change per year as measured along transects.

Linear Regression Rate of Shoreline Changes

The coastline changes over the period of 1991 to 2021 are measured using linear regression rate (LRR) method. It fits the least square regression to all the shoreline from oldest to the newest transects. The results demonstrated in Table 2. displays the total coastline variation rates measured from the analysis and outputs generated by DSAS tool.

Table 2 Coastline Variation from LRR for the 30 years using different interval of coastline

Year	Erosion (m/year)	Accretion (m/year)	Maximum (m/year)	Minimum (m/year)	Average (m/year)
1991 to 2021	-55.98	76.78	538.05	-1794.58	-1.81

The coastal progradation shows by positive values while the negative values are linked to the erosion of coastline. Over the span of 30 years, the LRR total averages rate shows an erosional trend for the coastline for overall segment. The average value stands for -1.81 m/year. From the Fig. 4, it can be analysed that most of the Gulf of Khambhat region has gone into erosion. The analysis shows that total number of erosional transects are 6162 while accretional transects are 4247. Table 3 depicts comparison of erosional and accretional transects.

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Table 3 Erosional vs Accretional Statistics for LRR

Category	Erosional Transects	Accretional Transects
Number of transects	6162	4247
% Out of total transects	59.2%	40.8%

% Of transects having statistically significant erosion/accretion	14.45%	4.32%
Maximum value	-1794.58 m	538.05 m
Average of rates	-55.98	76.78

From the above Table 3, trend shows erosion over the Gulf of Khambhat. Most of the erosional areas are where the river meets the ocean i.e., estuaries of various rivers. Maximum erosion has taken place near the Sabarmati estuary. Above Fig. 5 shows the variation of coastal length over the Gulf of Khambhat region. With such graph in display, it can be clearly noted that most of the coastal line has gone under erosion. From the endpoints, the max erosion value is nearly -1800 m while maximum accretion nearly 600 m.

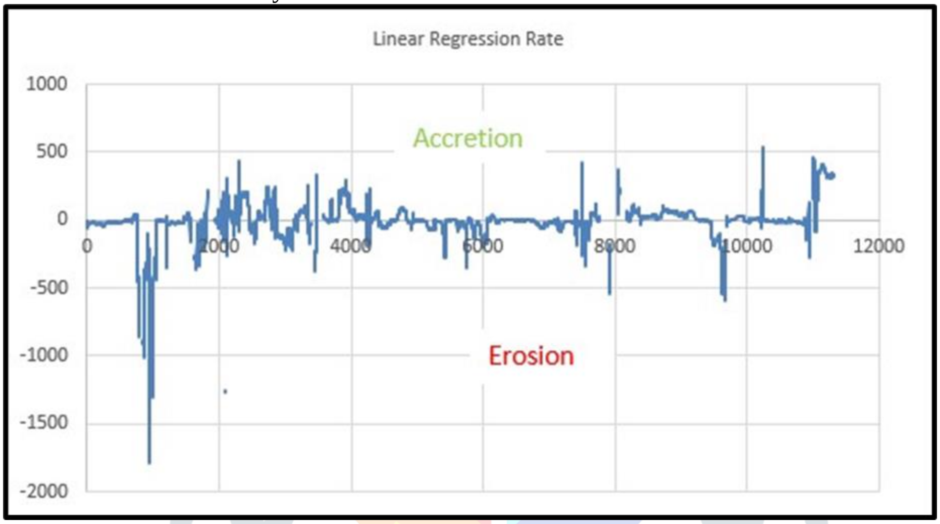

Figure 4 Accretion/Erosion vs Coastal Length via LRR Method

End Point Rate of Shoreline Changes

The coastline over the period of 1991 to 2021 are measured using End point rate (EPR) method. This method defines the rate of change statistics by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline.

Table 4 Coastline Variation from EPR for 30 years using different interval of coastlines

Year	Erosion (m/year)	Accretion (m/year)	Maximum (m/year)	Minimum (m/year)	Average (m/year)
1991 to 2021	-57.17	91.65	1049.52	-1793.87	-1.17

Same as output generated by LRR, EPR too shows erosional trend over the past 30 years. The average stands out to be -1.17m/year. The maximum accretion occurred is 91.65 m/year in the year 2016 while the maximum erosion is -57.17m/year in 2006. As it can be observed, most of the Gulf of Khambhat has gone under erosion. Most of the erosion has taken place where river meets the ocean.

Table 5 Erosional vs Accretional Statistics for EPR

Category	Erosional Transects	Accretional Transects
Number of transects	6753	4047
% Out of total transects	62.37%	37.63%
% Of transects having statistically significant erosion/accretion	60.62%	35.6%
Maximum value	-1793.87 m	1049.52 m
Average of rates	-57.17	91.65

From the above stats, EPR proves that coastal line of Gulf of Khambhat has gone under erosion over the past 30 years.

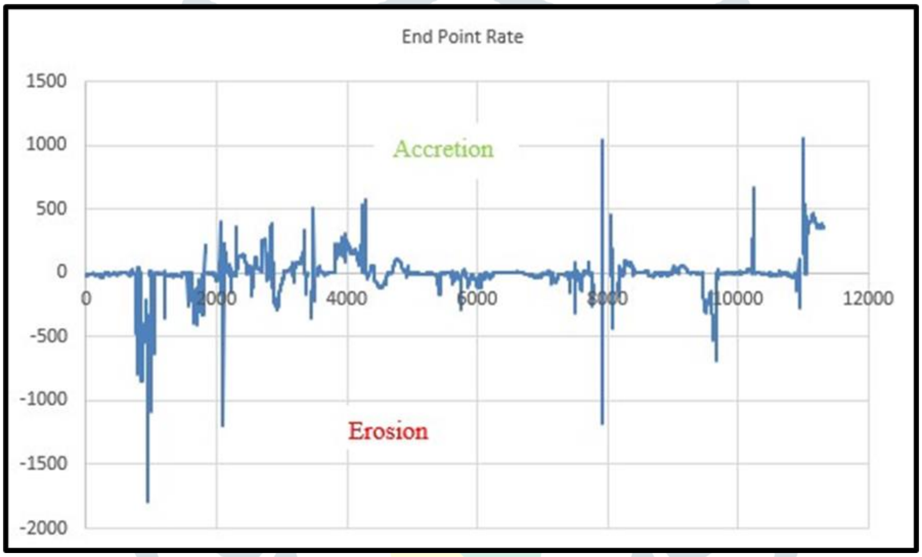

Figure 5 Accretion/Erosion vs Coastal Length via EPR Method

Above Figure shows erosion and accretion trend based on the coastal length over the Gulf of Khambhat region. Most of the part has shown erosion. The drastic changes in values can be seen here, this area are the estuaries of various rivers falling under the study area. The maximum erosion has taken place at the value 800 which is almost -1800 meters. While the maximum accretion has happened at 8000 which is approximately 1000 meters.

4. Conclusion

Remote sensing and GIS applications proves to be powerful tool for studying the coastal dynamics for a long period over the vast area like Gulf of Khambhat. DSAS tool takes shoreline for various years to be studied as input and generates the statistical results along with the spatial maps for better visualization of the trend. For such purposes, shorelines for the period of 1991 to 2021 is extracted using OTSU algorithm in the gap of 10 years.

From the results obtained by DSAS tool, it can be concluded that, from the period of 1991 to 2021 the rates of shoreline position changes indicates that the transects are erosional and less accretional. Majority of accretion is visible near the Sabarmati River meeting the Gulf areas. Whereas majority of erosion can be seen near the bottom left i.e., parts near the Setrunji River.

Over the period of last 30 years, the average erosion is 552.35 m/year, and the average accretion is 926.41 m/year by combining the results from all the three methods. The long-term shoreline changes analysis indicates that most of the shorelines in Gulf of Khambhat region have undergone erosion. Maximum erosion is observed in estuary areas where major river meets the gulf area.

5. Future scope

Future study can be carried out for more detailed and scaled area of the region to observe the erosional or accretional trend. There are many factors affecting the shoreline dynamics for example transportation of the sediments from various estuaries, morphological changes happening in the region and many more. Intertidal zoning can be carried out to observe the land use changes affecting the shoreline and nearby environment. Various data of constructions of dams, expansion of any industries or ports, deforestation, etc. taking place over the years can be considered to analyse the coastal dynamics more closely.

References

[1] K. Addo and K. KS, "Quantitative analysis of shoreline change using medium resolution satellite imagery in keta," vol. 1, no. 1, 2011.

[2] O. Frihy and L. MF, "Shoreline changes and beach-sand sorting along the northern Sinai coast of Egypt," *Geo-Marine Letters,* no. 2, pp. 140-146, 1997.

[3] N. Chandrasekar, C. Anil, M. Rajamanickam, and and G. Rajamanickam, "Coastal landform mapping between Tuticorin and Vaippar using IRC-1C Data," *Ind. Jour. Geom.* , vol. 5, no. 1, pp. 114-120, 2005.

[4] S. Charatkar, D. Mitra, R. Biradar, and and K. Radhakrishnan, "A Study of erosion and accretion along the Gulf of Khambhat, Gujarat coast using remote sensing and GIS," *In Joint Congress on Agriculture,* pp. 574-589, 2004.

[5] R. Dolan, M. Fenster and S. and Holme, "Temporal analysis of shoreline recession and accretion," *Journal of coastal research,* pp. 723-744, 1991.

[6] H. Rachel, K. Meredith, A. H. Emily and S. F. Amy, "usgs.gov," WOODS HOLE COASTAL AND MARINE SCIENCE CENTER, 4 October 2018. [Online]. Available: https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas#overview.

Web Links:

- http://www.hydrobharat.nic.in
- http://kalpasar.gujarat.gov.in
- http://cwc.gov.in
- http://www.nio.org
- www.eathexplorer.gov.us
- https://bhuvan.nrsc.gov.in/
- www.soinakshe.uk.gov.in

Books:

- Dr. Ajai; Dr. Shailesh Nayak (2012), "Coastal Zones of India", published by Space Application Centre, ISRO, Ahmedabad.
- DSAS Manual
- "Integrated Hydrological Data Book" (2015), published by Central Water Commission, New Delhi