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Research Article

Shoreline Change Analysis Using Digital Shoreline Analysis System (DSAS) in the Coastal Area of Jambusar, Gujarat, India

Sarita Singh[1], Hitesh Solanki[1]* and Indra Prakash[2]

[1]Department of Climate Change Impacts Management, School of Science, Gujarat University, Ahmedabad, Gujarat, India

[2]Bhaskarcharya Institute for Space Applications and Geo-informatics (BISAG), Gandhinagar, India

***Corresponding Author:** Hitesh Solanki, Department of Climate Change Impacts Management, School of Science, Gujarat University, Ahmedabad, Gujarat, India.

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Abstract

The shoreline keeps changing with respect to time due to hydrodynamic actions of sea/ocean waves in the open coast. In the Gulf area shore line changes are controlled by river flows and sediments movement from inland besides sea waves. The Gulf of Khambhat, India is a dynamic area in the Arabian Sea with tidal waves height varying from 8 m to 11m modifying the morphology of coastal zones. In this study we have selected Jambusar taluka forming eastern boundary of this Gulf for shoreline change analysis using Digital Shore Analysis System (DSAS) software. Remote sensing and GIS techniques were used for demarcating and extracting coastline from Landsat images of 1998, 2009, 2017, and 2021 as an input in the DSAS for change detection and assessment. The results of the study indicated that the Jambusar coastline is mainly under erosion: 20% under high to moderate and 52.83% under Very low erosion, 20%. About 26% coastline is showing accretion, out of which 17.19% under high accretion. DSAS has also provided the rate of erosion and accretion in the coastal zone of Jambusar which can be used for proper coastal management considering shoreline changes.

Keywords: Shoreline Change; DSAS; Remote Sensing; GIS; Jambusar

Introduction

Shorelines or coastlines are one the most dynamic landforms on the earth. The shoreline can be defined as physical interface of land and water [20]. Around 10% of the world's population's lives in the coastal areas within 10 meters above sea level. As a borderline between the land and sea, the shorelines are subject to continuous change due to their dynamic environmental setting [4], this makes it very important to study and monitor the coastal belts.

The shoreline change can be a long process or a result of short term extreme events, therefore, shoreline change occurs on wide range of timescale [13]. There are two forms of shoreline change namely accretion and erosion. These changes can take place by natural or manmade activities, the natural activities contributing to changes are waves, tides, sediment deposit, periodic storms, winds [16]. The manmade activities include building of infrastructures, beach sand removal for construction, dredging activities for ships movement, creation of recreation facilities and hotels [14,15].

To study the shoreline changes analysis we have selected Jambusar taluka, Bharuch District, Gujarat, which is located in the Gulf of Khambhat, India in the Arabian Sea (Figure 2). The entire shore lines in this Gulf is dynamic and marked by fluctuating mudflats, tidal flats [19]. In general coastline along the gulf of Khambhat shows more of erosional behaviour as compared to accretion [19]. Additionally, there are studies on the estuarine areas of Mahi River [17,18]. They also indicate erosional activities and due to this there has been change in the course of the river flow and creation of two small islands from the mainland [6].

Globally, qualitative and quantitative analysis of shoreline spatio-temporal variations has been addressed by several studies [4,5,13]. The most common statistical method used for shoreline change analysis are End Point Rate (EPR) and Linear Regression Rate (LRR) [11,12]. In this study we have carried out shoreline change analysis in the Jambusar coastal zone extending in about 100km length from the mouth of the Mahi River to the Mouth of the Dhadhar River using Remote sensing and GIS technology; and Digital Shoreline Analysis System (DSAS) software. DSAS is a computer software that helps in understanding the positional changes of the shoreline [1]. The Jambusar coastline data of four different year's period: 1998, 2009, 2017, and 2021 was used in the change analysis study.

Study area

In this study we have selected coastal zone of Jambusar Taluka, Bharuch district, Gujarat, India as a study area. Jambusar is forming part of the eastern boundary of the Gulf of Khambhat between 21°45' and 22°15' N latitudes and 72°30' and 72°45' E Longitudes bounded by the Mahi River in the North and Dhadhar River in the South (Figure 2). The length of the shoreline of Jambusar is about 100 km. The coastal geomorphology of the area is marked by estuaries, mudflats, shoals and salt pans [8,10]. The height of the tidal range in Gulf area varies between 8 to 11 m. The current velocities are very high in the Gulf reaching up to 10 m/s [7]. In general, climate of the area is sub humid to moderately humid. Satellite image studies show that mangrove vegetation in the area increased from 279.87 ha in 1978 to 1298.26 ha in 2012 and subsequently it is decreasing in the southern part of Jambusar Coast [9] (Figure 1). This may be due increase of Salt pan industries in the area.

Figure 1: NDVI image of study area showing mangrove vegetation and salt pans.

Material and Methodology

Materials: Landsat 5 and 8 Images and Google historical images were used for the present study of the shoreline extraction and change analysis. Details of Landsat images used in this study for covering 23 years period are given in table 1.

The images used are in World Geodetic System (WGS 84) and UTM projection system.

Figure 2: Location map of the Study area.

S.no	Satellite	Resolution	DATE_ACQUIRED	Spectral Bands	Path/Row
2	LANDSAT_5	30m	1998-05-02	7	148/045
3	LANDSAT_5	30m	2009-10-23	7	148/045
4	LANDSAT_8	30m	2017-03-19	11	148/045
5	LANDSAT_8	30m	2021-04-15	11	148/045

Table 1: Details of Landsat images of the year 1998, 2009, 2017 and 2021.

Methodology

Methodology of the study included demarcation and extraction of shorelines from the multi-temporal satellite images using Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) by adopting binary classification method. Figure 2 show NDWI methodology of extraction of shore line from Landsat image. NDWI was considered better for demarcating the land and water interface [3]. For the calculation of NDVI equation used is NDVI = (NIR – Red)/(NIR + Red), whereas for the calculation of NDWI equations (1), (2) and (3) were used to extract shorelines.

NDWI = (G - NIR)/(G + NIR) ------------(1)

Where NIR is Near Infra-Red Band and G is Green band.

Formula for the calculation of NDWI from Landsat 5 image is given in Equation 2.

NDWI = (Band 2 – Band 4)/(Band 2 + Band 4) ------------(2)

Formula for the calculation of NDVI from Landsat 8 image is given in Equation 3.

NDWI = (Band 3 – Band 5)/(Band 3 + Band 5). ---------- (3)

Figure 3: Methodology of extraction of shoreline/ coastline from LANDSAT 2017 image using NDWI

The demarcated and extracted shorelines were validated using historical Google earth images (Figure 4).

Figure 4: Extracted shorelines covering different period (1998, 2009, 2017 and 2021) using NDWI method.

Application of Digital Shoreline Analysis System (DSAS) for shoreline change analysis.

DSAS is a computer software developed by ESRI for the calculation of shoreline change (https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas). Figure 5 describes the methodology of the use of DSAS software. The requirements to operate DSAS are the polyline shape files of the coastline extracted of all the years in merged form and a buffer area covering all the shoreline for baseline creation.

Figure 5: Methodology of DSAS sftware for the use in shoreline change analysis.

The DSAS software is run using the shoreline and Baseline features and transects are created perpendicularly from baseline to the shoreline. Figure 6 shows transects created on the satellite image of 2017 with historical shorelines along with the baseline. DSAS calculates a range of Statistical changes based on shorelines of different years, these changes are NET Shoreline Movement (NSM), Shoreline Change Envelope (NCE), End Point Rate (EPR), Linear Regression Rate (LRR) etc.

Figure 6: An output from DSAS analysis of the study area in ArcGIS showing the transects and the historical shorelines.

Of all the statistical calculation in present study only EPR and LRR has been taken into consideration for comparison and calculation of rate of erosion and accretion.

$$EPR = \frac{NSM}{\text{time Between oldest and most recent shoreline}} \quad \text{- ---------(4)}$$

LRR is determined by fitting a least - square regression line to all shoreline points for a transect. The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. (User Guide DSAS version 5). Both EPR and LRR result values comes in positive and negative, where Positive value means the shoreline is showing accretion and the negative value indicated the region is having erosion.

Result and Discussion

In total 1571 Transect lines were created across 100 Km length of shoreline of Jambusar Coast. These Transects were of 50 m spacing within a length of 3500 Meter to cover all the four zig zag shorelines. Table 2 mentions the net result of the DSAS calculation related with shoreline changes.

Region		Jambusar Coastline
Number of Transects		1571
Transect Spacing (m)		50
Transect Length (m)		3500
Baseline Distance from Coastline		800
Average Accretion (m/yr)	EPR	12.70722222
	LRR	8.151831325
Average Erosion (m/yr)	EPR	-13.01228435
	LRR	-12.01937443
Max Accretion (m/yr) (transect number)	EPR	200.58 (906)
	LRR	31.28 (905)
Max Erosion (m/yr) (transect number)	EPR	-135.59 (1434)
	LRR	-105.16 (1163)

Table 2: Shoreline Change trends in Study area.

Results indicate that the average accretion EPR is 12.7 m/year and the average erosion EPR of the coastal region is -13.01 m/Year. Maximum accretion is shown by the transect number 906 with EPR of 200.58 m/year and the maximum erosion is shown by the 1434 transect with EPR value of -135.59 m/year. The LRR average accretion is 8.15 m/year and the average erosion is -12.01 m/year. Figure 7 and Figure 8 shows the statistical change rate of erosion and accretion by EPR and LRR respectively. Figure 9 and 10 show correlation of shoreline changes with DSAS results. Visually it can be seen that DSAS results can be very well correlated with the historical Google Earth images. Figure 11 depicts the overall shoreline change rate accretion or erosion using EPR and LRR.

Figure 7: Transects showing the change rate using EPR.

Figure 8: Transects showing the change rate using LRR.

Figure 9: Google Earth Image of 2021 superimposed with shoreline of year 1998

Figure 10: Transects Created in DSAS overlapping with Google earth images.

Figure 11: DSAS result of shoreline change rates (accretion/erosion) using EPR and LRR.

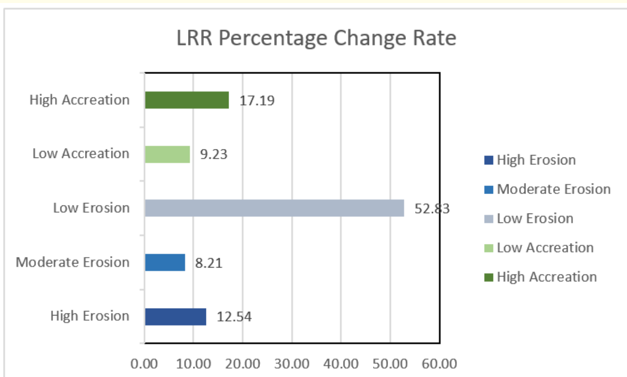

Figure 12: Percentage change rate (erosion and accretion) using LRR.

Concluding Remarks

The shore line change analysis of the Jambusar taluka, Gujarat, India has been conducted using DSAS software and results were validated from historical Google earth images and available published records. It has been observed that the shoreline in this area is following general trend of Gulf of Khambhat. Major part of the coastal zone is under erosion. The average accretion EPR is 12.7 m/ year and the average erosion EPR of the coastal region is -13.01 m/Year. The shoreline change analysis by DSAS will help not only Jambusar but entire Gulf and also open coastal areas if applied by correctly extracting shore lines with the help of remote sensing and GIS technology. It is proposed to carry out this study further for the forecasting of shoreline changes by combining other hydrodynamic and meteorological parameters.

Conclusion

The present study represented a shoreline changes analysis of 23 years using satellite image and DSAS Software. Four satellite images of different years (1998, 2009, 2017 and 2021) were collected and processed for shoreline extraction and shoreline change calculations using DSAS. It was found out that the major portion of the shoreline was undergoing erosion activities, this is attributed majorly because of the location of the study area near the gulf and is accompanied with two close estuaries and few other estuaries associated in the same gulf. In the southern region portions of the shoreline shows high accretion rate and the credit is given to the mangrove plantation and the salt pan industry expansion Figure 1. There have been fewer studies in the Jambusar coastal regions pertaining to shoreline change, the continuous monitoring of shoreline change represents a vital step in understanding the dynamism and evolution of coastal area and stakeholder could do better for reducing risk of coastal erosion and also minimized social, physical and economic loss [2]. Improvement in land management, focusing on protection of existing natural barriers like Mangroves, strengthening of infrastructure is the best adaptation options.

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