Shoreline Change Analysis along Eastern Part of Kachchh Coast, Western India

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Abstract: Shoreline is a dynamic and complex region of all geomorphic features, as it is affected by mix effects of aeolian, tidal, tectonic and riverine activities. The coasts are of immense geological, geomorphological and ecological interest. Monitoring and mitigation of shoreline erosion along populated coastal areas is an important task and remains a difficult goal to achieve. The rapid coastal changes are monitored by Remote Sensing and GIS tools. The aim of this paper is to monitor the shoreline change. The study area is rapidly changing at alarming rate due to natural and anthropogenic activities. The coast of Eastern Kachchh extends from Mandvi in west to Kandla in east covering a distance of about 110 km. In this study, an attempt has been made to investigate the shoreline transformation along the East Kachchh coast. Data used are derived from fair weather satellite images of LANDSAT from 1990 to 2014 to delineate the shoreline. A Linear Regression Rate-of-change (LRR) and an End Point Rate (EPR) statistic were carried out using Digital Shoreline Analysis System (DSAS) computer software of United States Geological Survey (USGS).

Index Terms: Shoreline, Remote Sensing, GIS, DSAS

1. Introduction

Shoreline idealistically defined as the interface of land and water (Dolan et al. 1980 and Horikawa 1988), is supposedly to be one of the most active processes in the coastal area. The evolution of coastal systems is controlled by various factors viz., morphology, size and geology of the catchment, nature of sedimentation basin, climate leading to rainfall and river discharge at coastal zone, freshwater input and coastal hydrodynamics - waves, tides and currents (Albert and Jorge, 1980). Wind, waves and currents are natural driving forces that easily move the unconsolidated sand and soils in the coastal area, resulting in rapid changes in the position of the shoreline. The coastal system have also been affected by several anthropogenic and developmental activities such as ports, industries, aquaculture farming and other human intervention in the form of coastal defenses.

Remote sensing provides a platform for rapid delineation of the coastlines at relatively low cost. Repeated observations over the time allow a detailed quantification of shoreline changes. In addition, coastal morphology may be quantified by the union of remotely sensed data with information on the historic coastline position from archived sources. Remotely sensed data can also provide valuable preliminary estimates of changes and is a unique tool for research and monitoring coastal areas and deltaic environments (Ciavola et al. 1999; Yang et al. 1999).

Shoreline is subjected to continuous changes due to natural causes and anthropogenic interventions in coastal areas. Identifying the region vulnerable to erosion and quantifying its extent is essential for coastal zone management. Shorelines are always vulnerable to changes due to coastal processes, which are controlled by wave action, sediment characteristics, beach forms, etc. (Kumar et. al., 2010). Studies examining long-term and short-term shoreline changes have generally utilized satellite data (Maiti and Bhattacharya, 2009; Ford, 2013); beach profile analysis (Thom and Hall, 1991; Dora *et al*., 2012) and aerial photographs (Anders and Byrnes, 1991; Jimenez *et al*., 1997; Kurosawa and Tanaka, 2001; Ford, 2013). Factors influencing coastline changes in an intermediate time scale are more complex and which includes both natural and anthropogenic causes. In most of the studies shorelines are manually digitized from satellite images and calculate the changes using GIS analysis (Chen and Rau 1998).

The GIS and Remote sensing technology has been recognized as one of the most dominant tool for quantifying the shoreline changes on temporal scales as it provides the information in digital form (Nayak 2002; Zuzek *et al*., 2003; Thieler *et al*., 2009). Dolan *et al*. (1991) compared long-term and short-term erosion rates with various methods such as end point rate (EPR), linear regression rate-of-change (LRR). The objective of this research work is to determine the baseline information of shoreline changes for eastern part of Kachchh coast using remote sensing (Satellite) data in GIS environment, vis-a-vis monitoring and understanding of long-term seasonal as well as short-term shoreline changes necessary to develop sustainable shoreline management plans.

2. Study Area

The study area (Fig. 1) fall between the east Kachchh coast between Longitude 69°20'46" E and 70°11'49" E and Latitude 22°49'59" N and 22°59'49" N, with length of about 120 km and consists of coastal stretch of Mandvi, Mundra, Anjar and Gandhidham taluka of Kachchh district of Gujarat. The coast is bordered by Gulf of Kachchh in the east and Arabian Sea in the west. Gulf of Kachchh, a semi-enclosed basin with a high tidal range of ~4m at its mouth to ~7m at its head is having shallow depth of around 60 m at the mouth to less than 20m near the head. The temperature of the region varies from 12 °C to > 36 °C. Humidity is higher in monsoon i.e. up to 80% while remaining year around 55 to 70 %.

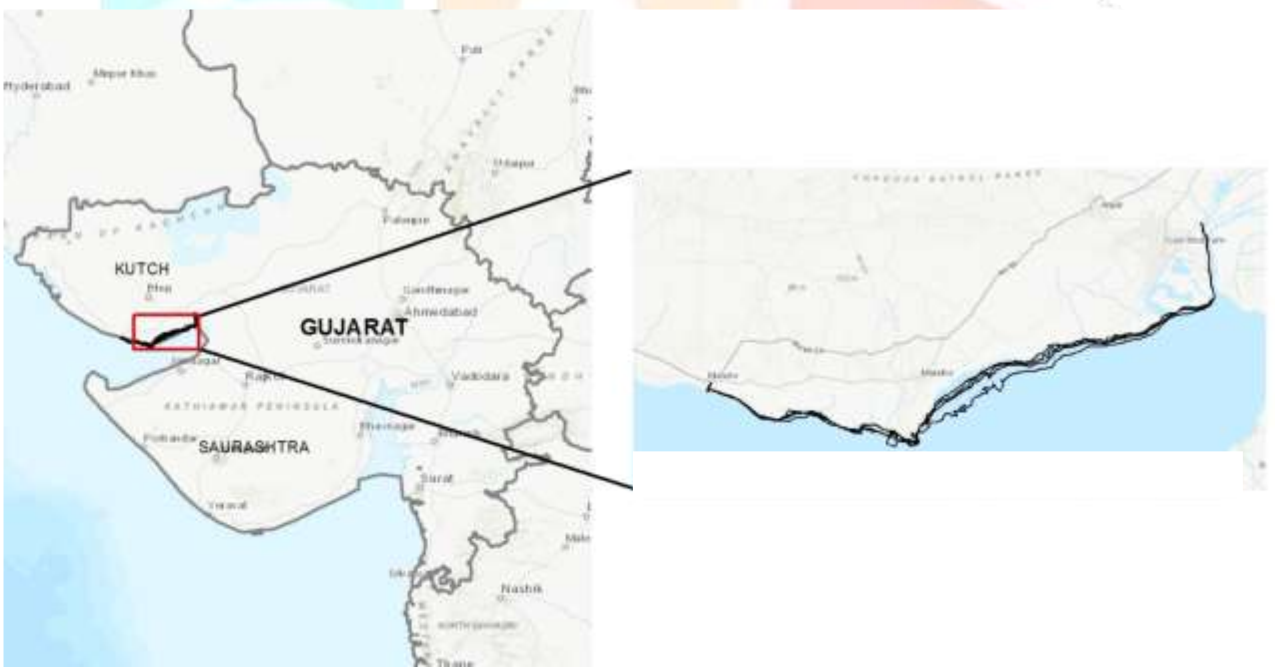

Fig.-1 Map of the Study Area: Location Map. Inset showing the coastline from Mandvi to Kandla Coast, Eastern Kachchh Coastline

3. Methodology

The Shoreline change of the coast in the study area was analyzed for a period of 25 years (1989 to 2014), which is regarded as medium term analysis (Crowell et al. 1993; Anfuso and Martinez Del Pozo 2009). Ortho-rectified satellite images of study area from the sensors Landsat MSS, ETM+ and OLI-TIRS in the years, 1989, 1999, 2008, and 2014 were downloaded from USGS Earth Explorer. Additional information about the specifications of satellite data used in the study is given below in Table 1. The average tidal range along the study region is moderate to high about 3 to 7 m

(Nair, 2002) hence no additional corrections are undertaken for the delineation of shoreline other than approximately common acquisition time and period of the year.

Sr. No.	List of Image	Pixel Size (m)	Date	Source
1	Landsat 5 TM	30	02-11-1990	USGS
2	Landsat 7 ETM+	30	18-10-1999	USGS
3	Landsat 5 TM	30	11-05-2008	USGS
4	Lanssat 8	30	17-04-2017	USGS

Table – 1 Detail of Images procured for Shoreline demarcation.

The most suitable band for the demarcation of the land–water boundary has been identified as the near infrared band (Maiti and Bhattacharya 2009), is used in the study to extract the shoreline from satellite. A binary image was formed using near infrared band of each image by histogram splicing technique and were classified unsupervised to form image with complete separation between land and water classes. These classified images were used to extract the shorelines in the form of vector layer using ArcMap 10.1. The digitized shorelines in the vector format of the years 1991, 1998, 2006 and 2014 were used as input in Digital Shoreline Analysis System (DSAS) extension of ArcGIS, for calculating shoreline change rate. DSAS computes rate of change statistics from multiple historic shoreline positions residing in a GIS (Thieler et al. 2005).

Using DSAS, transects were spread perpendicular to the baseline at a 50 m interval all along the shoreline. Interactions of these transects with shoreline along the baseline is then used to calculate the rate-of-change statistics. Linear Regression Rate (LRR) method of shoreline change rate estimation was used in this study. LRR uses all the available data to find a line, which has the overall minimum of the squared distance to the known shoreline and is an established method for computing long-term rates of shoreline change (Crowell and Leatherman, 1999).

In addition to the LRR, End Point Rate (EPR) for the shoreline was also computed for the shorelines making use of the same transects. EPR is calculated by dividing the distance of total shoreline movement by the time elapsed between the earliest and latest measurements at each transect. Study does not involve specific analysis at different morphological features.

4. Geographical Information System (GIS)

Continuous shoreline positions were extracted automatically and digitized manually for four different periods i.e. 1990, 1999, 2008 and 2014. Digital Shoreline Analysis System (DSAS) version 4.4, an extension of ESRI ArcGIS software was used to calculate shoreline rate-of-change statistics from a time series of multiple shoreline positions. The shoreline positions were compiled in ArcGIS with 5 attribute fields that included ObjectID (a unique number assigned to each transect), shape, shape length, ID, date (original survey year) and uncertainty values. All different shoreline features were then merged within a single line on the attribute table, which enabled the multiple coastline files to be appended together into a single shape file. The Shoreline change rate was calculated by End Point Rate (EPR) for short term and Weighted Linear Regression (WLR) for long term period. DSAS is purely a statistical approach. A baseline was digitized onshore by closely digitizing the direction and shape of the outer shoreline, which was used as the starting point for all transects cast.

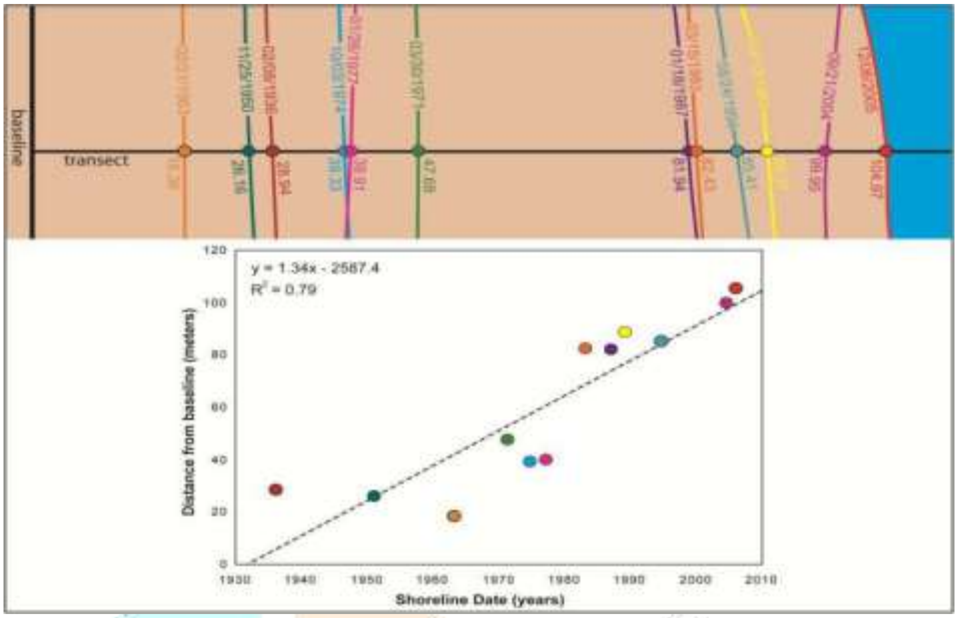

Fig-2 Example of Linear Regression Rate Calculation

Using DSAS transects were taken perpendicular to the baseline at a 50 m interval all along the shore. Interactions of these transects with shoreline along the baseline were used to calculate the rate-of-change statistics. Linear Regression Rate (LRR) method of shoreline change rate estimation were used in this study. LRR uses all the available data to find a line, which has the overall minimum of the squared distance to the known shoreline and is an established method for computing long-term rates of shoreline change (Crowell and Leatherman, 1999).

LRR and End Point Rate (EPR) for the shoreline was calculated for the shorelines making use of the same transects. EPR is calculated by dividing the distance of total shoreline movement by the time elapsed between the earliest and latest measurements at each transect. Rate of change calculated in this study is particular to total Kachchh coastline.

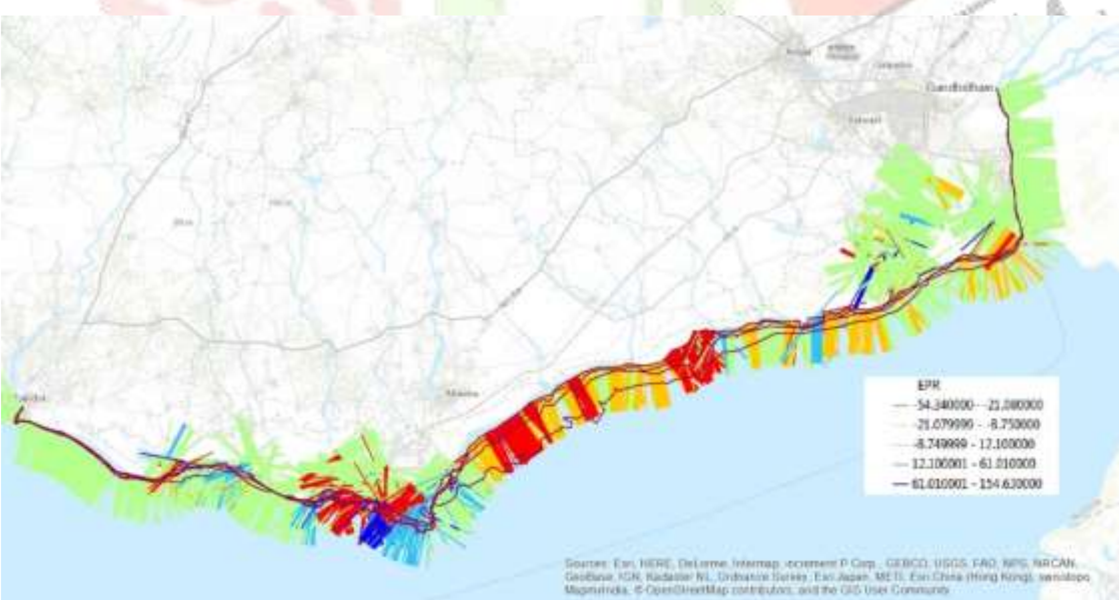

Fig – 3 Transects showing EPR of the Study Area

5. Result and Discussion

Overall an average of 4.6 m/yr accretion and about 3.2 m/yr erosion was noticed along the study area. Table 2 provides the details of LRR and EPR for 4 sections. The average rate in the table is the average of LRR values for the number of transects taken into consideration for statistical analysis. Negative values in the table indicate the erosion where as positive values represent accretion. Highest accretion rate in the study area of 159 m/year in Kandla segment followed by 90.68 m/ year in Mandvi, 85.01 m/year in Mundra segment, 75.28 m/year in Bhadreshwar segment respectively was noticed. Mean rate of LRR is highest in Mundra segment which shows overall depositional nature of this segment and in particularly northern part of Mundra port has acccretional nature while west of port has bit of erosional nature. Mundra segment has most erratic behavior as far as accretion and erosion is concerned. Maximum accretion is in Bhadreshwar segment and i.e. between 1990 and 2008 but later this section has undergone erosion till 2014 and still it is in erosional phase, which has reduced overall effect of accretion in Bhadreshwar area. Mandvi and Kandla coast shows little depositional nature with average 2.0 to 4.0 m/year but overall it shows stable characteristics. Overall mean accretion is seen in area with 8.42 m/year in Mandvi, 9.66 m/year in Mundra, 7.34 m/year in Bhadreshwar and 0.75 m/year in Kandla respectively. There was more of deposition in area from 1990 to 2008 but since then till 2014 it has shown erosional trend.

Segment		Mandvi	Mundra	Bhadreshwar	Kandla
No. of transects		1-1000	1000-2100	2100-3000	3000-4500
LRR	Mean Rate	8.42	9.66	7.34	0.75
(m/yr)	Standard Deviation	23.64	19.90	21.13	22.14
	Highest Accretion	90.68	85.01	75.28	159
	Highest Erosion	-74.67	-158.84	-158.84	-148.21
EPR	Mean Rate	4.44	-10.71	8.27	-0.4
(m/yr)	Standard Deviation	26.63	20.15	21.27	19.40
	Highest Accretion	94.47	103.33	75.28	149.75
	Highest Erosion	-101.02	-157.65	-158.84	-124.69

Table 2: Details of LRR and EPR for each section

6. Conclusion

The study focuses on the medium term shoreline change analysis of Kachchh coast from Mandvi to Kandla, being having two very important ports of country, i.e. Mundra and Kandla of Kachchh coast using combination of remote sensing and GIS techniques for the detection of coast movement that changes over time in response to economic, social, and environmental forces, since know how about the changes can facilitate suitable planning, management, and regulation of coastal zones. Overall average accretion was 4.6 m/yr and erosion was 3.2 m/yr along study area. Highest accretion was observed in Bhadreshwar area between 1990 and 2008 and almost equal amount of erosional effect is also seen in the same area giving the net accretion of 7.0 m/yr. The present study suggests that multi-dated satellite data along with statistical techniques can be effectively used for prediction of shoreline changes.

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