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SHORELINE CHANGE MONITORING ALONG THE SOUTH GUJARAT COAST USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

The present study is to investigate the shoreline changes along the South Gujarat coast using multi temporal satellite images of Landsat MSS (1972), Landsat TM (1990), Landsat ETM (2001) and IRS P6, LISS-IV (2011). The coastal stretch of the study area is 124 km and it is distributed in part of three districts of Surat, Navsary and Valsad district in Gujarat and part of Daman union territory. The shoreline is considered as the high tide line (HTL) as it is easily photo interpreted and field located. Visual interpretation of satellite imagery has been carried out to demarcate the HTL based on various geomorphology and land use & land cover features. The satellite data has been processed in ERDAS IMAGINE s/w and HTL is demarcated in ARC Map s/w. The study found that coastal erosion is a major problem in the study. Presently, (i.e., 2001 to 2011 time period) about 83.06 % of the South Gujarat coast is eroding, about 10.15% of coast is stable and about 6.78 % of the coast is accreting in nature. The highly eroding areas occur along the southern portion of the study area particularly Valsad district. The main causes of coastal erosion of the study area were the strong tidal currents accompanied by wave action and reduced the sediment of the river. Various protection measures are observed such as sea wall and rubble dumping etc. The severity of erosion is alarming and draws immediate attention.

Key Words: *Shoreline, High Tide Line (HTL), Remote Sensing, GIS*

INTRODUCTION

An idealized definition of shoreline is that it coincides with the physical interface of land and water (Dolan *et al.*, 1991). Shoreline change is considered to be one of the most dynamic processes in the coastal area and the change in shoreline, caused due to physical as well as anthropogenic process and have a large environmental significance (Chen *et al.*, 2005). These changes occur over both long and short terms and involve hydrodynamic, geomorphic, tectonic and climatic forces (Scott, 2005; Thom and Cowell, 2005). Therefore, the study of shoreline position is of utmost importance for management purposes like developmental planning and hazard zonation or academic endeavours, determination of erosion and accretion, estimation of regional scale sediment budgets etc (Sherman and Bauer, 1993; Zuzek *et al.*, 2003). In the present study analyses the shoreline changes along the south Gujarat coast, India using multi temporal and multi resolution optical satellite images.

Long-term shoreline changes assessment had been carried out using aerial photographs (Dolan *et al.*, 1979; Leatherman, 1983; Leatherman and Zaremba, 1986; Smith, 1990) and using satellite images (Gangadhara and Subrahmanya, 1993; Gangadhara, 1995) and by many others researchers. Because of their synoptic viewing capability, multispectral observations, high resolution, receptivity and its cost effectiveness in comparison to conventional techniques, the remotely sensed data products are extensively used for detecting long-term shoreline changes and to know the evolution of the coastal and near shore areas. Shoreline-change mapping was carried out for the entire Indian coast for the periods 1967–68, 1985–89 and 1990–92 using LANDSAT MSS/ TM and IRS LISS II data on 1 : 250,000 and 1 : 50,000 scale (Shailesh Nayak, 2002). Shoreline changes study along the different part of Indian coast has been carried out by many researchers such as Mani *et al.*, (1997), Thanikachalam and Ramachandran (2003), Navrajan *et al.*, (2005), Sathyanarayan *et al.*, (2009), Pritam and Prasenjit (2010), Mujabar and Chandrasekar (2011), Abdulla *et al.*, (2011), Abhisek *et al.*, (2011), Saranathan *et al.*, (2011).

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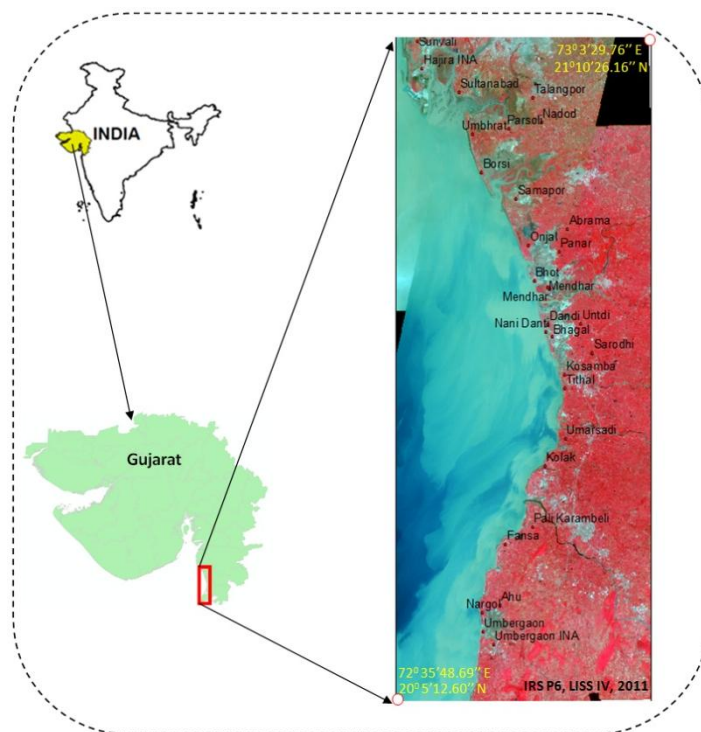


Figure 1: Study Area

Study Area

A coastline of about 124 km in South Gujarat, falling part of three district of Gujarat such as Surat, Navsari, Valsad and Daman union territory) has been investigated in the present study (Figure 1). The geographical extends is from $21^{\circ}05'12.60''\text{N}$ to $21^{\circ}10'26.16''\text{N}$ in latitudes and $72^{\circ}35'48.69''\text{E}$ to $73^{\circ}03'29.76''\text{E}$ in longitudes. The coast line of the study area is comparatively uniform and broken by few indentions. Narrow sandy beach is present between Mindhola and Purna rivers and extends up to Daman. Mudflats, marsh and mangrove vegetation are found along the estuaries of the Mindhola, the Purna, the Ambica, the Auranga and the Damanganga. Numerous small tidal creeks are also found along the study area. South of Auranga estuary, the coast is rocky. The major rivers of the study area are Damanganga, Kolak, Par, Purna, Auranga, Ambica and Mindhola etc which are comparatively smaller and rise within the boundaries of the state from the eastern trappean highlands. The maximum tidal height and significant wave height increase from northern side i.e. near Hajira to southern side i.e. near Umbergaon. The maximum tidal height near Hazira and Valsad are 5.78 m and 7.77m respectively where as the maximum significant wave height near Hazira is 0.97 and near Valsad is 2.47m.

MATERIALS AND METHODS

Data Used

In the present study, we used Landsat MSS of January, 1972, TM January, 1990 , ETM of January, 2001 and Indian remote sensing satellite IRS P6 (Resourcesat-2), December, 2011 for monitoring shoreline changes along the south Gujarat coast (table 1).

Pre-processing of Satellite Imagery

Four satellite imageries of the years 1972, 1990, 2001 and 2011 have been considered in this study. Landsat MSS and TM data sets have been acquired from USGS [website <http://glovis.usgs.gov>]. IRS P6

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LISS IV data has been procuring from NRSC [www.nrsc.gov.in]. The satellite data has been process in ERDAS IMAGINE s/w.

Table 1: Details of satellite data date of acquisition and resolution

Satellite and Sensor	Date of Acquisition	Path & Row	Band Used	Spatial Resolution (M)
LANDSAT MSS	11/10/1972	159-45	VNIR	60
	11/10/1972	159-46	VNIR	60
LANDSAT TM	19/10/1990	148_45	VNIR	30
	19/10/1990	148_46	VNIR	30
LANDSAT ETM	10/11/2001	148_45	VNIR	30
	25/10/2001	148_46	VNIR	30
IRS-P6 LISS-IV	02/11/2011	93/57/a	VNIR	5.8
	22/11/2011	93/56/c	VNIR	5.8

All the data sets are projected in UTM projection with zone no 46 and WGS 84 datum. Satellite imagery of 1990 has been considered as base data and images of 1972, 2001 and 2011 have been co-registered using first order polynomial model with base data with 0.4 pixel (RMSE) accuracy. Normal false colour composites (FCCs) prepared using, bands 2, 3, 4 (Landsat MSS ,TM and IRS p6 resourcesat-2, LISS IV) in contrast to black and white (B/W) images yield better discrimination for the wetlands and are, therefore, more suitable for mapping and delineation of shoreline. The satellite data has been enhanced linearly for better visualization and delineation of shoreline.

Shoreline Indicator

There are many shoreline indicators such as high water line, mean high water line, low water line, and mean tide line. The high water line (HWL) is the preferred indicator for shoreline delineation due to easily photo interpretation, field location (Mary and Stephen, 2002). High water line means the line on the land up to which the highest water line reaches during the spring tide. The horizontal location of the mean high water line on a gentle sloping sandy beach, although precisely defined with respect to elevation, highly variables because the beach and foreshore are dynamic. Thus, the use of the high water line is a practical solution to locating the land/sea boundary in a dynamics environment (Pajak and Leatherman, 2002). The position of the high water line is affected by astronomical tides, seasonal beach change, storm events, and wind and tides (Pajak and Leatherman, 2002).

Detection of Shoreline

In the present study high tide line (HTL) is considered as shoreline. HTL means the line on the land up to which the highest water line reaches during the spring tide. Satellite data has been interpreted to demarcate HTL based on various geomorphological and land use / land cover features like land-ward berm /dune crest, seawalls or embankment, permanent vegetation line, landward side of mangroves, beaches, salt pans, high-tidal mud flats and salt marshes. Sea ward side of agricultural/horticulture land etc. are also used. Arc Map s/w was used to delineated the HTL. The erosion, accretion and stable coast area were found out in overlay techniques in GIS system.

Ground Trough

Finally, erosion, accretion and stable coast were assessed for the time period of 1972-1990, 1990-2001 and 2001-2011 (Figure 2). After the shoreline change detection field survey was carried out all along the study area. The aim was to collect more data and information from the field and interview the people from the study area. The people interviewed were asked about the status of the shoreline in relation to previous years. A number of photographs were also taken of the study site using a digital camera in order to capture the area's current appearance. The photographs show some vivid examples of

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shoreline erosion from the ruins of buildings that had collapsed due to shoreline erosion and protection structure of the coast (Figure 3).

RESULTS AND DISCUSSION

Analysing the multi temporal satellite images, the study find that about 83.06 % of the South Gujarat coast is eroding, about 10.15% of coast is stable and about 6.78 % of the coast is accreting in nature presently (i.e., 2001 to 2011). About 103 km length of the south Gujarat coast is eroding with a loss of about 3.65 sq. km area during the 2001 to 2011 time period.

Table2: Erosion and accretion during 1972 to 2011

Year	Erosion Area (Sq Km)	Erosion Length (Km)	Stable Length (Km)	Accretion (Sq Km)	Accretion Length (Km)
2001-2011	3.65	103.00	12.59	0.87	8.41
1990-2001	2.57	83.54	28.08	0.93	12.38
1972-1990	10.21	92.09	12.80	3.74	19.11

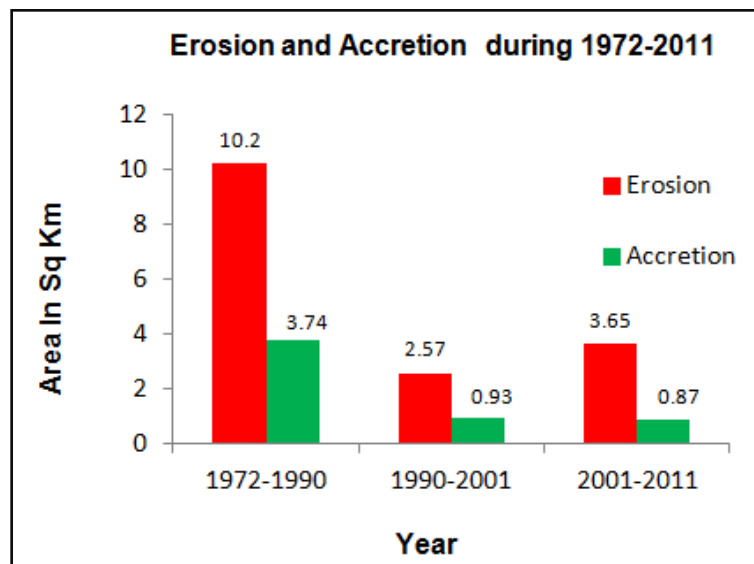


Figure 2: Erosion and accretion in south Gujarat coast

The highly eroding areas occur along the southern portion of the study area particularly Valsad district. The major erosion area were South of Umargam, near lighthouse, both side of Varoli river, Maroli, Phansa, Kolak-Udwada, Umarsadi, Sai Temple and Swaminarayan Temple in Tithal, Macchiwadd, near Onjal, Dandi and Dandi march. The total land gained by accretion was about 0.87 sq. km over a length of about 8.41 km during 2001-2011 time periods. Accreting coast occur along northern side of study area near Hajira, Chorasi taluk, Surat district, upper portion of Umarssadi, Navsari district. The remaining 12.59 km of the coast is stable in nature during 2001 to 2011. The stable coasts found near Daman, Umbhrat to Borsi, in Jalalpore taluk, Navsari district. During the period of 18 year (i.e., 1972 to 1990) the erosion and accretion areas were 10.21 and 3.74 Sq Km distributed over coastal length of 92.09 km and 19.11 km respectively. Presently (i.e., 2001-2011) the accretion length has been reduced as compare with the accretion length of 1972-1990. The erosion and accretion areas were 10.21 and 3.74 Sq Km respectively during the period of 1972 to 1990. The areas of erosion and accretion during 1972 to 2011 are shown in figure 2. The analysis of shoreline changes of three different time period, the study found

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that the erosion length is more as compare with the accreting and stable coast. The most erosion area was found along the Valsad district as compare to Navsari and Surat district. The erosion, accretion and stable coast in three different time period are shown in figure 3. The study found that the coastal erosion is a major problem in the study. The main causes of coastal erosion of the study area were the strong tidal currents accompanied by wave action and reduced in sediment input from the river. This large scale erosion in terms of time frame and extent may be due to sea level rise or tectonic movement. Various protection measures are observed such as sea wall and rubble dumping etc.

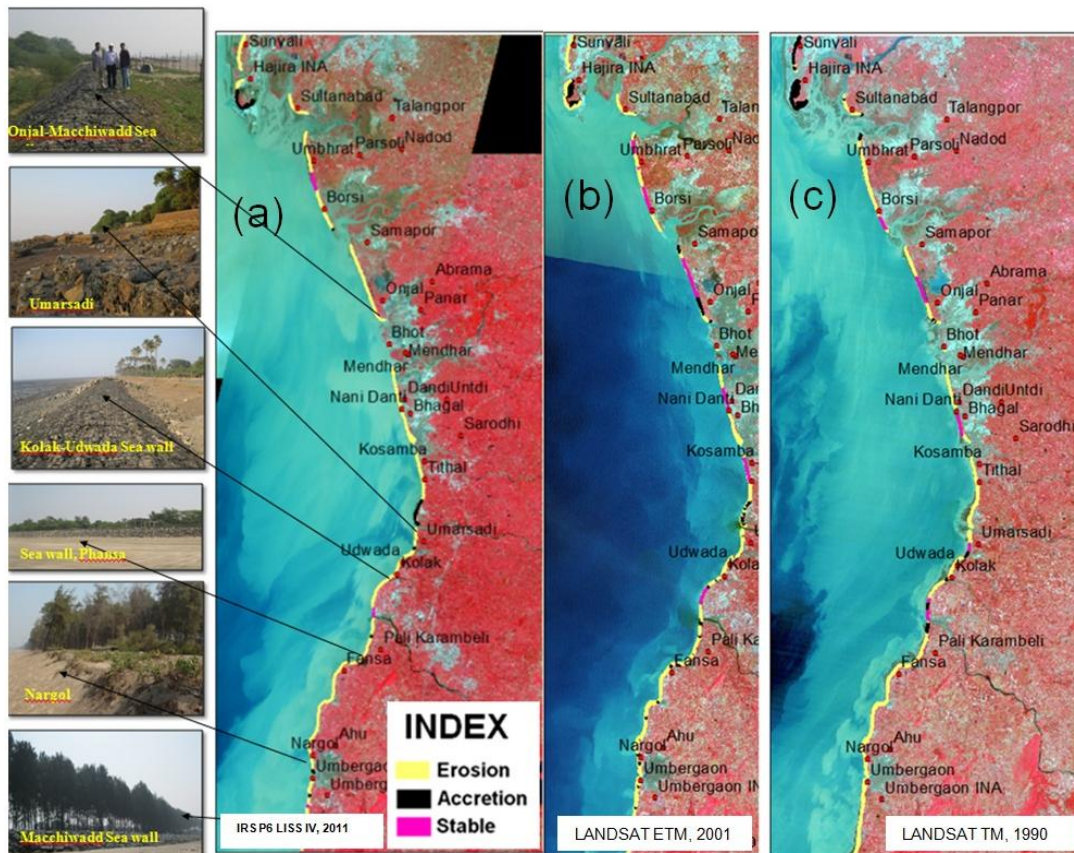


Figure 3: Erosion, accretion and stable coast (a) 2001-2011, (b) 1990-2001, (c) 1972-1990

The severity of erosion is alarming and draws immediate attention. The further study can be carried out based on high resolution satellite images so that the shoreline detection and shoreline changes can be studied more details and more accurately.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to Shri A S Kiran Kumar, Director, SAC, Ahmedabad for providing overall guidance and support. The authors are thankful to Dr. J S Parihar, Deputy Director, EPSA, SAC, Ahmedabad for providing overall support. The authors are also thankful to Dr. Ajai, Group Director, MPSG, SAC, Ahmedabad for providing their valuable guidance and constant encouragement.

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