

Assessment of Coastal Vulnerability along Chavakkad, Kerala Coast in India, using Geospatial Techniques

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Abstract— *The coastal zone, because of its exposure and low-lying form, is extremely vulnerable to the ravages of nature (hurricanes, storms, earthquakes, volcanoes, tsunamis, etc) and this effects the environment, economy, livelihood and public health. Another threat that could have a far more devastating effect on the coastal zone, is the potential rising of the sea level as a result of global warming. This study makes use of the satellite imageries of Chavakkad coast from different years to assess the change in the shoreline, with the aid of remote sensing and geospatial tools. Then the susceptibility of the coast is evaluated using the Coastal Vulnerability Index.*

Keywords— *Vulnerability, Shoreline Change, Histogram Threshold, Band Ratioing, DSAS, CVI*

large human settlements in close proximity to the sea. Out of a total area of 38,863 sq. km. of Kerala, 3,355 sq. km. falls in the coastal area supporting a population of 72.72 lakh. The density of coastal urban population is 4,228 per sq. km, as compared to the average urban density of 2,097 in the state. The coastal rural population density is 1700, far above the state average rural population density of 603. Considering the large number of people, the high concentration of industries, the existence of small and large ports, and the enormous fishing potential, the question of limiting development or putting in place a regime of regulatory measures for human activities on the coast is bound to be highly contentious.

In the present study, the shoreline rate change along the coast is computed using the Digital Shoreline Analysis System(DSAS) and the coastal vulnerability index (CVI) is used to assess the impact.

I. INTRODUCTION

COASTAL erosion is a global problem. Coastal erosion is the wearing away of land and the removal of beach or dune sediments by wave action, tidal currents, wave currents or drainage. Coastal erosion, may take the form of long-term losses of sediment and rocks or merely the temporary redistribution of coastal sediments i.e., erosion in one location may result in accretion nearby. References [5] and [9] have discussed the coastal processes and resulting shoreline erosion. Erosion intensity and development depend to a high degree on the equilibrium state of coastal dynamics and beach stability [3].

One of the major issues concerning the coastal zone of Kerala, is erosion. Natural factors that cause erosion in Kerala are heavy rainfall, loose sandy sea shore, sub-terrain pressure from low inland areas, increase of water level in the sea due to melting of ice in the polar region, and destruction of mud deposits in the sea. Kerala has been experiencing accelerating coastline erosion, alike other parts of the world. The coastal erosion has become critical for the state because of the acute shortage of land due to the high population density in the coastal zone. Under the physiographic conditions of Kerala, the population density tends to increase towards the coastal region (Fig. 1.5). Even the unstable coastline has not deterred

II. STUDY AREA

The study area considered is the Chavakkad Taluk coastline, in Kerala with 60km length. The coastline lies between north latitudes 10°27'8.2" N and 10°41'3.9" N and east longitudes 75°57'24.4" E and 76°6'43.5" E. It lies in the tropic region, and is mostly subjected to humid tropical wet climate. Chavakkad has an average maximum daily temperature of around 36.7 °C and a minimum of 19.8 °C.

III. METHODOLOGY

A. Historic Shoreline Change Rate

The dataset includes the Landsat MSS image dated 10/02/1973, and Landsat ETM+ image dated 12/04/2013. The toposheets used are 58b and 49n.

1) *Image Analyzing*: First the histogram threshold method is used on the NIR band so as to separate land from water. A binary image is obtained then ratioing method is used with ratios green/ NIR and green/ MIR. The two ratio images are then multiplied, to give the third image. The isolated pixels are removed by sieving and filtering techniques. The resultant shoreline extracted is transformed into vector format and then analyzed using DSAS software [2]. The flowchart of shoreline extraction is given in Fig. 1.

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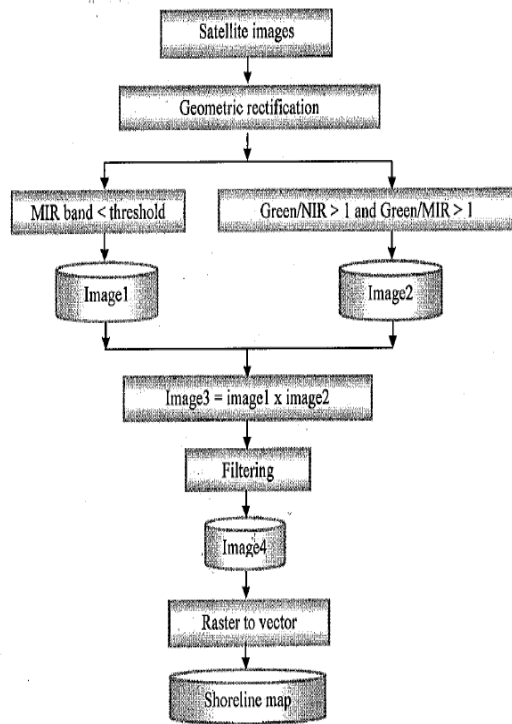


Fig. 1: Extraction of shoreline from satellite image [13]

2) *Digital Shoreline Analysis system*: The software is an extension of arcGIS . The steps involved are as stated below,

- a) Creation of a geodatabase
- b) Appending the obtained shorelines of different years (with the necessary attribute fields)
- c) Establishment of a baseline
- d) Casting of transects, perpendicular to the baseline
- e) Calculation of change statistics (End Point Rate: dividing the distance of shoreline movement by the time elapsed between the different year shorelines)

B. Coastal Vulnerability Index

The methodology consists of calculating the coastal vulnerability index (CVI), which is dependent upon six variables,

The geologic variables include

- (a) historic shoreline change, (b) geomorphology and (c) coastal slope.

The physical variables include

- (d) mean tidal range, (e) mean significant wave height and (f) global Sea Level Rise.

The CVI allows the six variables to be related in a quantifiable manner that expresses the relative vulnerability of the coast to physical changes due to future sea level rise. This method yields numerical data that cannot be equated directly with particular physical effects. It does, however, highlight areas where the various effects of sea level rise may be the greatest. Once each section of the coastline is assigned a vulnerability value, the CVI was calculated. Equation (1) gives the Empirical formula used.

$$CVI = \text{Sqrt} \{ (a * b * c * d * e * f) / 6 \} \quad (1)$$

where, (a) geomorphology, (b) shoreline change rate (m/yr), (c) coastal slope (%), (d) mean tidal range (m), (e) mean significant wave height (m), (f) global SLR (mm/yr)

These six variables include both qualitative and quantitative information. Actual variable values are assigned a vulnerability ranking based on value ranges, whereas the non-numerical geomorphology variable is ranked qualitatively according to the relative resistance of a given landform to erosion. In the present study, ranking was assigned for these variables along the stations in the study area and thus CVI was calculated for these stations. The ranges of vulnerability ranking (from Dwarakish et al., 2009) for the study area is specified in table 1.

Table1: Ranking of Coastal Vulnerability [2]

Sl No.	Variable	Ranking of Coastal Vulnerability				
		Very Low	Low	Moderate	High	Very High
		1	2	3	4	5
1	Geomorphology	Rocky cliff	Medium cliff	lateritic plain	alluvial plain	Coastal plain
2	Shoreline Erosion/Accretion(m/yr)	>+15	+5 to +15	-5 to +5	-15 to -5	<-15
3	Coastal Slope (%)	>0.6	0.5-0.6	0.4-0.5	0.3-0.4	<0.3
4	Mean Tide Range(m)	>4.0	3.0-4.0	2.0-3.0	1.0-2.0	<1.0
5	Mean Significant Wave Height(m)	<0.7	0.7-1.4	1.4-2.1	2.1-2.8	>2.8
6	Mean Sea Level Rise(mm/yr)	<1.8	1.8-2.5	2.5-3.0	3.0-3.4	>3.4

IV. RESULT AND DISCUSSION

A. Historic Shoreline Change Rate

Histogram thresholding is carried out, on the Landsat ETM+ image(year 2013), to get a clear demarcation between the water and the land pixels. Then band ratioing is applied. Next step is to allow the image through a high pass filter, for the purpose of edge enhancement. The shoreline is then digitized and the created vector file is projected to a Projected Coordinate System (UTM). For the year 1973, the Landsat MSS image (Band 6) corresponding to the NIR band image is obtained. The afore-stated steps are followed and the projected

shoreline vector file obtained. Fig.2 shows a part of the projected shorelines for the two years, 1973 & 2013.

Digital Shoreline Analysis System

A new personal geodatabase is created. The collected shorelines (as shapefiles), are appended to a single file and then imported into a geodatabase within ArcCatalog. Each shoreline vector represents a specific position in time and is assigned a date in the shoreline feature-class attribute table. A baseline is created, which serves as the starting point for all transects cast by the DSAS application. The transects intersect each shoreline at the measurement points to calculate the shoreline-change rates. EPR method is used to carry out statistical analysis. The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. The result obtained is given Fig. 3. Fig. 4 gives the reclassified transect map.

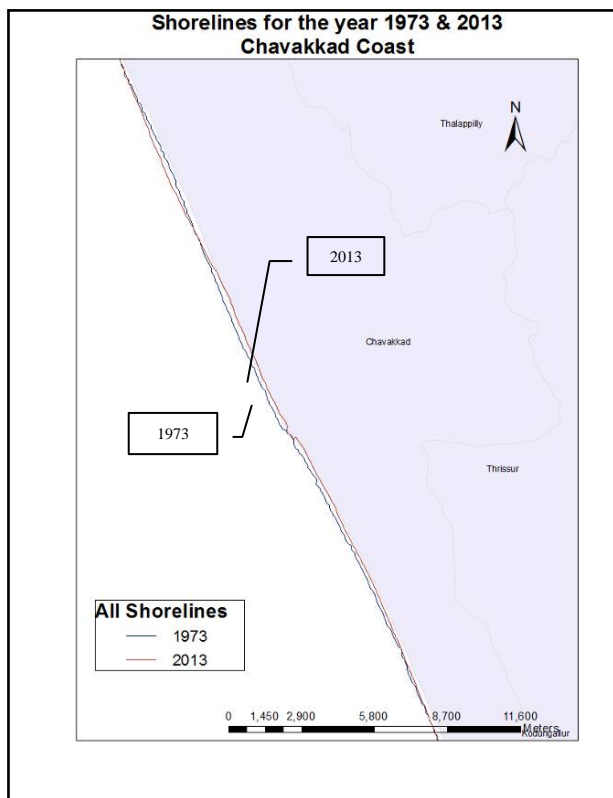


Fig.2: Shorelines (year 1973 & 2013)

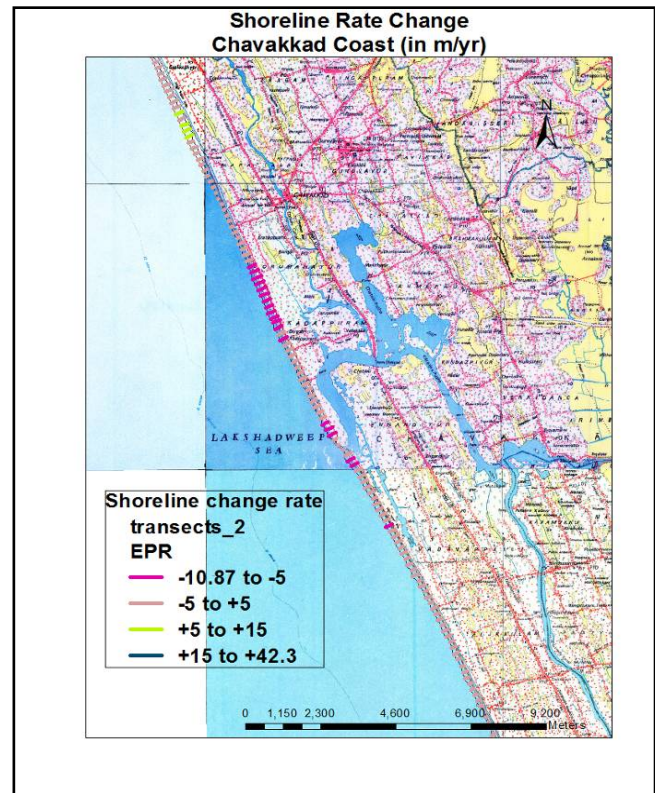


Fig. 3: Shoreline Change Rate (m/yr)

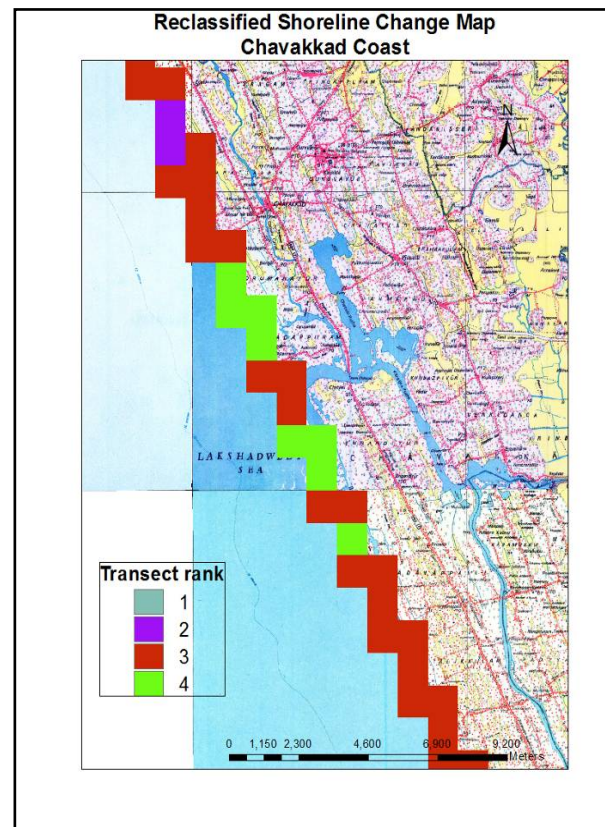


Fig. 4: Reclassified Shoreline Change Map

B. Geomorphology

This variable expresses the relative erodibility of different landform types. Correspondingly, ranks are provided to the different soil categories. The soil category in the study area is under 'coastal plain, beach, mud flats'. The rank given on the basis of Table 1 is 5(very high vulnerable).

C. Mean sea level rise

A rise in the mean sea level would result in a corresponding higher shift to the zone of wave action. Observed sea level rise is 1.2 mm per year. Rank given is 1 (for very low vulnerable area)

D. Mean Tidal Range

Lower the tidal range, higher is the risk of inundation from the storms & vice-versa. The tidal range along the Kerala coast varies from 1.5m in the north to 0.5m in the south. Vulnerability ranking is given as 4(high vulnerable area).

E. Mean significant wave height

The ability to mobilize and transport coastal sediments is a function of the wave height. For Kerala coast, the value ranges from 1.4m to 2.1m. Ranking given is 3(moderately vulnerable region).

F. Coastal Slope

Determination of the regional coastal slope identifies the relative vulnerability of inundation and the potential rapidity of shoreline retreat because low-sloping coastal regions are thought to retreat faster than steeper regions. The slope (in percentage) is obtained from SRTM DEM, 90m resolution. Ranks are provided accordingly (shown in Fig. 5).

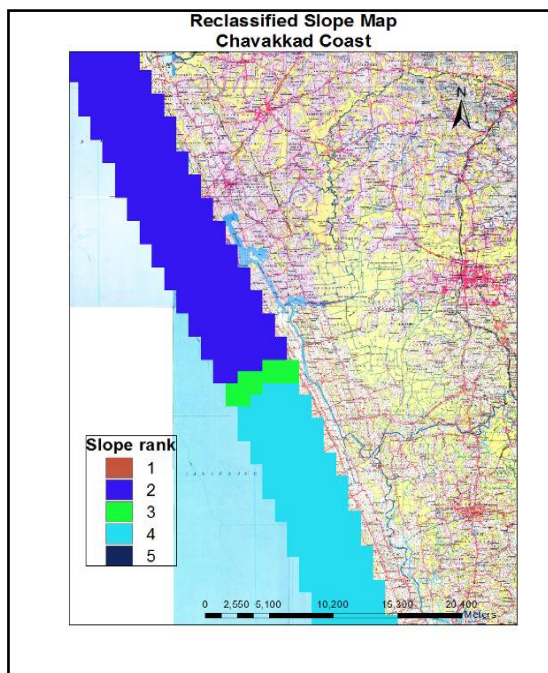


Fig. 5: Reclassified Slope Map

After assigning risk values to the data variables, the CVI is calculated using the empirical equation. The calculated CVI for the Kerala coast ranges from 5.66 to 15.77. The mean is 9.04

and the standard deviation is 1.98. Fig. 10 shows the resultant vulnerability.

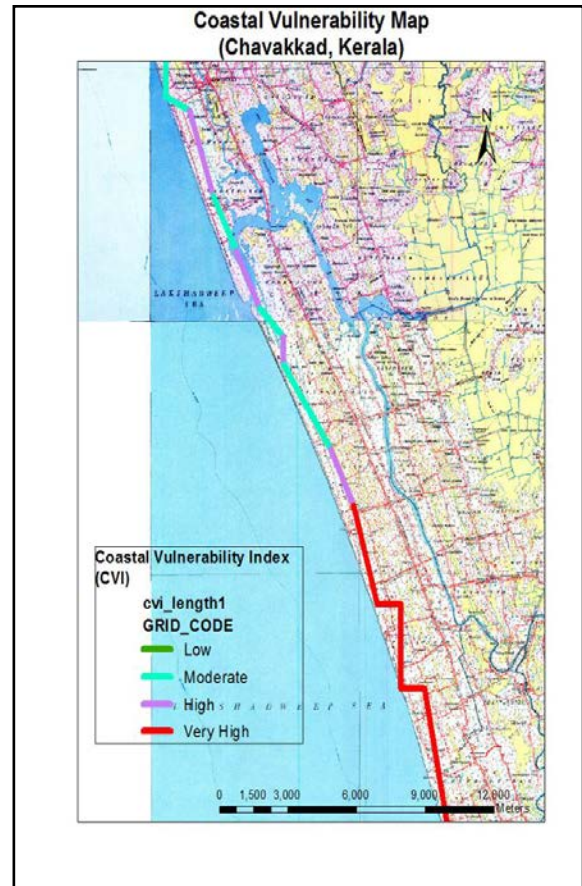


Fig. 6: Coastal Vulnerability Map (Chavakkad Taluk)

The 25th, 50th and 75th percentiles are taken and the scores are divided into low, moderate, high and very high vulnerable areas based on the quartile ranges. Very high vulnerable areas include Azhikod, Pallipuram, Perinjanam, Kulimuttam, and high vulnerable areas include Talikullam, Vadanapilly, Engandiyur, Orumanayoor. Veliyangod, Punnayur, Manattala are seen as moderately vulnerable to sea intrusion, while low erosion is seen at Edakkazhiyur. It is seen that about 65% length of the study area comes under very high vulnerable zone, 16% comes under high vulnerable zone, 16% comes under moderate vulnerable zone and 2% under low vulnerable category.

The results obtained were verified through site visits. One of the locations taken up for the validation of the results was the Vadanapilly beach, where erosion is quite evident every year in the monsoon season.



Fig. 7: Damaged road at Vadanapilly coast

Even the sea wall constructed a few years back has not deterred the sea from intruding the land. Fig. 7 shows the extent of damage along the Vadanapilly beach. The seawall at the afore-stated location, built 10 years back, has been damaged by the onslaught of waves and the sea has encroached the land up to a distance of approximately 40m (roughly 4m/yr). As per the study conducted, in the last 40 years (between 1973 and 2013) the ingress of the sea, along the Vadanapilly coast is shown in table2. From the field visits, it is inferred that the computed values complement the observed values.

Table 2: Erosion rate (in m/yr) along Vadanapilly coast

Sl. No.	Location	Computed erosion rate (m/yr)
1	Ganeshamangalam Beach	3.75
2	Vadanapilly Beach	3.22

V. CONCLUSION

The present study has facilitated in the identification of the vulnerable regions along the Chavakkad coast through the analysis of remotely sensed data along with the conventional data. The coastal vulnerability maps produced using this technique serve as a broad indicator of threats, to the people living in coastal zones. The vulnerability assessment can

provide a pedestal for the Disaster Management Department, based on which necessary protective measures can be provided.

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