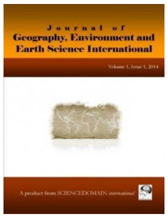

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Coastal Vulnerability Mapping using Remote Sensing and GIS Techniques in Tuticorin Coast of Tamil Nadu, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author BSK designed the study, managed the literature searches, performed the statistical analysis, prepared the maps, wrote the protocol and wrote the first draft of the manuscript. Authors AB and KT helped the field visit. All authors read and approved the final manuscript.

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ABSTRACT

The southern part of the Indian peninsula of Tamil Nadu coast is potentially more vulnerable to hazards. This research aims to classify the coastal vulnerable zones of the Tuticorin, Tamil Nadu using Coastal Vulnerability Index (CVI). The multi-spectral satellite data of Landsat series was used for shoreline change analysis from 1978 to 2017. The Digital Shoreline Analysis System (DSAS) software extension was used to calculate the shoreline rate-of-change statistics from multiple historic shoreline positions developed by the United States Geological Survey. The study reveals significant erosion and accretion demarcated based on DSAS computed values along the coastal stretch. The six physical variables characterizing the vulnerability of the coast, including the geomorphology, shoreline change rate (m/yr), coastal slope (deg), relative sea-level change (mm/yr), mean wave height (m) and mean tide range (m). The geomorphology map was created

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using Landsat OLI satellite data in 1: 50,000 scale. The Shoreline change rate was calculated using temporal satellite data. Based on the CVI value, low vulnerable to very high vulnerable areas were identified. Besides, Vembar, Periyasamypuram, Vaippar, Kallurni, Pattanamarudur areas were identified in erosion. The Muttayyapuram coast has accretion by the consequence of sediment transport from the Thamiraparani estuary. The coastal zones are highly fragile for dynamic nature and resource. The sources of anthropogenic and natural processes are accelerating the erosion and accretion along the coast. Hence the vulnerability map prepared for the southeast coast of India and it can be most helpful for stakeholders and future coastal disaster mitigation and management.

Keywords: Geomorphology; shoreline changes; DSAS; relative sea level rise.

1. INTRODUCTION

Scientist and engineers understand much about the natural world. Disaster is a sudden calamitous event bringing great damage, loss and destruction and devastation to life and property. The damage caused by disasters is immeasurable and varies with the geographical location, climate and the type of the earth surface/degree of vulnerability. A disaster can be natural or manmade. Natural disasters are (rain, flood, cyclone, storm, landslide, earthquake, volcanoes). The developing countries are affected at huge costs when a disaster hits and moreover many deaths are caused by disasters. A tsunami is an ocean wave generated by a submarine earthquake, volcano or landslide. It is known as a seismic sea wave and incorrectly as a tidal wave. Storm surges area waves caused by strong winds. The largest earthquake ever recorded in Samoa was8.3 on the Richter scale. It is a well-known fact that coasts are highly dynamic and fragile. From the last four decades, coastal areas have enormous population growth and developmental activities. United Nations estimates in 1992, more than half of the world population live within 60 kilometers of the shoreline. The present study attempts to assess the vulnerability of the Tuticorin coast for various hazards like erosion and accretion using CVI based on a multi-indicator approach to finding out the low-lying places and vulnerable areas using techniques of Remote Sensing and GIS.

Exposure to the multiple kinds of natural hazards and the rapid population growth in hazardous urban areas have caused to make the impacts severe and widespread in the areas of built environment, economic, social, critical infrastructure, loss of life, and etc. The experiences gained through the recent disasters such as Indian Ocean Tsunami (2004), and challenges faced by national and local governments showed that metropolitan areas are more vulnerable due to population accumulation and properties. It is estimated that 864 million inhabitants are affected by various kinds of natural hazards such as river flood (379 million), earthquake (283 million), wind storm (157 million), storm surge (33 million), and tsunami (12 million) in 616 major metropolitans [1]. The Earthquake and Tsunami of Japan in 2011 imposed about 210 billion dollars economic loss and 15,880 fatalities. According to Munich RE [2], during the last 25 years, the 10 destructive earthquakes have imposed about 365 billion economic damages and 753,000 casualties. Earthquakes have a very high capability for causing human causalities and physical disruptions and therefore, they have ranked as high priority in disaster risk reduction and management [3,4,5].

Vulnerability refers to the propensity to be harmed, in this case by a hazard, and to be unable to deal with that harm alongside the social processes creating and maintaining that propensity. Vulnerability encompasses human decisions, values, governance, attitudes, and behaviour forming situations in which hazards could potentially cause harm. Harm might be casualties, social and business interruption, and property damage [6].

2. STUDY AREA DESCRIPTION

Geographical coordinates of the study area extend from 77°48'31.035" E to 78°22'24.481" E longitude and 8°18'51.239" N to 9°10'28.263" N latitude. The study area (Part of Tuticorin District) is located in the southern part of Tamil Nadu. It covers a distance of approximately 163.5 km in length and covers a study area of 1630.32 Sq.km (Fig. 1). It is bounded by Virudhunagar and Ramanathapuram in the north, Tirunelveli in the south and, the Gulf of Mannar in the east. Tuticorin district enjoys tropical climatic conditions with immensely hot summer and gentle winter. The annual average rainfall for the year 2011 is 645 mm, and the district registers a maximum temperature of 35.7°C and a minimum temperature of 24.4°C. Tuticorin has a very high humidity being in the coastal sector. Rainfall along Tuticorin district is observed in the southwest and northeast monsoon seasons. The summer season begins in March and it extends to May [7,8]. The Tuticorin district is divided into 8 taluks. The talks are further divided into 12 blocks, which are further divided into 462 villages [7]. The river, originating from the Western Ghats and Tamil Nadu uplands, controls the drainage network of the district. A few streams begin in the hillocks within the district and flows directly into the sea after flowing 10 to 20 km. Vaipar, Tambraparani and Karamanaiyar are the major rivers draining into the district. The major soil types are black soil, red soil and sandy soil. Irrigation in the district occurs through pipes, tanks, and canals. Tuticorin constitutes 70 per cent of the total salt production of Tamil Nadu and 30 per cent of that for India. Tamil Nadu is the second largest producer of salt in India next to Gujarat.

3. METHODOLOGY

The followed study methodology for the present study is adopted by Kumar et al. [9]. The coastal vulnerability index is calculated based on the six vulnerable parameters namely geomorphology, coastal slope, relative sea-level change, mean wave height and mean tide range, shoreline change rate. According to that, each parameter is given individual rank and weightage and by integrating the above parameters using GIS platform, the coastal vulnerability index is calculated (Fig. 2).

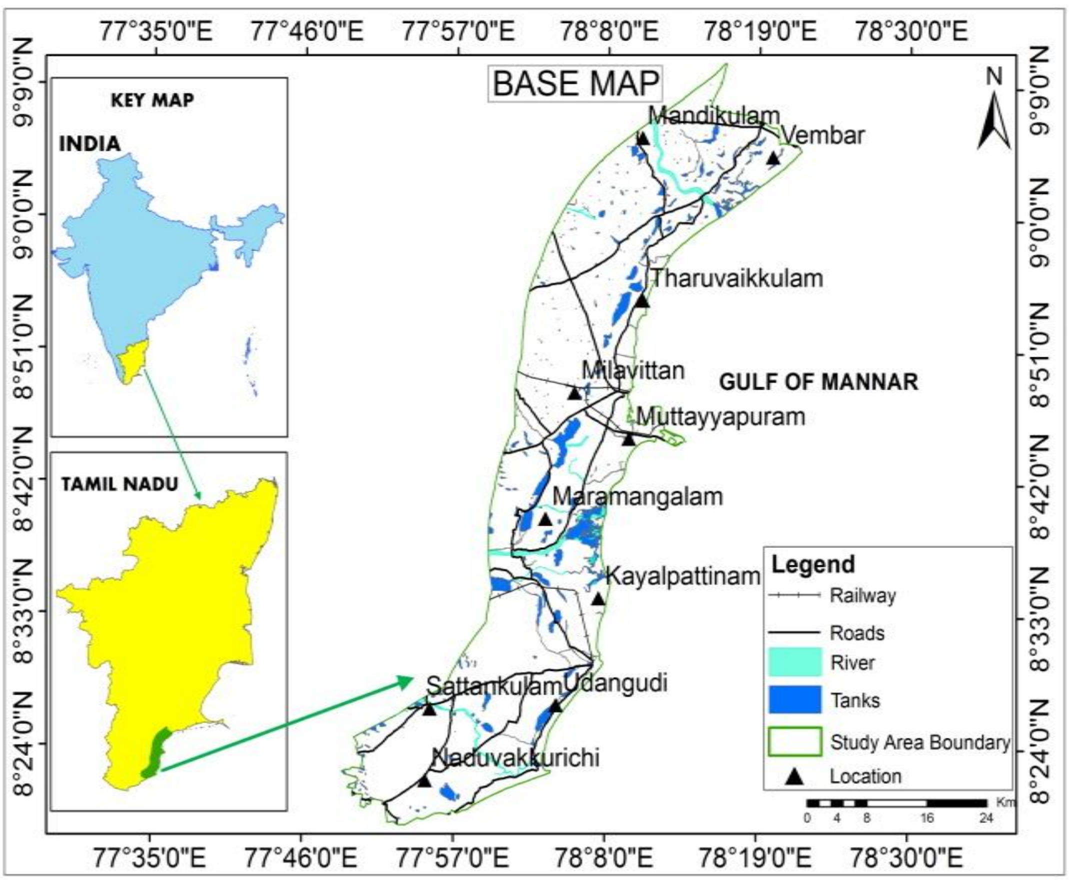

Fig. 1. Study area location map

The mathematically processed described as below,

$$CVI = \sqrt{[a \times b \times c \times d \times e \times f/6]}$$

Where,

a -risk rating assigned to geomorphology; b -risk rating assigned to coastal slope; c -risk rating assigned to relative sea-level change; d -risk rating assigned to mean wave height; e -risk rating assigned to mean tide range; f –risk rating assigned to shoreline change rate.

Data from different sources to be acquired analyzed and processed derived from Remote sensing, GIS, and numerical model data. The data sets used for the present study in deriving each of these parameters is presented in Table 1.

4. RESULTS AND DISCUSSION

4.1 Geomorphology

Geomorphology may be defined as the scientific study of surface features of the earth's surface involving interpretative description of landforms, their origin and development and nature and mechanisms of geomorphological processes which evolve the landforms with a view that all landforms can be related to particular geological processes, and that the landforms thus developed may evolve with time through a sequence of forms dependent in part, on the relative time a particular process has been operating. Geomorphology seeks to identify and understand the regularities

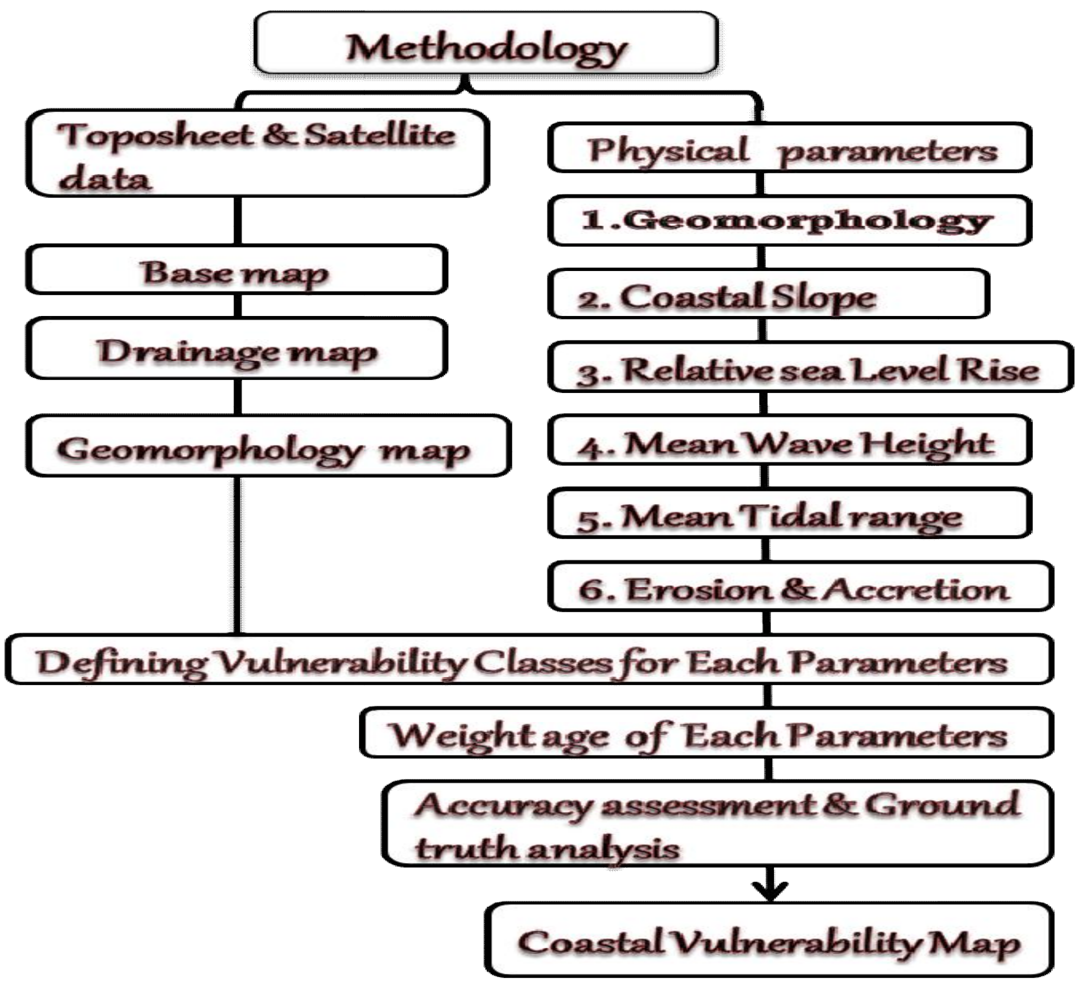

Fig. 2. The overall methodology of the present study

Table 1. Data sources

S.No	Parameter	Data Source
1	Geomorphology	Landsat OLI [(2017) (30m resolution)]
2	Coastal Slope (in %)	SRTM Data (90 m Resolution)
3	Relative Sea-Level Change (m/yr)	PSMSL
4	Mean Wave Height (m)	Naval Hydro graphic Chart
5	Mean Tide Range (m)	Naval Hydro graphic Chart
6	Shoreline Change Rate (m/yr)	Landsat MSS (70 m Resolution) Landsat TM (30 m Resolution) Landsat ETM+ (30 m Resolution) Landsat OLI (30 m resolution)

among landforms and pattern. On the basis of source geomorphic processes are derived into two broad categories namely endogenetic and exogenetic processes (Fig. 3). The internal or endogenetic processes originating from within the earth fostered by diastrophic and sudden forces, caused by thermal condition of the interior of the earth and varying physical and chemical properties of the material of which the earth's interior has been composed of, introduce vertical irregularities on the earth's surface and create various suites of habitats for biotic communities. The exogenous or external processes originating from the atmosphere driven by the solar energy change the face of the earth's surface through erosional and depositional activities. It includes running water (rivers-fluvial process), groundwater, sea waves (marine process), wind (aeolian process), glacier (glacial process), periglacial process ect. The general processes involved in the sediments, streams remove soluble materials from the parent rocks and the chemically eroded sediments are suspended in the running water of the streams. According to the estimation of Murray every cubic kilometer water of the river contains about 7,65,587 tons of suspended materials of which about 50 per cent is calcium carbonate. On average, the Worlds Rivers discharge about 6500 cubic kilometer of water into the oceans every year. On the basis of Murray's estimate, it may be inferred that about 5 billion tons of minerals are removed from the bedrocks by the world river's every year. The southern part of the Tuticorin town including sandy and gravel, it has been created by the longshore sediment transport and low tidal energy in the coastal areas.

In the coastal region, it gives basic understating of the coast-al environment and settings. Landsat image of 2017 Pan sharpened FCC (band 4, 3 and 2 combinations) data have been used to extract the geomorphological landforms. The satellite data imported to Arc-GIS 10.2.1 software environment and data were geo-corrected using toposheets and projected to the UTM (Universal Transverse Mercator) with the reference to WGS-84 datum. By the onscreen digitization technique, geomorphic landforms were extracted based on the visual interpretation. The various coastal geomorphic features identified in the study area based on the classes and risk ranks are classified.

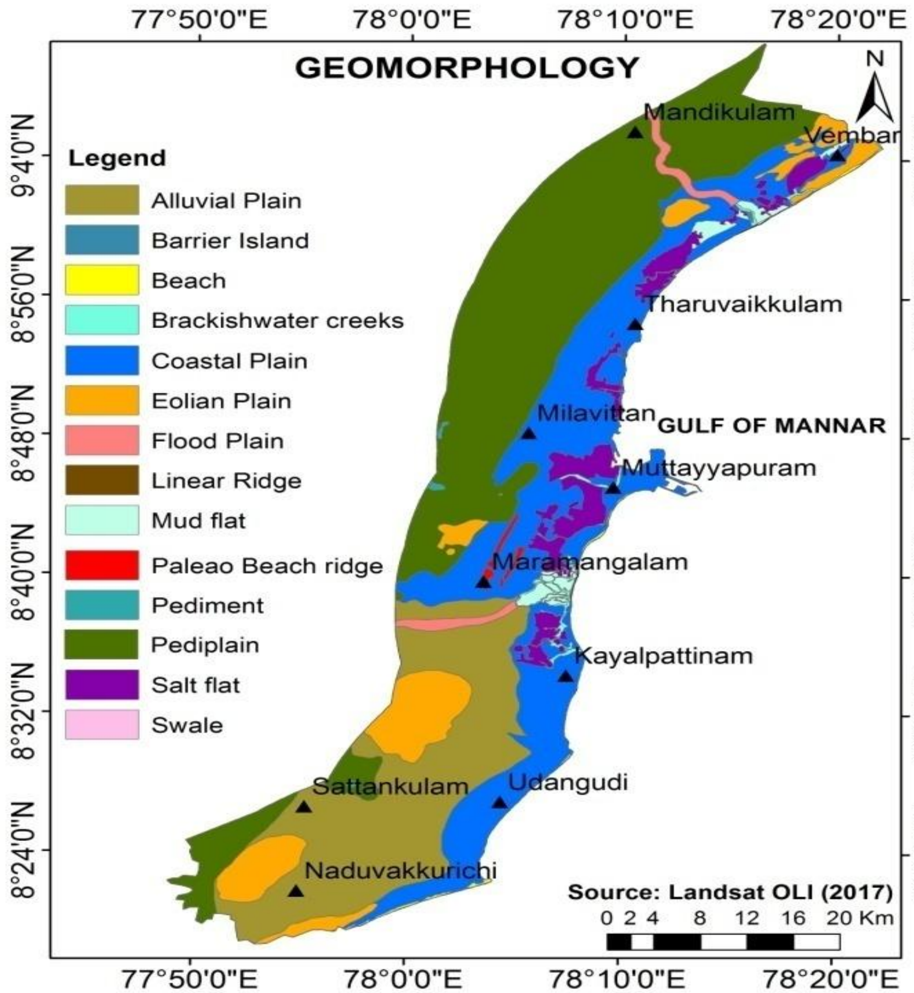

Fig. 3. Geomorphology map

4.2 Coastal Slope

Slope is used to describe the measurement of the steepness, incline, gradient, or grade of a straight line. Coastal slope (steepness or flatness of the coastal region) is linked to the susceptibility of the coast to inundation by flooding (Thieler). The SRTM data of 90 meters resolution used to generate the contours. Slope is one of the most influenced parameters for tidal inundation, where are the places having a low slope, prone to highly vulnerable. The regional coastal slope has played a crucial role in inundation and vulnerability.

4.3 Relative Sea-Level Change

Relative sea level rise is measured by increasing and de-creasing level of seawater elevation over the period. Sea level rise is highly affected by the coastal nearby population and the coastal ecosystems. The main contributors to sea level rise are oceans thermal expansion and glaciers melting and polar ice caps. Changes in relative sea level rise were computed by the tide gauges of Permanent Service for Mean Sea Level. In the stations in Tamil Nadu namely Chennai, Nagapattinam, Thangachimadam and Tuticorin were used. According to IPCC (Intergovernmental Panel on Climate Change), every mm rise of mean sea level on the coast would result in a shoreline retreat of about 1m.

4.4 Significant Wave Height

The height of the waves depends on characteristics of the wind responsible for generating them. The hazard level associated with the critical wave height depends on its return period and the highest return period of the critical wave corresponds to a minimum hazard. The mean wave height is estimated from the naval hydrographic chart and risk ratings were assigned. In the significant wave height has influenced the erosions and low significant wave height, the area has a low effect.

4.5 Mean Tide Range

The tidal range is defined as the vertical difference between the highest high tide and successive lowest low tide. An area having the high tidal range is considered as more vulnerable and low tidal range as low vulnerable. Tide plays an important role for ecological and environmental aspects including groundwater aquifers, geomorphological processes and flooding etc. Mean tide range is calculated from the predicted tide data from naval hydrographic chart and risk ratings were assigned.

4.6 Shoreline Change Rate

Shorelines are always subjected to changes due to natural and anthropogenic activities. The natural coastal processes, including wave actions and sediment transport etc. And the anthropogenic activities are sand mining on the beach area etc. Coastal areas are very fragile nature and any minor action against those natural processes that consequences will be several hundred kilometres. In the present study, toposheets and ground control points (GCPs) were used to rectify the geometric corrections. Ortho-rectified Landsat MSS, TM, ETM + and OLI images were used to isolate the shoreline changes for the years 1973, 1978, 1987,1992, 2005, 2010 and 2017. The data have been projected to the Universal Transverse Mercator (UTM) projection system with WGS-84 datum in the Arc-GIS platform. The most suitable near-infrared band is used to extract the shorelines. Extracted shoreline in the vector format was used as the input to the Digital Shoreline Analysis System (DSAS) software developed by United States Geological Survey (USGS 2005). The End Point Rate (EPR) calculations are used to calculate the shoreline change rates. Transects were generated by the DSAS software with baseline and shorelines, be-sides erosion and accretion were calculated and risk ratings were assigned based on the resulted values (Fig. 4).

4.7 Coastal Vulnerability Index

To generate the vulnerability indexes for each parameter 500m grids were generated by the ET-Geowizards and buffered out from the shoreline and each grid is assigned weightages (Fig. 5).

The identified various coastal geomorphic landforms in the study area including alluvial plain, barrier island, beach, brackish water creeks, coastal plain, Eolian plain, flood plain, linear ridge, mud flat, paleao beach ridge, pediment, pedi plain, salt pan and swale are classified as very highly vulnerable to high vulnerable categories. Majority of Naduvakkurichi, Udangudi, Muttayyapuram coast has lower coastal slope of less than 0.3 % which falls under very high-risk category and Tharuvaikkulam, Kallurani, Vembar coast has 0.4% which falls under high-risk category . The present study observed that Rate of sea-level rising at 1.26 mm/year and Rate of sea-level falling is -2.70 mm/year. The very high-risk categories are Muttayyapuram, Tharuvaikkulam, Kallurani, Vembar identified and low-risk categories Mappilaiurani, Mullakadu, Udangudi. The significant wave height ranges in the Kuttam, Manapad, Kayalpattinam, Muttayyapuram area are 0.9m falls under the very high vulnerability category and Keela Arasadi, Tharuvaikkulam, Vembar coast has 1.6m falls under high risk category. The study area experienced mean tidal range is 0.62m and comes under very high risk vulnerability category. In the Rate of shoreline change erosion rates is -9.1 and accretion is 19.6 m/year area observed (Figs. 6-10). From Vembar, Periyasamypuram, Vaippar, Kallurni, Pattanamarudur areas are experienced -2.0 m/year erosion and falls under very high-risk vulnerability and Muttayyapuram coast has accretion by the consequence of sediment transport from the Thamiraparani estuary in the moderate risk category. In the Padukkapathu area falls under the low-risk category. Sediment transport is one of the major issues in this area by the high influence of sediment concentration by the Thamiraparani river (Table 2). Meanwhile northeast monsoon, south-west monsoon are played very vital role in this process and sediment are transported and deposited by the littoral drift. The longshore sediment transport direction on northerly from the march to December, besides southerly in January and February [10].

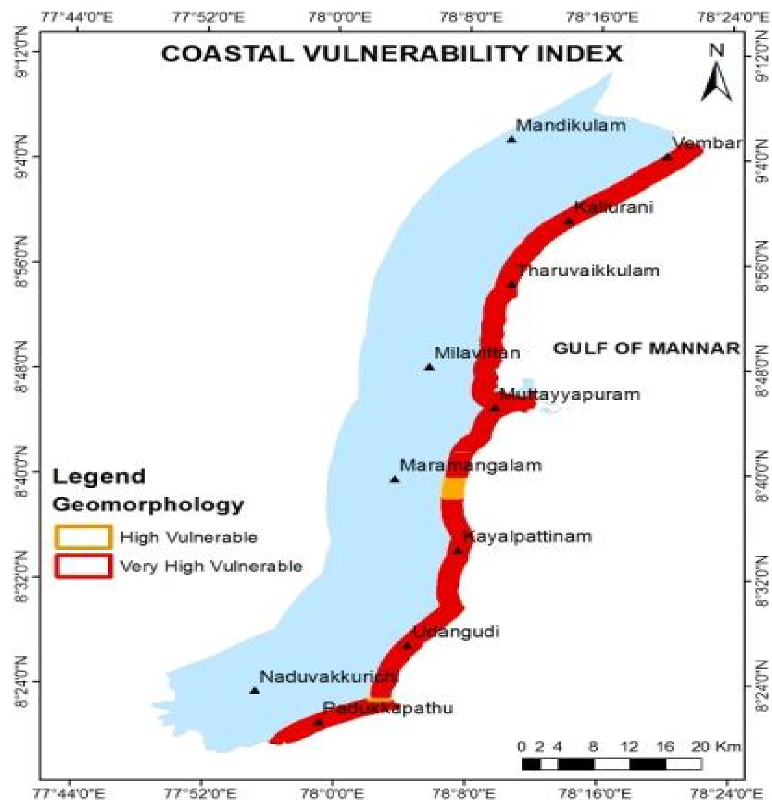

Fig. 4. CVI-Geomorphology

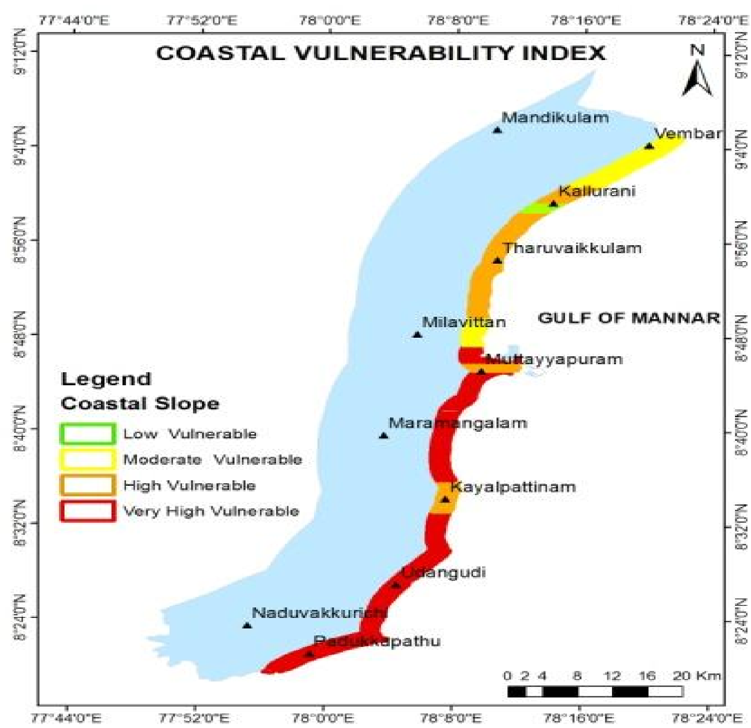

Fig. 5. CVI-coastal slope

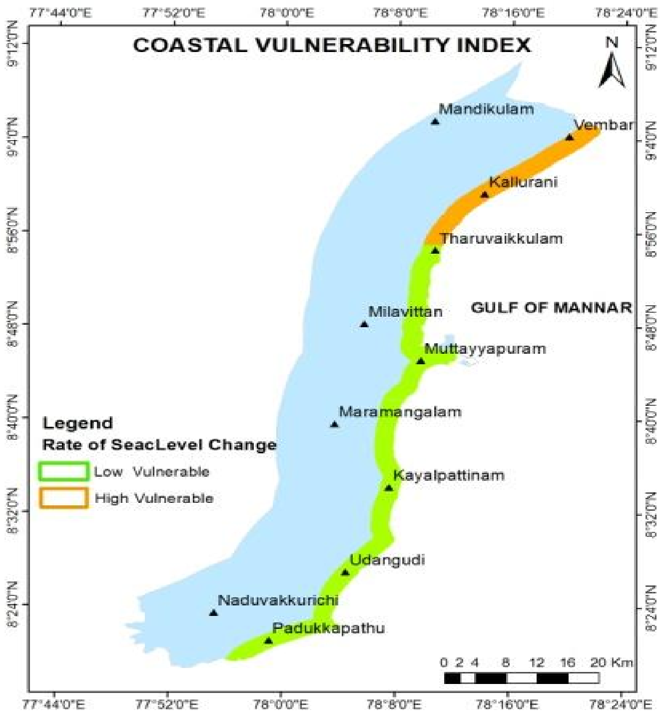

Fig. 6. Rate of sea level change

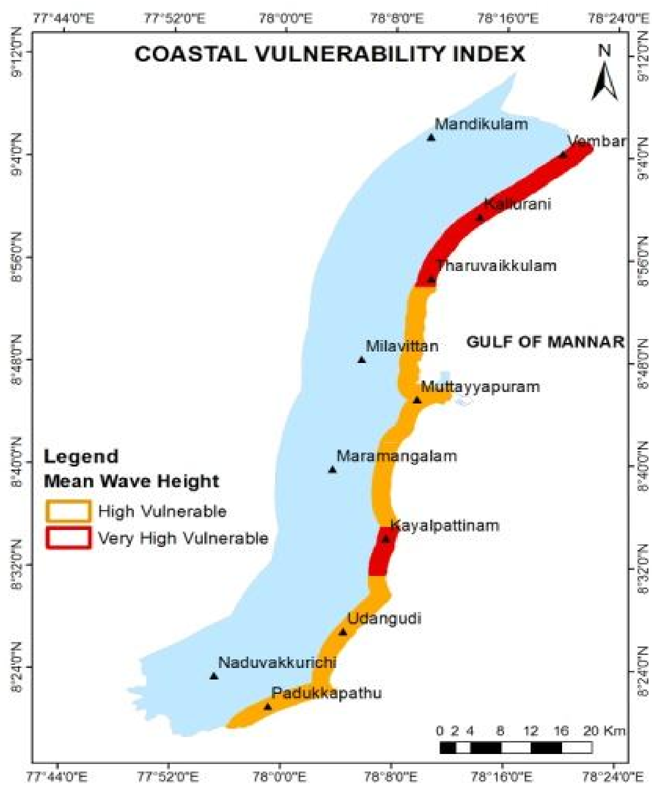

Fig. 7. CVI-mean wave height

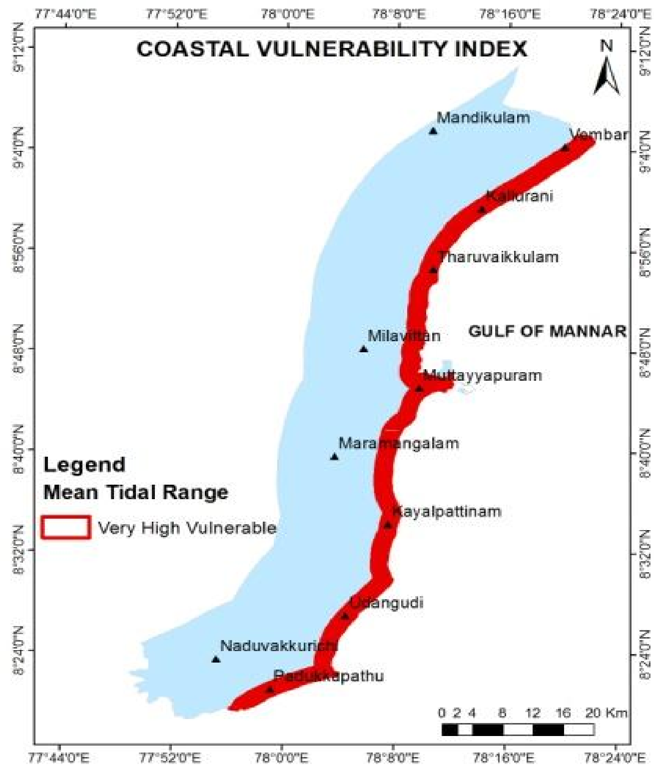

Fig. 8. CVI- mean tidal range

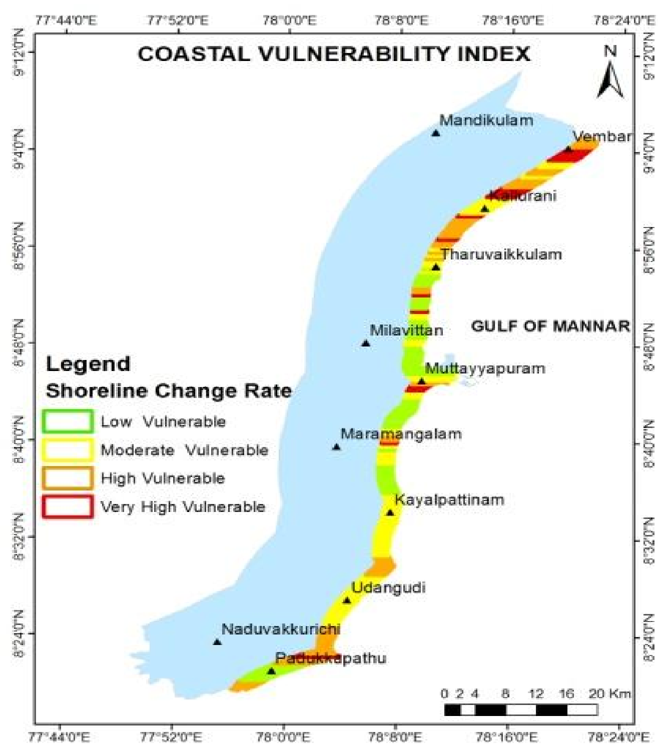

Fig. 9. Shoreline change rate

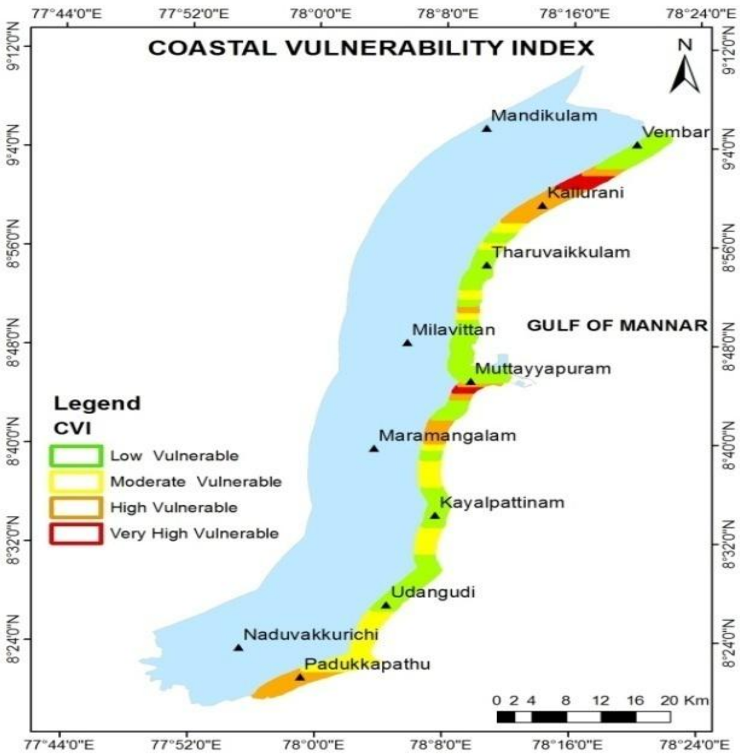

Fig. 10. CVI- final output

Table 2. Vulnerability indices for various parameters

Variables	Rank for risk Level				
	1	**2**	**3**	**4**	**5**
Geomorphology (GEO)	**Rocky cliffs**	**Medium cliffs**	**Low cliffs, Alluvial plains**	**Cobble Beaches, Estuary**	**Sand beaches, Salt marsh, Mud flats**
Shoreline change rate (SHL) (m/yr)	>3.0	1.0 to 3.0	-1.0 to 1.0	-1.0 to -3.0	<-3.0
Coastal slope (SLO) (deg)	>4.5	4.0 to 4.5	3.5 to 4.0	3.0 to 3.5	<3
Relative Sea level change (SLR) (mm/yr)	<1.8	1.8 to 2.5	2.5 to 3.0	3.0 to 3.4	>3.4
Mean wave height (MWH) (m)	<0.30	<0.30 0.30 to 0.60	0.60 to 0.90	0.90 to 1.20	>1.20
Mean Tide range (MTR) (m)	>6.0	4.0 to 6.0	2.0 to 4.0	1.0 to 2.0	<1.0

5. CONCLUSION

Some of the coastal belts in India with its dense population face coastal erosion threats and prone to vulnerable. The coastal stretch of Tuticorin is classified as low, medium, high and very high categories based on their vulnerability to the six relative risks vulnerable. Based on the CVI values Vaippar and Muttayapuram coastal regions has very high vulnerable. The integration of all the parameters resulted in minimum value of 4.3 and maximum is 29.8 were obtained. The CVI developed in the present study provides an understanding about the vulnerability of the Tuticorin coast to erosion/accretion, flooding and relative sea level rise and as well as helpful for governmental implementation, policy makers, stakeholders, fisherman and evacuation for coastal disasters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Swiss Re. Open minds connecting generations. Wiss Re Report. 2013;1-41.
2. Munich Re. Munich Re's global presence. Group Annual Report. 2015;1-312.
3. Michel Bruneau, M. EERI, Stephanie E. Chang, M.EERI, Ronald T. Eguchi, M.EERI, George C. Lee, M.EERI, Thomas D. O'Rourke, M.EERI, Andrei M. Reinhorn, M.EERI, Masanobu Shinozuka, Kathleen Tierney, M.EERI, William A. Wallace, and Detlof von Winterfeldt. Earthquake Spectra. 2003;19(4):733–752.
4. Chris S. Renschler, Andrei M. Reinhorn, Lucy A. Arendt, Gian P. Cimellaro. "3rd Eccomas Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, Corfu, Greece. 2011;1-10.
5. Ainuddin Syed, Jayant Kumar Routray. Community resilience frame work for an earthquake prone area in Baluchistan. International Journal of Disaster Risk Reduction. 2012;2:25-36.
6. Kelman Ilan. Catastrophe and conflict: Disaster diplomacy and its foreign policy implications. Diplomacy and Foreign Policy. 2016;1–76.
7. Central Ground Water Board, South Eastern Coastal Region Chennai. Government of India, Ministry off Water Resources, "District Groundwater Brochure Thoothukudi District, Tamil Nadu". 2009;1-19.
8. Anitha Parthasarathy Usha Natesan. Coastal vulnerability assessment: A case study on erosion and coastal change along Tuticorin, Gulf of Mannar. 2015;75:1713–1729.
9. Srinivasa Kumar T, Mahendra RS, Shailesh Nayak, Radhakrishnan K, Sahu KC. Coastal vulnerability assessment for Orissa State, East Coast of India. Coastal Education & Research Foundation, Inc. 2010;26(3):523-534.
10. Chandramohan P, Nayak BU. Longshore sediment transport model for the Indian West Coast. Journal of Coastal Research. 1992;8(4):775-787.

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