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ASSESSING THE IMPACT OF SEA LEVEL RISE USING COASTAL VULNERABILITY INDEX FOR CUDDALORE DISTRICT, TAMIL NADU, INDIA

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Abstract

Due to persistent global warming there is a constant rise in sea level which puts the coastal inhabitations at serious risk thereby insisting a plan to identify the regions that are most likely to get affected in the near future.We have used the Coastal Vulnerability Index(CVI) as a tool to cull out the regions that are prone to sea level rise along the coast of Cuddalore district,Tamil Nadu by taking eight parameters namely,Geomorphology,Coastal Slope,Wind Speed and Direction,Shoreline Erosion/Accretion rate,Offshore Bathymetry,Wave Height,Coastal Villages and Landuse/Landcover.The coastal stretch of Cuddalore District is divided into two kilometer segments and the CVI Values for each segment is calculated. The Coastal Vulnerability Index(CVI) calculated varies from 2.44 to 30.98 indicating a significant amount of variance among different two-kilometer segments of the coast. Since the main purpose of this project is to conceive an output that will indicate the regions prone to sea level rise so that precautionary measures can be taken in advance to prevent the loss of life and property,Coastal villages and land cover along the coast play a pivotal role in influencing the results.

Keywords: *Coastal Vulnerability Index; Sea Level Rise; Cuddalore.*

I. INTRODUCTION

Coastal Vulnerability Index(CVI) as the name implies is one of the simplest methods to ascertain the vulnerability of a coast which is subject to sea level rise using factors that cover various aspects of the place of interest.It is primarily used to get an idea about how prone a coast is to inundation of sea water using which necessary precautionary measures can be adopted at the earliest[1].CVI was developed by Gornitz et al(1990) which he later modified to include seven variables.In order to suit the topography and climatic conditions of Cuddalore district certain indigenous modifications are made to the variables used to arrive at the results.

II. METHODS AND MATERIALS

Study Area

Cuddalore is one of the major districts of the South Indian state of Tamil Nadu having Latitude and Longitude coordinates in the range 11 degree 45 minutes North and 79 degree 45 minutes East with an average elevation of about 6 meters above MSL.It has an area of 3.564 square kilometers bounded on the north by Villupuram district,on the east by Bay of Bengal,on the south by Nagapattinam district and on the west by Perambalur district.The coastal stretch of Cuddalore measures around 46 kilometers with two rivers namely,Gadilam and Pennayar draining into the sea further with the existence of Pichavaram mangrove forests at the fag end.The coast of Cuddalore is one of the highly prone regions in Tamil Nadu when it comes to monsoon activities recording excessive amount of damage to livelihood and property due to it's low lying geographic nature.

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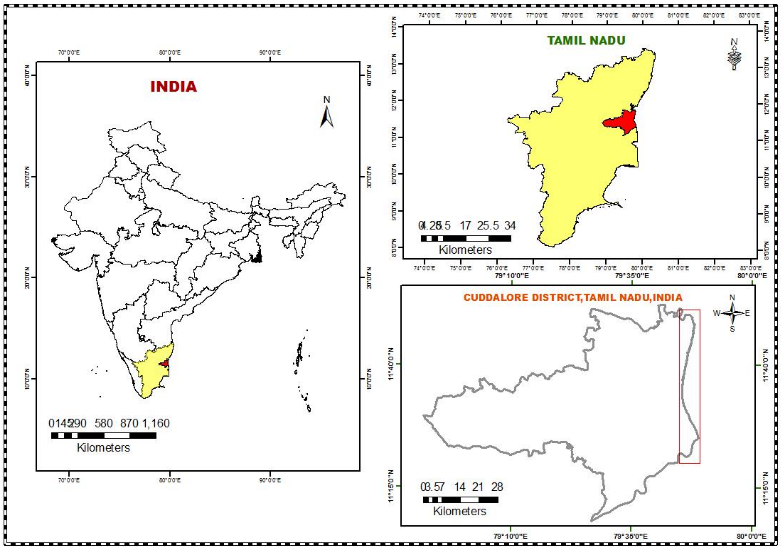

Figure 1:Study Area – Cuddalore District

Methodology

ArcGIS 10.2.2 proprietary Geographic Information System software is used for performing basic geoprocessing operations like Clip,Extract as well as integration and analysis of the eight variables obtained from different sources in data formats like Vector,Raster and NetCDF.The geometric average of variables[1,2] is used as it is sensitive to smaller changes in the individual rankings they have been assigned to followed by a square root to mitigate extreme changes.

The modified CVI consisting EIGHT variables is calculated as follows,

$$CVI = (\sqrt{a*b*c*d*e*f*g*h/8}) \text{ where,}$$

- a = Geomorphology
- b = Coastal slope
- c = Wind Speed and Direction
- d = Shoreline erosion/accretion rate
- e = Offshore Bathymetry
- f = Significant Wave Height
- g = Land use / Land cover(LULC)
- h = Coastal Villages (or) Settlements along Coast.

The factors mentioned are ranked ranging from 1 to 5 based on their characteristics and impacts on the coast (say High=5 and Low =1) for different segments of the coast to demarcate them into different zones of vulnerability. Since the nature and potency of sea varies across Countries,the formula to calculate CVI is manipulated to suit the indigenous conditions which has been done here to get better results.

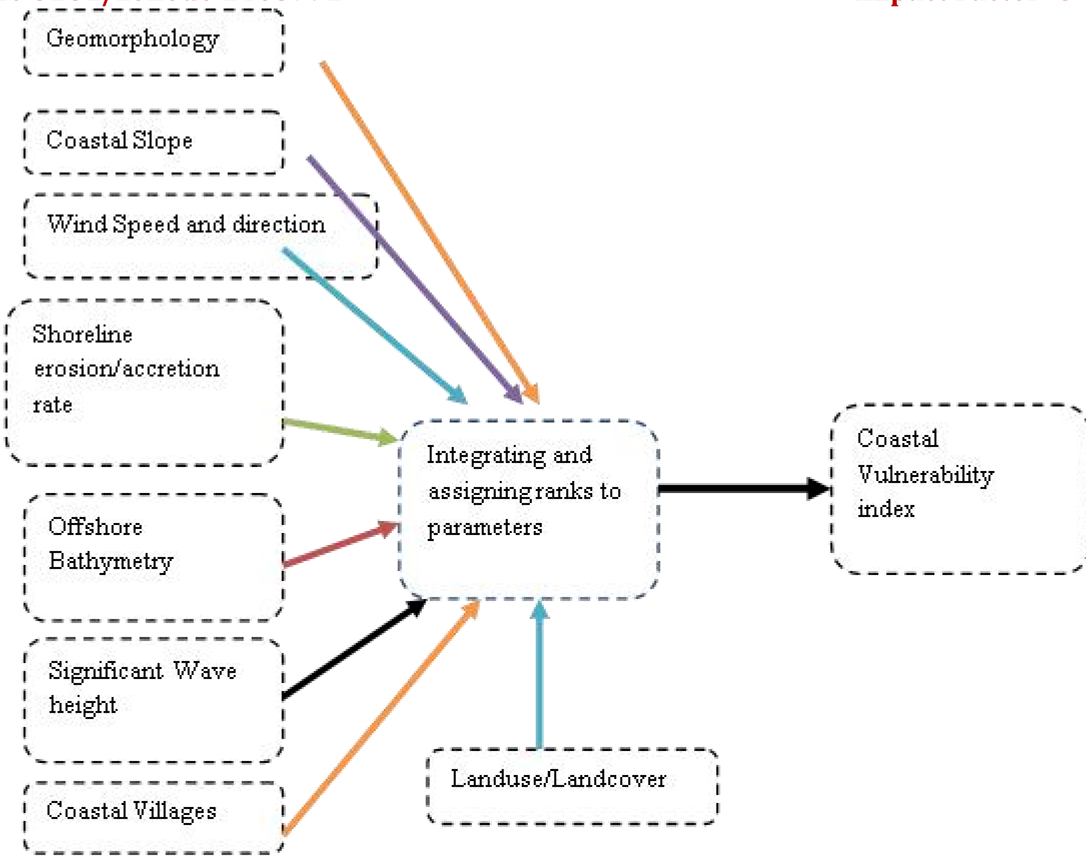

Figure 2,Flow Chart of Methodology

Aforementioned eight parameters are derived from appropriate sources which is explained later and assigned ranks accordingly based on their characteristics to estimate the vulnerability of the coast.

III. RESULTS AND DISCUSSION

The variables derived and analyzed for identifying regions prone to sea level rise are visualized in the form of maps.

Geomorphology

Geomorphology,as the name suggests exhibits the naturally occurring morphological features that lie above the surface such as the type of land mass or landforms,say for instance an Alluvial Plain,Flood Plain etc.It is one of the major factors that influence the degree of threat a coast faces due to sea level rise as these features can act either as a catalyst or an inhibitor thereby preventing the inundation of sea water.

Geomorphology map for the year 2005-06 is obtained from Bhuvan,An Indian Geo Platform of ISRO as a Web Map Service Layer and is added to the proprietary GIS Software,ArcGIS.The WMS layer is superimposed with the digital boundary of Cuddalore district obtained from Diva GIS,a platform for downloading regional boundaries in shapefile(.shp) format so that it can be demarcated into different geomorphological zones.By doing so, the coastal stretch is categorized into three zones namely,Flood Plain,Younger Coastal Plain and Older Coastal Plain.Based on some research and evidences it has been found that Coastal plains are more vulnerable to sea level rise compared to Flood plain as they exhibit low relief thereby making them more susceptible to inundation.On the other hand,Flood plains have somewhat good relief and can prevent significant amount of inundation.

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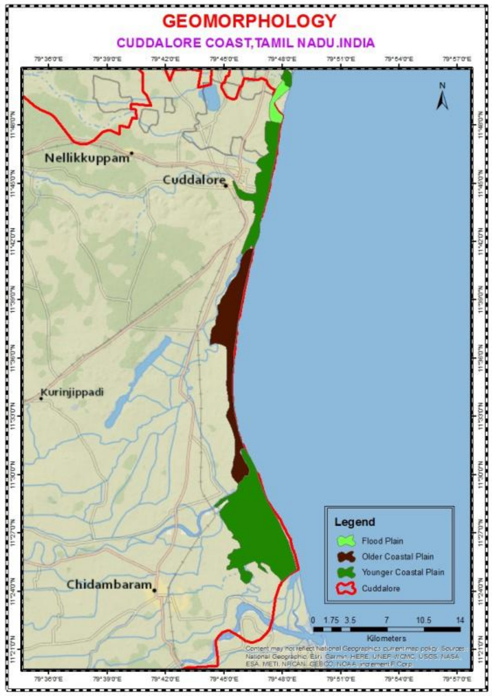

Figure 3. Cuddalore Coast - Geomorphology

Coastal Slope

Coastal slope defines the degree of steepness along the coast as more slope can hamper the process of inundation and vice versa.

The ASTER Digital Elevation Model(DEM) for the district of Cuddalore is downloaded from USGS Earth Explorer web portal using which slope is determined by utilizing the Spatial Analyst functions of the GIS Software ArcGIS.A landward buffer of 1 KM is created and Extract tool is used to cull out the slope values within it.Figure 4 shows the slope variations along Cuddalore coast.

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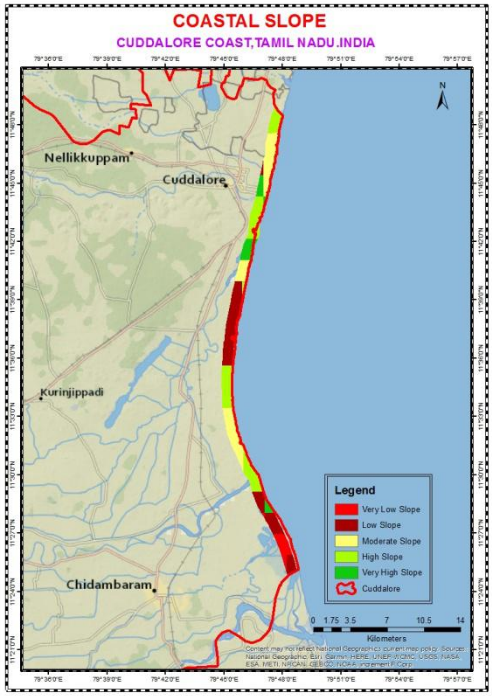

Figure 4. Cuddalore coast - Coastal Slope

Wind Speed and Direction

Speed of Wind and the direction in which it is blowing can influence the magnitude and intensity of ocean waves approaching the coast.Though Wind directions periodically change based on climatic conditions a definite wind pattern is culled out by observing them yearly in the month of June from 2010-2017.The predominant wind direction is North-West with some slightly oriented towards North-East.

The Zonal wind speed(u) and Meridional wind speed(v) components of OSCAT Wind dataset are derived using with the direction in which they are oriented is found out as per Oceanographic conventions which varies from Meteorological convention in the sense it represents the direction in which the wind is headed towards rather than where it originates from.

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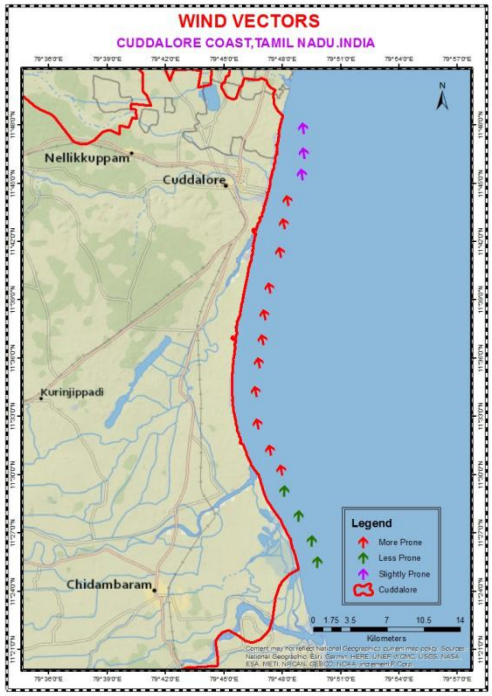

Figure 5. Cuddalore coast – Wind Direction

Shoreline Erosion/Accretion Rate

Erosion indicates the landward movement of water whereas Accretion is the seaward movement of land,erosion increases the chances of inundation while accretion prevents it.Stable is a condition that lies between Erosion and Accretion where no significant change along the shore is observed over a considerable amount of time.Identifying and mapping the segments of the shore that are subject to erosion and accretion is necessary for efficient planning and mitigation purposes at the earliest.

To get an idea about the shoreline erosion and accretion rates sufficient data is collected regarding the historical appearance of the shore spanning from the year 2006 to 2018 in regular intervals.Digital Shoreline Analysis System(DSAS) is open source tool provided by the USGS to calculate the erosion and accretion rates through casting of transects perpendicular to the shorelines and a buffered baseline(created with merged chronological shorelines as the origin,say 250 meters landward) that are given as inputs.The transect spacing given here is 500 meters and 1 km in length.Figure 4 represents the level ofErosion and Accretion taking place along the coast.

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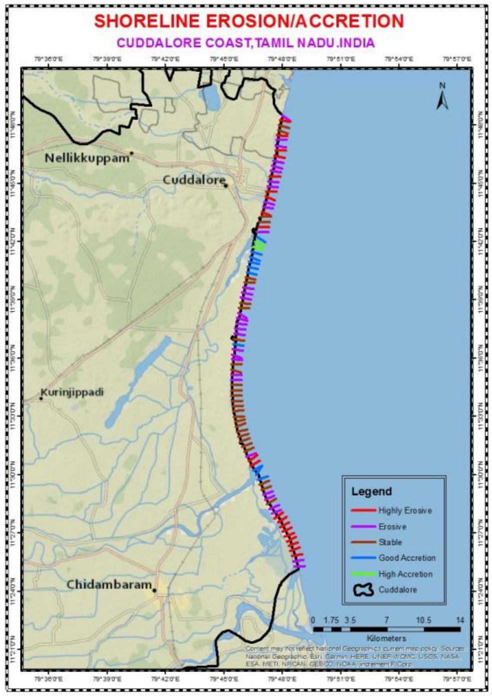

Figure 6.Cuddalore coast – Shoreline Erosion / Accretion rate

Offshore Bathymetry

Bathymetry is a type of surveying that measures of depth of surfaces beneath the ocean drawing an analogy with contour surveys where the elevations above the land surface are measured and equal values are joined with imaginary lines.They can be very vital in studying about the topographic nature of the oceans.It has been found that the friction between the layers of a ocean and it's bed is inversely proportional to it's speed,that is the more the friction between them the lesser will be the speed of the wave hitting the coast at a particular place.For this reason,Offshore bathymetric data is collected and mapped to visualize the vulnerable areas of the coast.

General Bathymetric Chart of the Oceans(GEBCO) dataset for the northern Indian ocean region is collected from the British Oceanographic Data Centre(BODC) in raster format and clipped to suit the study area.Quantile classification method is used to classify the data evenly and ranks are assigned to each segment of the coast based on their degree of closeness to higher ocean depths.For example,a segment more closer to an ocean depth of say 2 meters is ranked higher than others.In this way,entire coastal stretch is ranked accordingly.Figure 5 represents the Bathymetric data.

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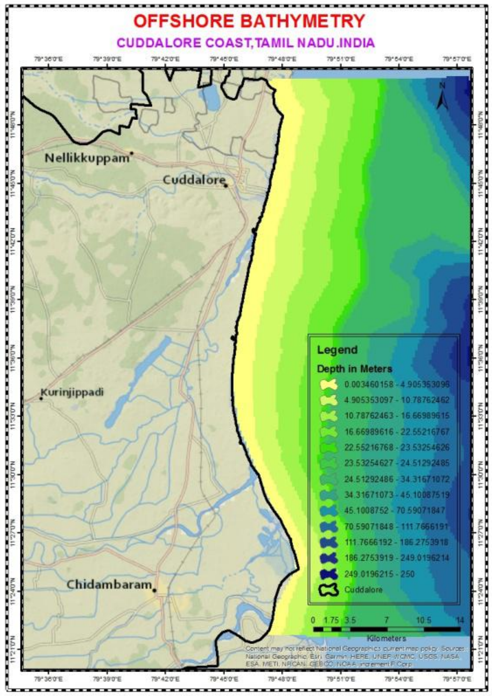

Figure 7.Cuddalore Coast – Offshore Bathymetry

Wave Height

Wave height signifies the reach of an approaching wave landward on hitting the coast.this is one of the default parameters used to calculate CVI,Datasets for each month of the period 2015-17 were collected from the Meteorological and Oceanographic Satellite Data Archival Centre(MOSDAC) and averaged out to get the mean significant wave height.Due to negligible amount of variations in the values,they are generalized to have only two categories.namely Low and High Wave height.

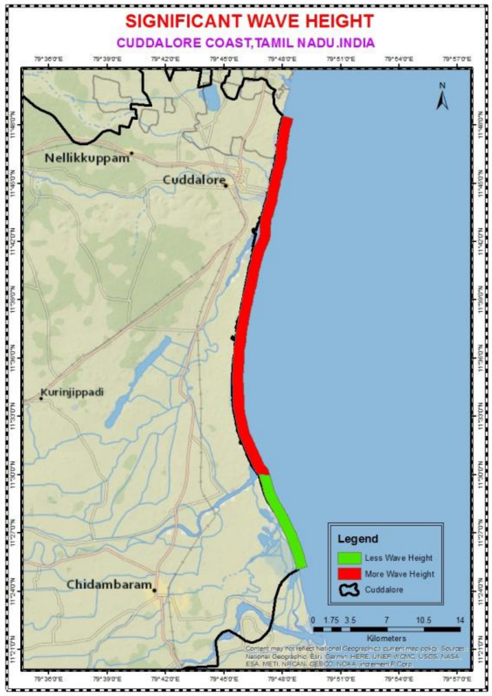

Figure 8.Cuddalore coast – Wave Height.

Coastal Villages

Since no model and analysis is complete without give prior importance to human life,an attempt is made to identify the places of livelihood along the coast and give weightage to them,as the very much goal of this model to prevent loss of life and damage to properties.

Google Earth,a software depicting the earth in three dimensional surfaces is used to figure out the villages that lie along the coast of Cuddalore,these places were marked as Placemarks which were later converted to Point Shapefiles in ArcGIS software and fed with population data derived from Census 2011 of India data.Proportional Symbol method is used to classify the data so that the size of the symbol that represent the point features varies according to it's quantity.

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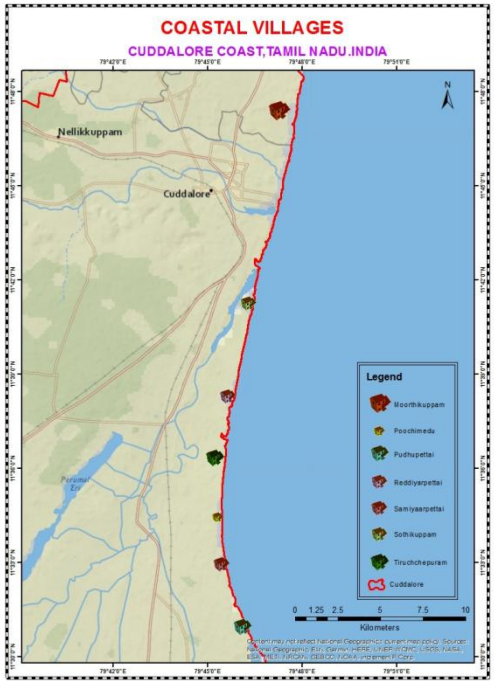

Figure 9.Cuddalore coast – Coastal Villages

Landuse/Landcover Classification(LULC)

Land use and Land Cover depict the manmade and naturally occurring features that are on the surface such as Agricultural lands,Forests,Settlements etc.They can play a pivotal role in determining the CVI as types like barren lands can be more conducive for inundation while plantations can prevent them.

Landsat 8 Satellite imagery of 15 meter Spatial resolution for Cuddalore District is downloaded USGS Earth Explorer web portaland a supervised classification for a 1 kilometer area buffered landward from the shoreline is performed with 7 iterations.The seven classes are verified and classified accordingly in ERDAS IMAGINE software by synchronizing them with Google earth like Waterbody,Settlements,Plantations etc.Weightages are given based upon the classes they represent with the Built up areas ranked the highest.

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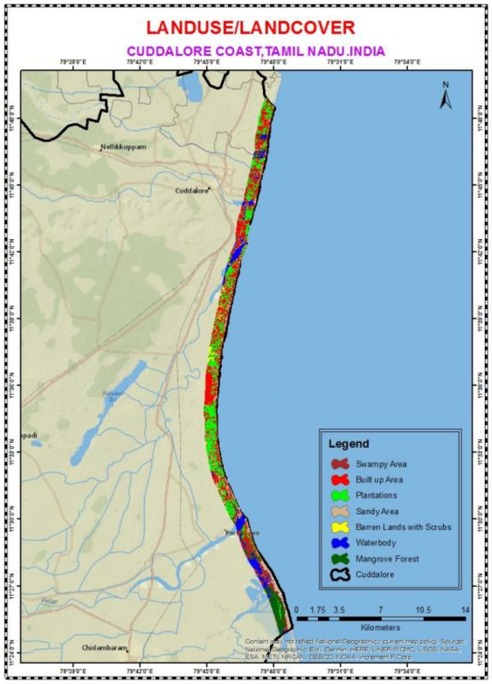

Figure 10.Cuddalore coast – Land Use / Land Cover

Integrating and Assigning ranks to Parameters:

Table 1.Assigning ranks for the 8 Parameters

Rank / Parameters	1	2	3	4	5
Geomorphology	Nil	Flood Plain	Younger Coastal Plain	Mix of Older and Younger	Older Coastal Plain
Coastal Slope	0,65m-2.41m	2.41m-3.05m	3.05m-3.48m	3.48m-3.98m	3.98m-5.74m
Wind Speed and Direction	Nil	Nil	Towards North-East	Slightly towards North-West	More towards North-West
Shoreline Erosion/Accretion Rate	9.95m-11.4m	7.86m-9.95m	5.63m-7.86m	2.94m-5.63m	-1.5m-2.94m
Offshore Bathymetry	0m-2m	>2m	Nil	Nil	Nil
Significant Wave Height	>0.68m	0.69-0.89m	Nil	Nil	Nil
Coastal Villages	No Villages	<1000 People	1000-2000 People	2000-5000 People	>5000 People
Landuse/Landcover	Nil	Plantations and Sandy area	Waterbodies and Barren lands with Scrubs	Mangrove Forests and Swampy Areas	Builtup Areas

Coastal Vulnerability Index

By giving appropriate ranks to the eight variables in each two kilometer segment,the CVI values are calculated and classified into five categories for easier understanding and interpretation.

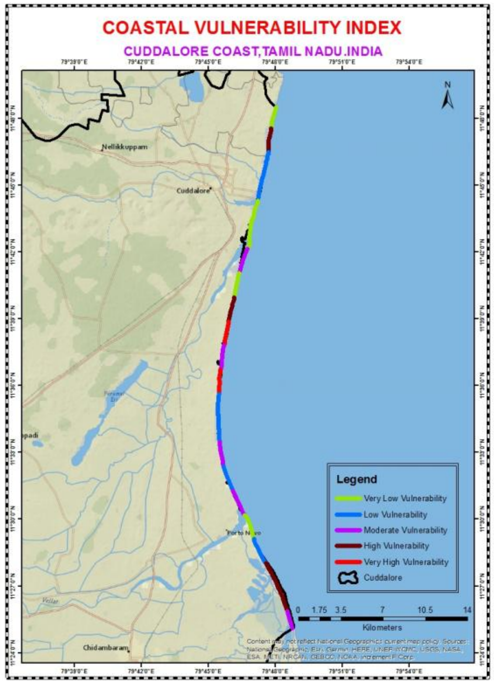

Figure 9.Cuddalore coast – Coastal Vulnerability index

The Coastal Vulnerability Index(CVI) calculated varies from 2.44 to 30.98 indicating a significant amount of variance among different two-kilometer segments of the coast. Since the man purpose of this project is to conceive an output that will indicate the regions prone to sea level rise so that precautionary measures can be taken in advance to prevent the loss of life and property,Coastal villages and land cover along the coast play a pivotal role in influencing the results as one can note the increased vulnerability in the settlement regions covered with swampy plains,whereas they are low in places having plantations other than Mangroves.The reason why some coastal segments such as are highly prone is due to the combined effect of the eight parameters,though the arrived results may not be precisely true,an overall idea about the segments that are vulnerable is obtained from this work with which the appropriate agencies can plan their mitigation activitiesAs this project involves a lot of time to collect and analyze various data to get a genuine result,due to time and manpower constraints this model is done only for a particular time span,say for a decade from 2006-2017,between which all the necessary data were obtained.By doing this no conclusive evidence can be arrived at as some places during the said time span may not be prone for now and might have been in the past and vice versa,so a CVI of may be 5 or 6 decades will definitely bring out a definite and authentic output that one can trust with for planning purposes.

IV. CONCLUSIONS

The Coastal Vulnerability index is calculated for the coast of Cuddalore and the segments that are prone to sea level rise are identified using the formula proposed by Gornitz et al(1990) thereby modifying it to suit the indigenous conditions using necessary variables.

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REFERENCES

1. ***Bhuvan,Indian Geo-Platfrom of ISRO***. *http://bhuvan.nrsc.gov.in/bhuvan_links.php.*
2. ***Digital Shoreline Analysis System****-Computer Software for calculating Shoreline changes. https://woodshole.er.usgs.gov/project-pages/DSAS/*
3. ***E.Robert Thieler,Erika S.Hammar-Klose,WoodHole***. *National Assessment of Coastal Vulnerability to Sea Level Rise:Preliminary Results for the US Atlantic Coast,* ***1999****, USGS Open File Report, 99-593.*
4. ***ESSO–Indian National Centre for Ocean Information Services.*** *http://las.incois.gov.in*
5. ***General Bathymetric Chart of the Oceans***. *https://www.gebco.net/data_and_products*
6. ***Google Earth***. *https://www.google.com/intl/en_in/earth/*
7. ***Meteorological and Oceanographic Satellite Data Archival Centre***. *https://www.mosdac.gov.in/*
8. ***USGS Earth Explorer***. *https://earthexplorer.usgs.gov/*
9. ***Vivien.M.Gornirtz,Tammy.W.Beaty,Richard.C.Daniels****;A Coastal Hazards Database for the U.S West Coast.*