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Monitoring and Modelling of Shoreline Change for Coastal Zone Management off Mangalore Coast, Karnataka, India

RahishaThottolil[1], Shreedhara V[2], K C Gouda[3]

[1, 2]Karnataka State Remote Sensing Application Centre (KSRSAC) Bangalore-01, India

[3]CSIR Fourth Paradigm Institute (CSIR C-MMACS) Wind Tunnel Road, Bangalore-37, India

Abstract: ***Monitoring and prediction of shoreline has a pivotal role in coastal zone management by realizing the durability of the coastal area. The Mangalore coast is known to experience severe soil erosion in some places and it leads to the changes in the shoreline. Therefore, regular monitoring is an essential tool for enriching the spatial database of shore-lines. Predicting the future position of shoreline is also an important fac-tor to support the environmental impact assessment by estimating the rate of change of erosion and accretion of coastal land. Therefore, in this study, a shoreline prediction model was attempted using remote sensing together with Geographical Information System (GIS) and a numerical model for Mangalore region. Nine shoreline maps were delineated be-tween the years from 1982 to 2015 and the analysis of shorelines revealed significant changes in its pattern over a period of 33 years. The rate of change in shoreline is embedded into an End Point Rate (EPR) numerical model and the shoreline of Mangalore has been predicted for the year 2020 and 2030. This model is validated by predicting the past shoreline position and comparing it with the actual position which is observed from the satellite images for the same year. The positional shift and the accuracy of predicted and actual shorelines are estimated by Root Mean Square error (RMSE) method. The study investigated to estimate the quantitative amount of erosion and deposition at the Mangalore coast from the period 2015 to 2020 (short-term) and 2015 to 2030 (long-term). From the results, that the rate of erosion would be about 0.46 Km2, and the net accretion would be 0.33Km2 along the Mangalore coast by the end of 2030. This study aims to utilizes geo-informatic technologies to increase the efficiency of shoreline prediction model along the study sites at Mangalore.***

Keywords: Shoreline mapping; Coastal zone; EPR Model; RS & GIS

1. Introduction

The rising sea levels and global warming are very much focused topics for re-search work, because these problems may cause many natural disasters. In addition to that, due to greenhouse effect the icebergs in polar region melt and leads to sea level rise which consequently results in reduction of land. So, studying the shoreline changes is important for protecting the environment and coastal area. The coastal areas of almost all the maritime states of India are always under great pressure due to high population densities linked with urban growth. The shoreline changes are mainly caused due to gradient in the littoral drift over the coast. The evolution of shoreline change is due to some activities like wind, currents, waves and sediment transport, and due to some anthropogenic activities like structural construction in coastal waters so on. As shoreline is changing rapidly, the accurate monitoring and marking of coastline changes (long-term, seasonal and short-term changes) are very important for the awareness of overall coastal processes. Geospatial technologies are the most efficient way to produce the coastline maps and to estimate the rate of changes of it. Observations made repeatedly on shoreline database, reveals the detailed shoreline changes over a period of time. Geographical Information System (GIS) enables to store the data in a digital form and also facilitates to share between users over electronic networks and the models can make prediction about future shoreline patterns.

Coastal zone has been more exploited because of its easy availability of re-sources has captivate the human beings but they have mistreated and damage it without considering its value to the environment and economy. With reference to sediment supply, a part of coast may have an equity, or have an insufficiency in sediment budget. A shoreline movement can occur due to boost or drop in its sediments in a short span of time. For visualization and analysing the coastal zone information, the geoinformatics approach could provide a better accuracy and time savings for its overall performance. Thus, RS and GIS are most adopted methods for coastline management and monitoring. To support, the financial and structural failure in a coastal region, the prediction model, which predicts the future coastline shifting are very influential. So, it is relevant to create a spatial database for coastline position and this data record can be used in coastal zone management. In this study, an attempt has been made to build a prediction model for the shoreline positionof Mangalore coast in order to suggest the apt coastal zone management. Natural disasters like tsunamis, flooding and typhoons etc. may cause damage to structures and harm livelihood in the coastal regions. So, monitoring the coastal line change is important when global warming and local concerns are considered.

2. Related Work

This section will describe existing research in the field of coastal zone management. Coastal management is most concerned about shoreline changes due to accretion and erosion of land area. The change in coastlines may cause consider-able impacts to the anthropogenic activities, its progression and hasty replicate systems (White and El Asmar, 1999). Using the historical dataset, aerial photographs, satellite images and recent map phenomena models are developed in order to mitigate the damage, overcome the negative impacts and to reconstruct the shoreline (Basile Giannini et al., 2011). The temporal and synoptic view of space borne satellite systems will provide accurate geo-spatial data for GIS, resulting in tracking down and monitoring of coastline changes (White and El As-mar, 1999). The coastline changes are in large scale along the populated coastal region, which will depend on a suitable model for prediction accuracy. The beach profile can be predicted by an empirical model that is showed by Bruun in his schematic erosion prediction method (Bray and Hooke, 2015). Moreover, population growth is high in coastal area than any other part in country. These population variations putting strain on coastal areas, marine animals and resources and natural resources. Coastal Zone Management activities strive to protect, conserve and manage the resources for future generation, while balancing to-days competing economic, environmental, social and cultural interests. There are large empirical literature studies are done in this domain, applications of RS and GIS in Shoreline mapping Change analysis, Prediction Model, Coastal Zone Management, Coastal resource management etc.

The shoreline location and the rate of change in coastal morphology are important in erosion/accretion, hazard zoning, setback planning and estimate modeling of coastal morph-dynamics (Sherman and Bauer, 1993; Al Bakri, 1996; Zuzek et al., 2003). The rate of shoreline changes which have influenced the coastal zone in the form of different position of shoreline in different times (Fenster et al., 2014). To forecast the future coastline location and summarize historical shoreline accurate coastline rate of changes are used through various modelling procedures (Li et al., 2001). Remote sensing act as a tool for fast and accurate mapping of the coastlines at a minimum price. In addition, Satellite image are the important platform for look into and track the coastal zones, and are also valuable in estimating coastline changes (Ciavola et al., 1999; Yang et al., 1999). These cutting-edge technologies have proved as a powerful tool in the extraction of information about coastal process, coastal landforms, delineation of shoreline, detection of land use changes and estimation of shoreline positions, (Raitala et al., 1985; Singh, 1989; White and El Asmar, 1999).

Alesheikh et al. (2007) analyses the coastline changes for Urmia lake, Turkey. He has noted that RGB (453) is the best color composite for digitizing coastline from satellite images. He has focused his attention on coastline mapping and change analysis and study for better management of coast. Kurt et al. (2010) re-port similar investigation to detect the coastline changes of Istanbul from 1987 to 2007. He suggests freely available Landsat images with medium resolution (30m) images are enough to estimate the coastal changes in a better way. Shore-line mapping by visual interpretation as well as digital number (DN) of satellite images is also possible; the concept has been developed by Marfai et al. (2008). Another study by Chand and Acharya (2010) reveals shoreline changes and impacts in Bhitarkanika wildlife sanctuary due to rise in sea level, Orissa. They explore the subtle issues of global effect of shoreline changes by reason of rise insea level and their effects to the coast and coastal community. His study indicates the geospatial and statistical methods for determining the shoreline change cover a time space. The results are based on the linear regression and regression coefficient methods. Finally, they attempt to infer a relationship between shoreline position and sea level rise. Barman et al. (2015) analyses the shift of shore-line of Balasore coast, Odisha; due to natural and manmade activities. These chronological shorelines positions used to predict the long term and short-term future shoreline positions. They survey the shoreline position approximately for 38 years. To predict the shoreline, the rate of shoreline change was computed using linear regression and EPR model.

Recent research also considered various models to simulate the shoreline changes. The structured model LITPACK tool is used to simulate the shoreline map(City et al., 2014). Observed shoreline maps from the historical data are used to calibrate the model. In light of this research coastal engineers and man-agers can decide and design the coastal structures such as break water length and orientation of Muthalpozhiharbour in Kerala. So, siltation of navigation channel could be minimized. For review of recent development in this research area, Coastal scientists have implemented various models to predict the coastal features. Xing et al. (2012) anew integration approach of beach evaluation model and GIS model has been developed to evaluate the long shore sediment transport rates. Prediction of coast land is also done in their research.

In Karnataka, the shoreline monitoring and prediction of its future position have been established by ChenthamilSelvan et al. (2014) for a period from 1989 to 2006 which is around 33 years using weighted linear regression models. Ku-mar et al. (2010) examine the 18 km long coast from new Mangalore port to Talapadi. They estimate the shoreline changes along the coast and have been noted that beach erosion/ accretion rate. Coast along the study area, the coast is divided into four sectors and changes in each sector are noted separately. Studies by Vinayaraj et al. (2011) have shown that qualitative and quantitative determination of coastal geomorphology changes along Karnataka coast. They study has been done for major hot spots of Karnataka Coast. They concluded significant loss is mainly at estuary of Karnataka coast due to frequent inter-actions of river flow, waves and tide etc. Bhat (1995) suggested that significant morphological changes noticed in Netravati-Gurpur River and Mulki-Pavnje estuaries by analysing Multi dated satellite data products. Kumar et al. (2010), Barman et al. (2015), has focused their attention on shoreline change analysis and future shoreline prediction model for a small region of Karnataka coast. Rate of shoreline change determination Cross verification done by using coefficient of regression and RMSE methods. Combination of geospatial and statistical approaches are very helpful in quantifying shoreline changes and spit morphology studies. Dwarakish et al. (2009) clearly pointed outgeo-informatics techniques can be successfully used for coastal vulnerability studies. The area of inundation as a result of future rise in sea level is calculated from Coastal Vulnerability Index (CVI). Evidence from their studies reveals how much area is going to sub-merge in Udupi district, Karnataka in upcoming year due to gradual sea levelrise. The coastal areas of Mangalore support significant industrial and commercial activities and many urban centers. These multifaceted activities combined with competing demands on the coastal zone require a coordinated management strategy. The Industrial and economic development has to maintain the ecological balance of the coastal area. In order to support the sustainable development and management of Mangalore coast, a shoreline prediction approach was carried out in this research.

3. Description of Study Area and Dataset

3.1 Study area

The present study is focused on Mangalore coast (12.87N 74.88E) is in Dakshina Kannada district of Karnataka state, India (Fig. 1). The elevation of Mangalore is 22mts (72 ft) above MSL. It is the district administrative headquarters and has the largest coastal area of Karnataka. Mangalore is located on west coast of the country and surrounded by Western Ghats in east and Arabian sea in west. It is a moderately earthquake prone urban Centre and it is classified under seismic III zone. The coastal zone of the Dakshina Kannada district is good developed region in state with good economy and population density (2011 Census). Coastline is connected with major port in Mangalore and minor ports.

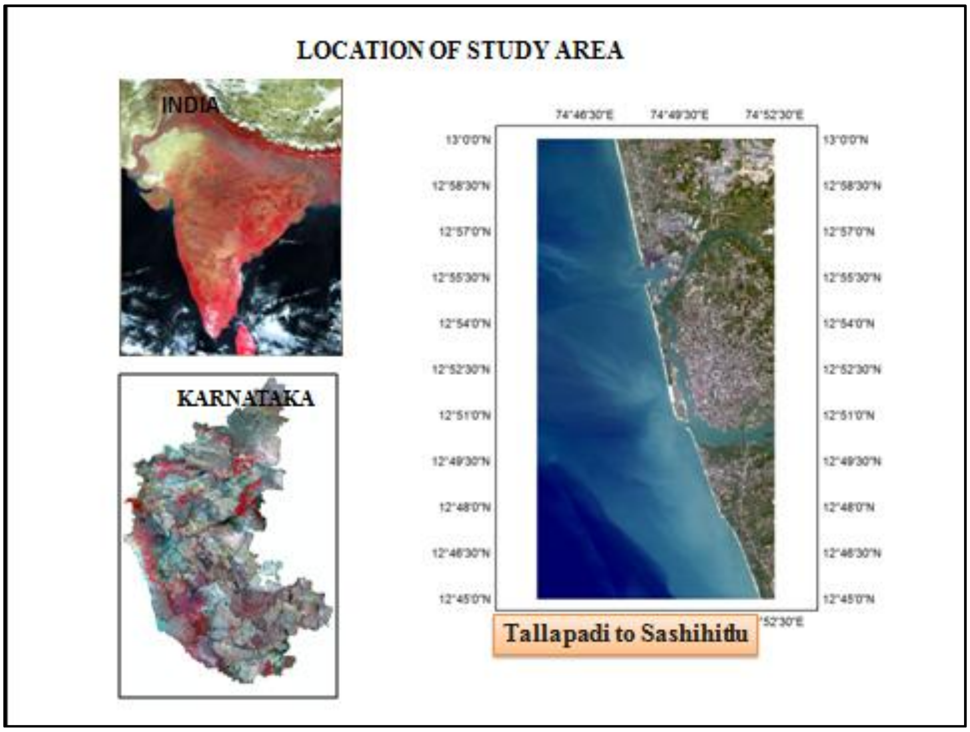

Figure 1: Imagery of the Study Area

The total length of shoreline in this study area is approximately 28 km from Tallapadi to Sashihitlu shown in Fig. 1. It is divided into four zones for shoreline change understanding (Tet al., 2016). Bengre and Ullal are the highly populated zones and also facing sever sea erosion problem during monsoon season. Man-galore is directly influenced by Arabian Sea in south-west monsoons and has tropical monsoon climate. The major 95 per cent of rainfall occurs in between May and October. Mangalore has average maximum and minimum humidity is 93 and 56 percent in the month of July and January respectively. In Mangalore, as per the IMD report the highest temperature is 38.1 C (101 F) as recorded (IMD). In the monsoon season, Mangalore city receives the highest rainfall when compared to all other urban centers in India, because of the Western Ghats.

3.2 Dataset

This section details the different types of data, the source, and the data structure which are necessary and used for this study. In order to study the coastal process and shoreline changes over the past three decade, Landsat remote sensing satellite images have been obtained from United States Geological Survey (USGS) for the year between 1989 to 2015. Nine satellite images with different sensors (Landsat TM and ETM, OLI-TIR) of the year 1989, 1991, 1993, 1995, 1998, 2000, 2002, 2013, and 2015 have been collected from USGS. A uniform spatial resolution of 30 meters to all the dataset is maintained to avoid scale transformation error. All the satellite images are projected in UTM coordinate system with zone node 43 and WGS 1984 datum. The details of the satellite data used are given in Table. 1

Table 1: Landsat Mission and its Sensor specifications used in the study

Satellite	Sensor	Spectral resolution	Spatial resolution	Radiometric resolution (Bit)	Temporal Resolution (Days)	Year of data obtained Coastline Mapping
Landsat 5	Thematic Mapper (TM)	7	30m (bands1 to 5 and 7) 120m (Band 6)	8	16	1989,1991, 1993,1995, 1998
Landsat 7	Enhanced Thematic Mapper Plus (ETM+)	8	30m (bands 1to 5 and 7) 60m (band 6) 15m (band 8)	8	16	2000, 2002
Landsat 8	Operational Land Image (OLI)	11	30m (bands 1to 7 and 9) 15m (band 8) 100m (10 and 11)	12	16	2013, 2015

In order to prepare the base map of the study area the survey of India topographical sheet prepared on 1: 25,000 scale was used. The study area covers in two grids namely 48/L/13/NW, 48/L/13/SW and they are surveyed during the year 1982-83.

4. Methodology

4.1 Shoreline delineation

Different Shoreline extraction methods have been developed from the earth observatory images. Shoreline can even be determined from an individual band image, as the reflectance of water bodies are approximately equal to zero in reflective Infrared bands and the reflectance of land area is always larger than water body. Experience shows that out of the six reflective TM bands, middle infrared (MIR) band 5 is most appropriate for separating the land and water interface. Shorelines are digitized from all the nine satellite images and compare with each shoreline map which is extracted from previous year shoreline map by overlying operation in GIS environment to determine changes along the coastline Fig. 2.

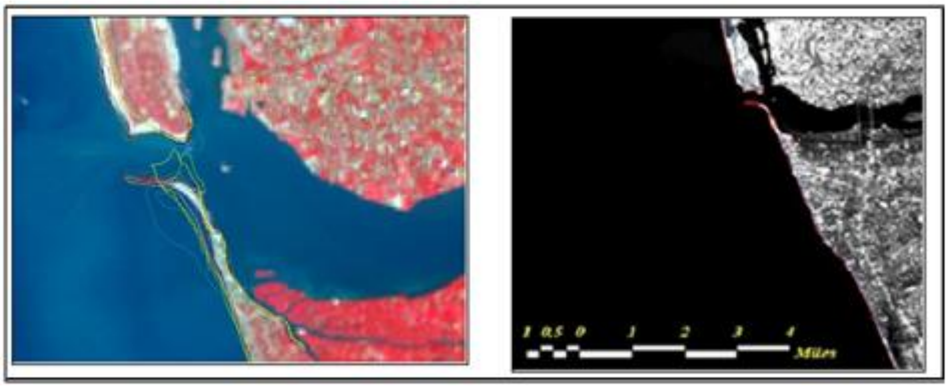

Figure 2: Typical Shoreline delineation using geospatial processing tool

4.2 Shoreline prediction -End Point Rate (EPR) model

Over a wide range of spatial-temporal scales dataset, the shoreline in Mangalore coast have experience both erosion and accretion. The quality of predicted shore-line position depends on capturing the historical coastal processes and gives the best data into the model for positioning the future shoreline. The rate of change of all the observed past shorelines are the primary feature set used to build a model for estimating the future shoreline positions. Among the various prediction models, End Point Rate (EPR) has been implemented in this research to predict the future shoreline position of Mangalore coast. EPR model is based on the assumption that only the speculated rate of change of past shoreline position in periodically is required to predict the future shoreline location. There is no prior knowledge regarding any coastal processes or sediment transport is needed to run the model. Fig. 3 illustrates the various steps involved for the shoreline prediction model. Rate of erosion and accretion were estimated for entire Mangalore coast by preparing 1Km X 1Km grid and clustered the grid numbers into four Zones (Tet al., 2016). In this study area, 47 number of 1Km2 grids are formed. The shoreline considered from the two end points on Landsat imageries of consecutive years for this present study. For example, the earliest coordinates (X1, Y1) is from year 1989 and the recent position is (X2, Y2) is from the year 1991. Then the distance between these points is determined using simple Euclidean distance formula. Changes in total length of shoreline in the period 1982-2015 are also measured by using ArcGIS software. A quantitative estimation of erosion/accretion map of Mangalore coast is also prepared between 1989 and 2015. Shoreline changes and rate of change of shoreline is measured based on the changes in position from earliest to recent shoreline.

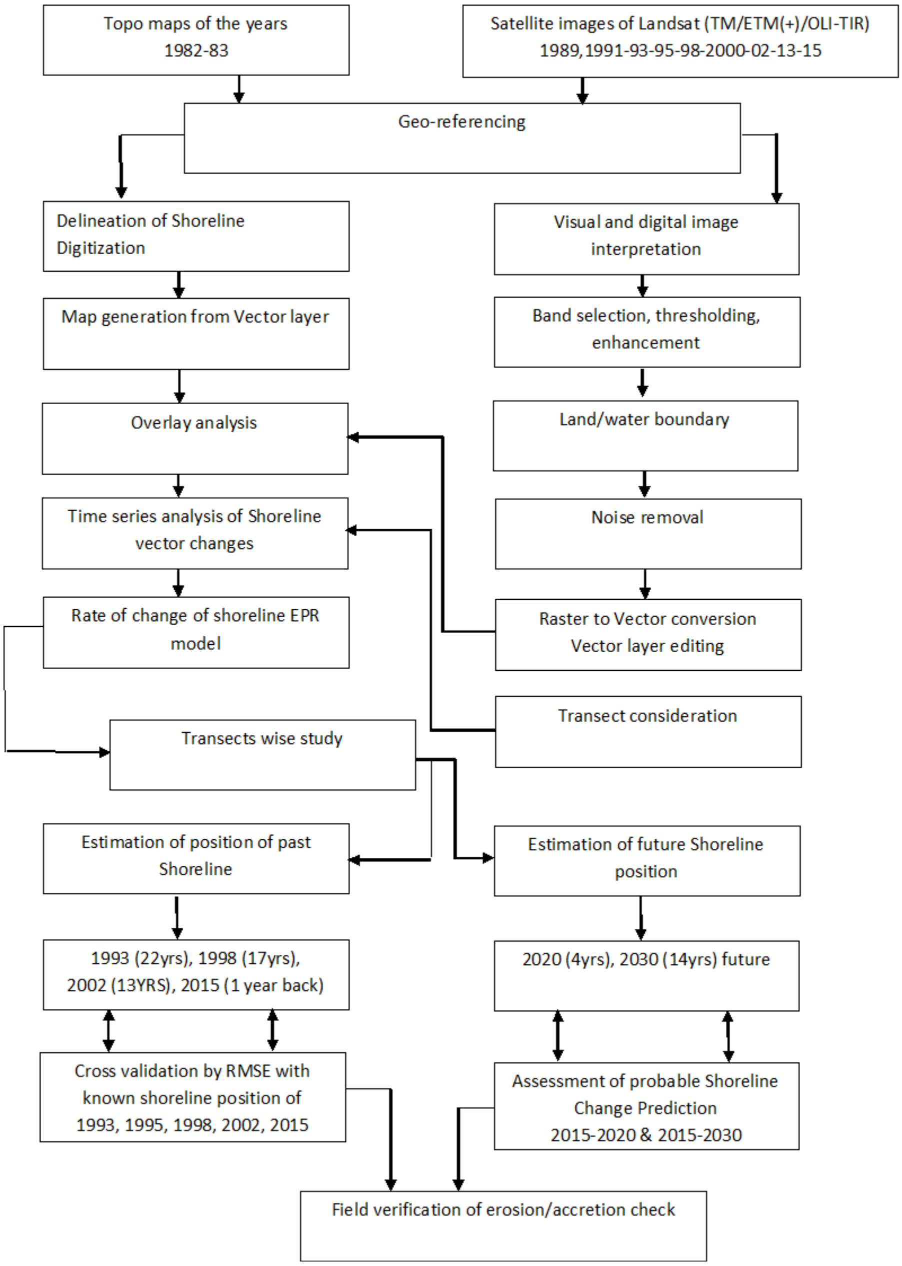

Figure 3: Flowchart showing various steps of methodology adopted for shoreline prediction

The geographical location of the future shoreline from the given data is estimated by applying the rate of shoreline shifting (slope-mEPR), time span (T) between the observed and predicted shoreline and model intercept (βEPR) which can be formulated as,

$$Y_{predicted} = (m_{EPR}) * T + \beta_{EPR} \qquad (1)$$

Model put to use the shoreline obtained from the two end points of digital imageries. Earliest (1989) shoreline position (X1, Y1) and recent shoreline position (X2, Y2) (1991), mEPR (y) is the rate of shoreline change in y direction, andβEPR is model intercept. Step 1: Rate of shoreline movement (mEPR)

Step 1: Rate of shoreline movement (**m_{EPR}**)

$$m_{EPR\,(y)} = (Y1 - Y2) / (T2 - T1) \qquad (2)$$

$$m_{EPR\,(x)} = (X1 - X2) / (T2 - T1) \qquad (3)$$

Step 2: Intercept of End Point Rate(β_{EPR})

$$\beta_{EPRY1} = Y1 - (m_{EPR\,(y)} * T1) \qquad (4)$$

Step 3: Position of shoreline prediction

$$Y_{predicted} = (mEPR_y) * (T_{Earliest} - T_{Recent}) + Y2 \qquad (5)$$

Similarly,

$$X_{predicted} = (mEPR_x) * (T_{Earliest} - T_{Recent}) + X2 \qquad (6)$$

Hence, the shoreline extracted from the year 1982, 1989, 1991, 1995, 1998, 2000, 2002, 2013 and 2015 images which was segmented at 1Km interval and the location of each points in a segment were sampled for the entire Mangalore shoreline which consist of 28Km. Slope mEPR is calculated for both x and y direction by considering the coordinates of each individual sample location. Initially, the model was calibrated using nine extractor shorelines which was efficiently analyzed using statistical model.

Fig. 4 depicts the coordinate system adopted in this model. The rate of shoreline change has been obtained and the future shoreline position of study area is predicted for both the short term which is 5 years (2020) and the long term which is after 15 years (2030). To validate the model, error factor is determined for the predicted shoreline of 1993 with respect to the actual extracted shoreline of 1993. This error values describes the positional shift in the model and the validation was carried out in terms of Root Mean Square Error (RMSE), equation 7 is listed below,

$$RMSE=\sqrt{1/N\sum_{i=1}^{N}(ActualOutput-EstimatedOutput)^2} \quad (7)$$

Where N is the number of transects.

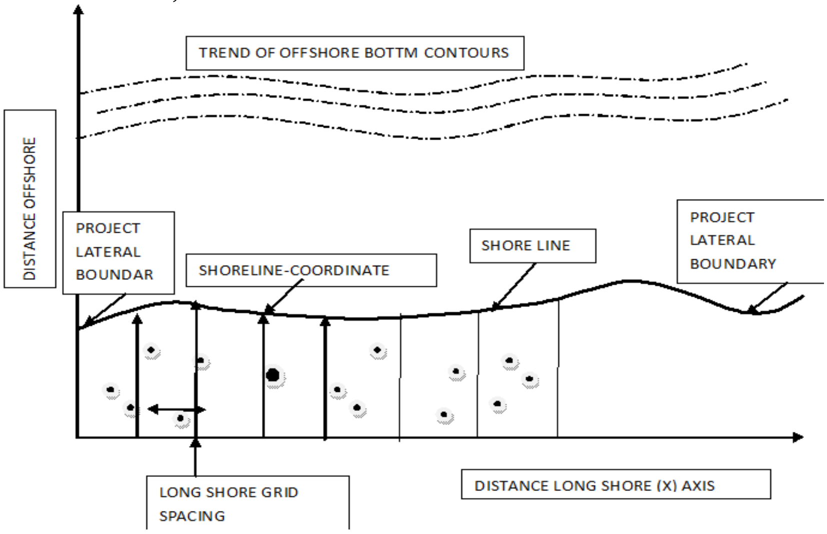

Figure 4: Co-ordinate system adopted in model

The position of future shoreline prediction in 2020 and 2030 was correlated by applying the error factor which is estimated at every sample point. The segmentation of shoreline using transects with the interval 1Km is shown in and the positional displacement of shoreline from 2013 to 2015 are represented in Fig. 5.

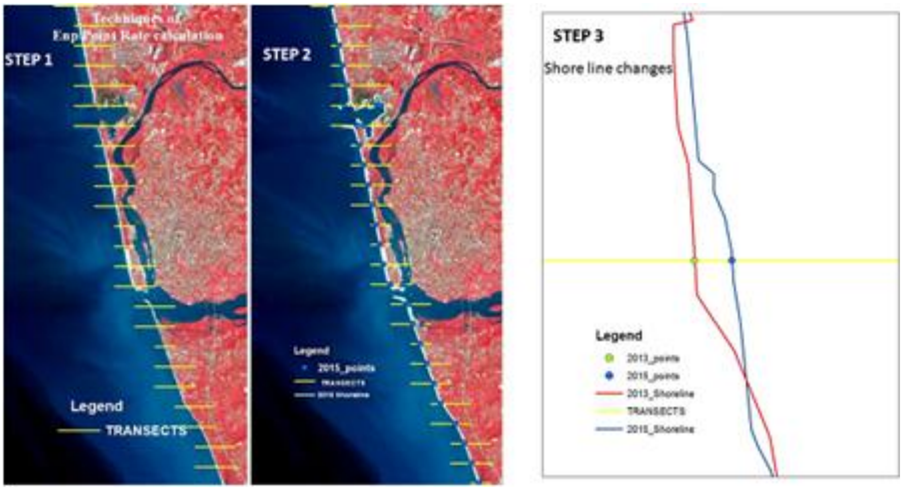

Figure 5: Representative images(left(Transects of 1 Km interval.), right(Calculating shoreline changes 2013-2015.)

5. Result and Discussion

5.1 The rate of shoreline changes during the period 1982-2015

In order to bring out the shoreline prediction, the shoreline of Mangalore coast for the period from 1982 to 2015 was considered as an input dataset. The result shows, the length of coastline is determined and it is extended by approximately 3.5 Km over the 33 years. Long-and short-term shoreline changes due to erosion or accretion pattern in different Zones have been estimated with base data of shoreline delineated using topographic map of 1982 along with multi-dated remote sensing satellite image of consecutive years till 2015(T et al., 2016). Shoreline changes are detected in meter with positive sign indicates accretion and negative sign indicates erosion illustrated in Fig. 6. The analysis of shore-line changes revealed significant variations in the form of shoreline erosion and the area of 0. 47Km2 was eroded during the last three decades. The erosion take effect along the southern part of Netravati-Gurpur estuary and Ullal spit.

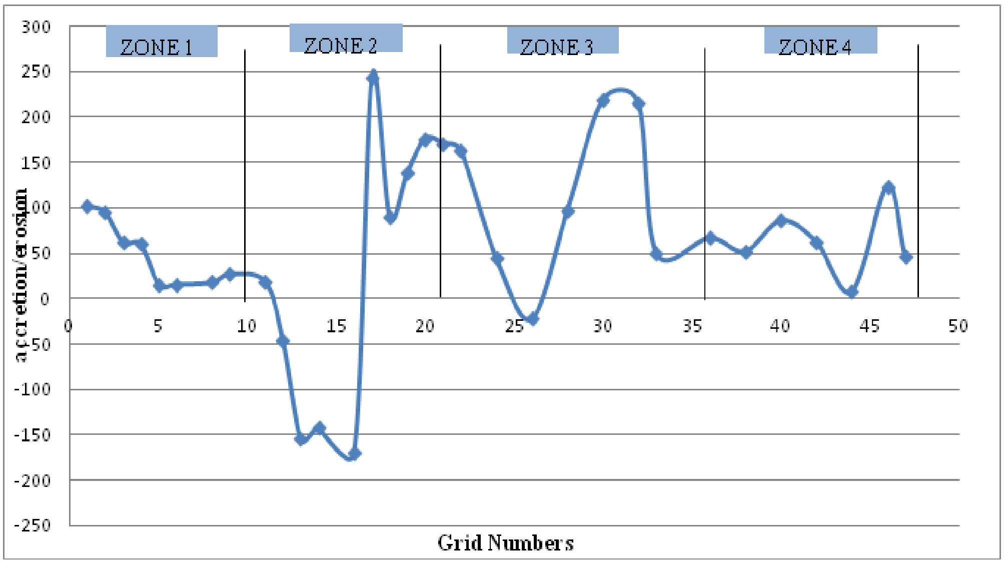

Figure 6: Long term(1982-2015) changes in erosion and accretion patterns in all the Grids

5.2 Prediction of past shoreline position for validation of EPR Model

From the observed shoreline of 1989 and 1991 the future position of shoreline in 1993 is predicted by EPR model. Shoreline of the year 1993, 1995, 1998, 2000, 2002, 2013 and 2015 are predicted by the same model. Observed shoreline and predicted shoreline of the Mangalore coast in 1993 shown in Fig. 7. The actual shorelines which are delineated from satellite images and predicted shoreline from EPR model are compared and positional shift or model error of each location is measured by RMSEs methods. The position error ranges from 25 m to 148 m.

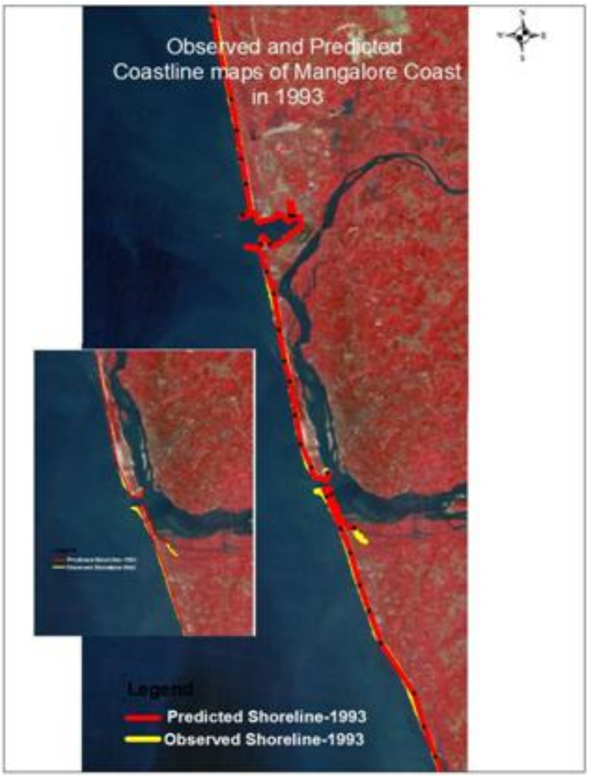

Figure 7: Observed and predicted shoreline along Mangalore coast with 1Km linear space interval

5.3 Predicted Future Shoreline positions

Using this statistical EPR model, the shoreline of the Mangalore coast has been predicted for the years 2020 and 2030. Past, present and future predicted shore-lines are shown in Fig. 8. Future shoreline position exhibits accretion pattern in most of the transects, but some transects are facing severe erosion trend from the base shoreline position of the year 2015. Maximum shoreline accretion is being predicted along transects number 11 and 12, which are closer to the Gurpur River, and Bengre spit. The study investigates the quantitative area estimation of coastal erosion and deposition at Mangalore coast from the period 2015 to 2020 and 2015 to 2030 Fig. 9. Erosion observed during 1982 to 2015 is not continuous all along the coast. Comparatively large amount of erosion observed southern part of N-G estuary. Statistical estimation of areal extend of erosion in 2030 along the study area is carried out by considering 2015 as base year. The study reveals 0.46 Km2 area will get erode along the coast by the end of 2030. However, the study also indicates that overall accretion along the region would be 0.33Km2 for the period 2015 to 2030.

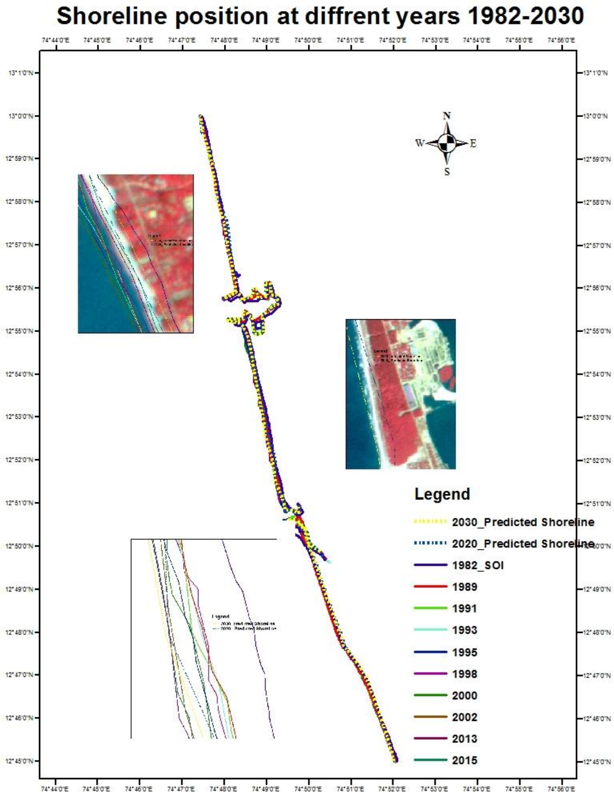

Figure 8: Comparing shoreline trend of Mangalore (1982 2030)

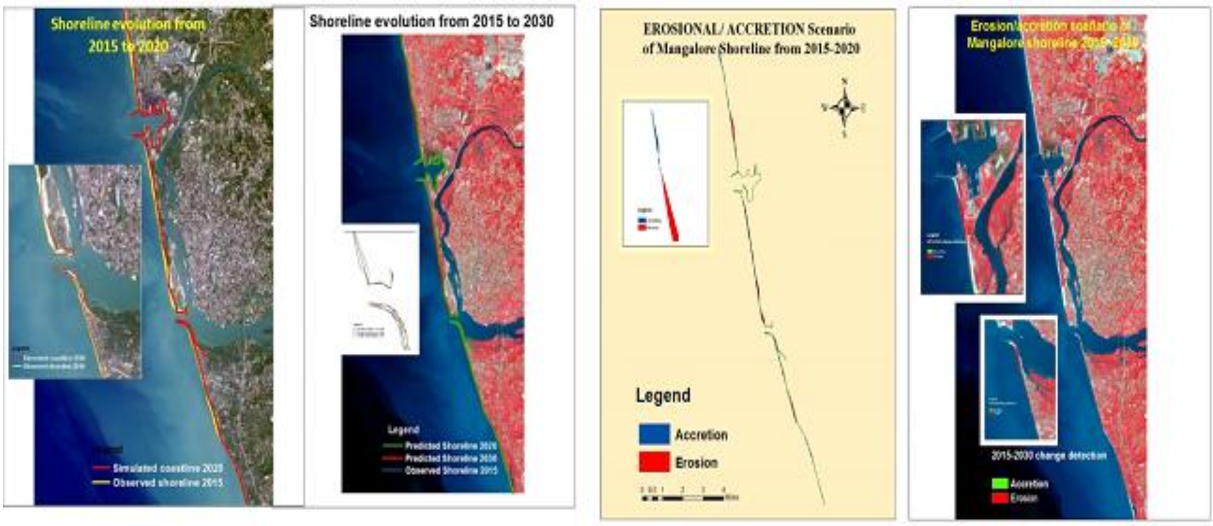

Figure 9: Representative images(left(Shoreline evaluation of the years 2020 and 2030 from 2015),right(Erosion/ Accretion at study area 2015-2020 and 2015-2030)

6. Conclusion

In order to bring out the shoreline change prediction model of Mangalore coast was carried out using muti-date satellite data and the prediction algorithms such as EPR model. This research highlights shoreline erosion which poses a severe threat to coastal environment, coastal community and tourism. Currently, Man-galore coast is subjected to severe alternation of shoreline, mainly due to erosion and accretion and discharge of sediments through Netravati-Gurpur estuary to the coastal waters apart from various point source pollution from industries. To meet the energy demand of coastal population and also enhance the economy of maritime, it is extremely difficult to control the industrial growth as well as ports/ harbours on the Mangalore coast. The fast-growing Mangalore urban centre leads to extensive sand mining along the coastal zone, which will alter the nature and structure of coast. If prediction of future shoreline positions needs to incorporate in coastal zone management plan to measure and to avoid coastal issues in the year ahead. Coastal development activities port/ harbour, break-waters etc after trend of sediment distribution patterns, which will ultimately end up with one side erosion and accretion on other side. The prediction model focused the changing of shoreline in long term and accuracy of the model could be improved by increasing number of shorelines vectors, number of transect intervals and applying high resolution of satellite images. Clearly, the model can be applied in other particular areas for coastal zone management. This study aims to utilize geoinformatics technology to increase accuracy of a shoreline prediction model along the study sites at Mangalore.

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Author Profile

RahishaThottolil received the M.Tech. degree in Geo-Informatics from Visvesvaraya Technological University (VTU) in 2016 with thesis work titled Integrated Coastal Zone Management of Mangalore Coast, India. Currently she is interacting and working with CSIR-CMMACS/KSRSAC on the various aspects of climate change and its impact studies in coastal Zone. She has clear understanding of atmospheric science, particularly global climate modeling, multi-source and multi-format data handling, remote sensing and GIS. She has handled large datasets from global climate model simulations and multi-source observation data.