Shoreline-change detection at kodungallur – chettuva region in kerala state

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Abstract. Coastline of Kerala has been experiencing severe erosion/accretion in the past decades, making it vulnerable to coastline changes alike other parts of the world. For a densely populated state like Kerala, the coastal erosion has become a critical issue because of the acute shortage of land especially due to large population density in the coastal zone. This paper mainly aims to prepare shoreline maps using ERDAS IMAGINE and ArcGIS.3 software’s, and to determine shoreline change occurred in the last two decades using DSAS software and identify the most vulnerable area susceptible to shoreline-changes. The study area selected is Kodugallur - Chettuva coastal region in Kerala State. From this study, it is found that the maximum change in shoreline occurred at Vadanappally with a magnitude of 726m due to erosion and at Koorikuzhi with a magnitude 94 m due to accretion. Other critical hotspots found in the study area are Engandiyoor, Palapetty, Poklai, Aattupuram, Kara and Azhikode. It is high time to strategically plan and implement hard/soft coastal protection measures to slow down or prevent further coastal erosion.

1. INTRODUCTION

Natural processes like erosion and accretion are the main sources of shoreline changes, which can be in response to several short-term events and long-term events. The short term events are storms, regular wave action, tides and winds, whereas the long term events are glaciations or orogenic cycles that can significantly alter sea levels, coastal land subsidence or emergence. Most of the coastlines are naturally dynamic and as a result of the rapid development of the economy and hazards, coastal erosion has become more and more serious. Moreover, negative environmental impacts due to anthropogenic activities like sand mining, over-exploitation of groundwater, land reclamation etc. are the other indirect causes of coastlines retreat. Coastal zone monitoring is an important task in national development and environment protection in which extraction of shoreline shall be regarded as the prime focus. Hence it becomes inevitable to map the shoreline-changes as it is the main input data for coastal hazard assessment and management. Hence in this study, an attempt is made to prepare shoreline map using ERDAS IMAGINE and ArcGIS.3 and to determine shoreline change occurred in the last two decades at Kodungallur – Chettuva region, Thrissur using DSAS software to identify the most vulnerable area.

2. LITERATURE REVIEW

Various literatures on studies related to the mapping and shoreline change detection is reviewed in detail. Shoreline-change is considered as one of the most dynamic processes occurring in coastal area.
In many coastal areas, dense population is seen next to the shoreline. It is observed that, in the past hundred years, the average sea level has shown a significant increase globally. Due to global warming, the annual rate of sea level rise is expected to be two to five times of the present rate. It is anticipated that, by 2100, the projected sea level will be approximately 50 cm higher than the present level. If the rise in sea level aggregate with the occurrence of greater and more frequent storms, coastal flooding and the erosion problems associated with it will become more and more severe [1].

Van and Binh (2009) have applied remote sensing technique for shoreline change detection. They have used geo rectification, histogram threshold method and rationing method, and finally filtering technique is applied to get the ultimate image of shoreline. The resultant shoreline is then converted into vector format. It is then exported to MapInfo format for analyzing the change of erosions/accretion areas [1]. Arun Kumar and Pravin (2012) investigated fifty-six km long coastal zone of Chennai districts in Tamil Nadu State, has experienced disasters such as storm, cyclone, flood, tsunami and erosion. This is one of the worst affected area during 2004 Indian Ocean Tsunami and during 2008 Nisha cyclone [2]. They have developed a Coastal Vulnerability Index (CVI) for the Chennai coast using 8 relative risk variables to know the high and low vulnerable areas, area of inundation due to future sea level rise, and land loss due to coastal erosion. Both conventional and remotely sensed data are analyzed through modeling technique and with the aid of the remote sensing and Geographic Information System (GIS) tools. A map for the Chennai coast is prepared which can be used by the state and district administration who are involved in the disaster mitigation and management scheme. Abdul et al. (2017) conducted a study on shoreline-changes to identify the patterns of changes occurred over a period of 1984 to 2013 in Selangor coastal area. Geographical Information System (GIS) along with Remote Sensing (RS) technology is found to be a useful tool to study these changes as it is able to generate information, monitor, analyze and predict the shoreline-changes [3]. Nassar et al. (2018) has detected shoreline change by using DSAS version 4.3, an extension to ArcMap 10.2.2 developed by the USGS. The software is used to compute the rate of change shoreline by means of statistics from five historic shoreline positions along the North Sinai coast [4]. Thus, this study offers a highly reliable tool of a decision algorithm to local coastal managers and decision makers in evaluating changes occurred in coastal zones.

3. STUDY AREA

The study area selected is Kodungallur – Chettuva region in Thrissur district of Kerala state, India. It lies between 10°10’24.01”N to 10°12’21.63”N latitude and 76°9’44.52”E to 76°13’32.68”E longitude. It has an area of 250 km² and maximum elevation of 14 m. It has a coastal length of 40 km and is surrounded by water bodies all around as shown in Figure 1. The western side of the area is bounded by Arabian Sea; North–East region by Karuvannur River (blue colour), South–East region by Kanoli Canal (yellow colour) and Periyar River (white colour). The major places in the coastal stretch of the study area are Azhikode, Paybazar, Aarattuvazhi, Kara, Thattukadavu, Koolimuttam, Aarattukadavu, Palapetty, Kothakulam, Valapad, Nattika, Vadanappaly, Chettuva etc.

The soil found on the coastal stretching from Kodungallur to Chettuva is coastal alluvium. The soil has high permeability and low water holding capacity due to the presents of marine deposits. This study area has a tropical and humid climate. The area, location, climate, size, land structure, history, management status etc. are highly influenced by the existence of water bodies. There are about fifty hectares of land uncultivated due to saline water intrusion, which is a serious problem affecting the agricultural in these areas. In the current scenario across the study area, many families from critical locations have been shifted to other places due to erosion/accretion. The road system has also been disrupted in many places. This has also resulted in drinking water problems in many parts of the study area. Figure 1 shows the location map of the study area.
4. METHODOLOGY
The methodology elaborates the step-by-step procedure for detecting, analyzing, extracting, and quantifying the shoreline change in the study area. Satellite optical images are used for the analysis and interpretation which can be obtained easily. Absorption of infrared wavelength region by water and its strong reflectance by vegetation and soil. It makes the images an ideal mixture for mapping the spatial distribution of land and water. These characteristics of water, vegetation and soil are made use in coastline mapping. To extract the shoreline and to study its change, the Landsat MSS image (1997) and Landsat ETM+ image (2014) are downloaded from USGS Earth Explorer. First step in this is the shoreline extraction by multispectral image pre-processing.

Figure 1. Location Map of Study Area

Various methods can be used to obtain Landsat images. One of the most popular online tools is USGS Earth Explorer. The satellite imageries are susceptible to various atmospheric and system errors. Thus once the imageries are procured, they have to be pre-processed. The Landsat satellite images thus obtained are used as the input for spectral pre-processing. The individual bands of the satellite image are converted into a False Colour Composite image by using the layer stack method. As the level-1 product is procured, they are projected to Universal Transverse Mercator (UTM) with reference to WGS-84 datum. The various pre-processing techniques used are Haze reduction, Noise removal, De-stripping, Focal analysis, Histogram equalization, Brightness inversion etc. Haze reduction increases the image sharpness and thus it is important to remove it from the image. Images may also have clouds which mask the actual information. Clouds seen on the shoreline are removed by adding holes in the images while mosaicking. Thus if clouds are found in the shoreline area, such images are
mosaicked using most recent, cloud free imagery. De-striping and focal analysis are the two tools in ERDAS to remove the black strips in images taken in SLC-Off mode. However, these two tools have used algorithms which fills the strips using the adjacent cell data, which is not applicable for curved portions. Hence a recently available good image is set under the stripped images. Pre-processing does not have any cut-and-dried rules. It must be done appropriately according to the distortions happened to the image and according to its intended purpose. Therefore, user must thoroughly observe the raw data before applying any image processing techniques. The pre-processing procedure of the Landsat image of the study area is given in Figure.3.

![Figure 3. A screenshot of pre-processing of landsat Image of study area](image)

The sub-set image of the pre-processed image is shown in figure.4. Extraction of shoreline needs better visibility of land-water separation. Hence for distinct land-water separation, supervised classification is done on the pre-processed image.

![Figure 4. The Subset Image of Study Area](image)

In this study, shoreline is extracted from the pre-processed image using ArcGIS and is shown in Figure.5. Here blue colour shows the sea area, green colour shows the land area and red thick line shows the shoreline.
Figure 5. Digitized shoreline done in ArcGIS

All the shorelines are digitized as line feature and are stored in a personal geodatabase using Editor toolbox. As per DSAS specifications, each shoreline has attributes such as object ID, shape, date, uncertainty and shape length. By following this procedure, the shorelines of 1997 and 2014 are digitized and are shown in Figure 6.

Figure 6. Shorelines of 1997 and 2014

The extracted shoreline is projected on to the Universal Transverse Mercator (UTM) coordinate system and exported to DSAS for analyzing. The main application of DSAS is in the utilization of polyline layers for their presentation of a specific shoreline feature at a particular point in time. By using DSAS software we can compute the rate-of-change statistics for a time series of shoreline positions. For this a baseline is constructed and it serves as the initial point for all transects. The statistics tool evaluates and address the nature of shoreline dynamics and trends in shoreline-changes. A range of statistical change measures are derived within DSAS, based on the comparison of shoreline positions through time. These include Net Shoreline Movement (NSM), Shoreline Change Envelope
(SCE), End Point Rate (EPR), Linear Regression Rate (LRR) and Weighted Linear Regression Rate (WLR).

The methodology adopted by Digital Shoreline Analysis System (DSAS) Version 5.0 User Guide; Open-File Report (2018) has been adopted for the shoreline change analysis. According to that, all DSAS input data must be managed within a personal geodatabase. This database will be storage location for the program generated transect feature class and the associated statistical output tables. Shoreline shape files, pertaining to different years need to be imported as feature classes within a geodatabase in ArcCatalog. For this, the collected shape files are appended to a single file and then imported into a geodatabase within ArcCatalog. Each shoreline vector represents a specific position in time and hence a date is assigned to it in the shoreline feature-class attribute table. The measurement transects that are cast by DSAS from the baseline intersect the shoreline vectors. The point of intersection provides the information about location and time which is used for calculating the rate of change. DSAS uses a measurement baseline method to calculate rate of change statistics for a time series of shoreline. The baseline, which serves as the starting point for all transects cast by the DSAS application is constructed. The transects intersecting each shoreline at the measurement points are used to calculate shoreline change rates. Transects are cast perpendicular to the baseline and stored in the geodatabase where the input feature classes (baseline and shoreline) are stored. The shoreline intersection threshold, which is the minimum number of shoreline to be intersected must be specified. The calculations are done by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline.

To display the statistical calculation output spatially, in ArcMap, the statistics table has to be joined to the transect features class by the transect ID field, which has the same values as the object ID field in the transect feature class. The computed transects are clipped with the Shoreline Change Envelope (SCE) and this creates a copy of the original transects clipped to the SCE extent [5].

5. RESULTS AND DISCUSSIONS
Rate of shoreline-change is quantified by using End Point Rate Statistical Analysis method in DSAS. The shoreline changes thus found for the period from 1997 to 2014 is shown in Figure.7.

![Figure 7. Shoreline Change in Study Area](image-url)
From the attribute table obtained after statistical analysis, it is found that the maximum change in shoreline due to erosion occurred at Vadanappally with a magnitude of 726 m and at Koorikuzhi with a magnitude of 94 m due to accretion. Other critical areas are Engandiyoor (411 m), Aattupuram (400 m), Kara (400 m) and Azhikode (503 m) by erosion and Palapetty (77 m), Poklai (75 m) by accretion. The line feature layer of shoreline is converted to kml file and is given as input in Google Earth. Thus the shoreline changes estimated using DSAS is compared with the actual condition during 1997 and 2014. The shoreline change occurred at Kara and Vadanappally during 1997 and 2014 are shown in Figures 8 and 9 respectively. The left part indicates the shoreline in 1997 and the right side indicates that in 2014. For visual comparison of the shoreline change and its inward movement, the shoreline of 2014 is inserted as a red line in the left Figures.

![Image of shoreline changes](image1)

**Figure 8.** Shoreline change occurred at Kara in 1997 (left) and 2014 (right)

![Image of shoreline changes](image2)

**Figure 9.** Shoreline change occurred at Vadanappally in 1997 (left) and 2014 (right)

The accuracy of extracted shoreline from the satellite imagery is verified using the actual shoreline positions collected from Coastal Engineering Field Studies (CEFS) Department. The accuracy is checked using the Shoreline Change Envelope (SCE) and found out the accuracy level as 90%.
6. CONCLUSION
The shoreline did change drastically in the study area over the last two decades. The maximum change in shoreline due to erosion occurred at Vadanappally with a magnitude of 726 m and at Koorikuzhi with a magnitude 94 m due to accretion. Other critical areas are Engandiyoor, Palapetty, Poklai, Aattupuram, Kara and Azhikode. Curved portions showed irregular pattern in shoreline-changes. On close examination, it is also found that straight reaches are less vulnerable to shoreline changes than curved areas. Thus the results obtained from this study will definitely be useful for the stakeholders, policy makers and coastal managers for evolving a sustainable coastal protection plan to safeguard its natural integrity and coastal resources. This study also ensures the potential of satellite images for change-detection studies of terrestrial features.

References
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