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Analysing the Shoreline Dynamics Along the Southern Coastal Region of Kerala: A Case Study of Kollam District in Kerala

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Abstract

Shoreline change is considered to be a serious issue because of the changing nature of oceans and its influence on people and land. The vital term shoreline can be defined as the rate at which shore gets worn or accreted due to wave action, sea level-rise or any supplementary hazards and processes that affect the land. All the natural processes are conserved to attain their equilibrium, coast as a physical feature is always in a dynamic state trying to change, and nature continually works for preserving its balance. The coastal regions of India are specified with varied ecosystem, high productivity and thickly populated, has increased its very own importance. The coastal areas are subjected to vulnerable hazards, and it affects the coastal community and its geomorphic features. The present study has been conducted along the coastal areas of southern Kerala, especially Kollam district with the help of multi- temporal satellite images of the years 1973, 1988, 2002, 2018 and 2022. The Digital Shoreline Analysis System (DSAS) technique is used for calculating the coastal erosion and accretion rates. The present study focuses on the pre and post tsunami effects and major and minor erosion and accretion occurred in Kollam. Tsunami is a series of waves caused by an earthquake, underwater volcanic eruption, landslide or other abrupt disturbances. The Indian Ocean tsunami of December 26, 2004, not only affected the Bay of Bengal coast of India, but also hit into the Arabian Sea coast with major damages in Kerala. Destructive waves were occurred through tsunami, and it has made changes in the coastal geomorphology. The study could be analyzed micro level shoreline change rate due to tsunami effects in association with anthropogenic activities occurred in the coastal areas of Kollam district.

Keywords: Digital Shoreline Analysis System (DSAS); Coastal Erosion; Accretion; Tsunami

1 Introduction

Shoreline refers to the actual physical boundary between land and water. It is recognised as one of the most dynamic areas on earth, with physical and human activities being the main drivers of shoreline modifications[(13)]. Because they function as an obstruction where land and ocean meet, shorelines are complex habitats [22]. A depositional aspect of wave motion is the shore. The rate at which the shore is eroded or accreted as a result of wave action, sea level rise, or other land-affecting activities is known as the shoreline change rate. Nature continually strives to keep the equilibrium, and coasts are constantly in a state of dynamic flux.

Because of human and environmental disturbances, coastal environments are extremely dynamic and sensitive. Tornadoes, storm surges, flooding, erosion, deposition, waves, currents, tides, wind, sea level rise, etc. can all cause significant natural disruptions. Contrarily, human disturbances include the building of jetties, ports, groins, seawalls, breakwaters, mining of beach sand, industrialisation, urbanisation, waste dumps, home waste and industrial effluent discharge, recreational activities, and a decrease in the amount of sediment input from rivers. These two variables have resulted in modifications to the shoreline that have both short- and long-term effects on erosion and accretion [3,4,11,17,23].

With the most varied ecosystem, great productivity, and dense population along the coast, India has become increasingly significant. The shoreline alterations brought about by human activity and global climate change pose a hazard to the Indian beaches. These pressures serve as catalysts for several vulnerabilities, including saltwater intrusion, frequent severe events, coastal erosion, and rising sea levels. The same vulnerabilities have a direct impact on the way of life in the study area's coastal settlements. Using multi-temporal satellite pictures from 1973, 1988, 2002, 2018, and 2022, the study was carried out along the coast of southern districts of Kerala, particularly in the Kollam district. The Digital Shoreline Analysis System (DSAS) has been utilised to compute the rates of coastal erosion and accretion that are ongoing.

The coastline line alterations in the southern coast of Kollam district, specifically from Eravipuram to Thangassery coast, are the primary subject of the current study. Using five-year intervals between the corresponding years 1973, 1988, 2002, 2018, 2022, the study examines the temporal changes in the shorelines from Eravipuram to Thangassery. A portion of the wind's energy is transmitted into the water as it blows over the water's surface. Therefore, waves are thought to be among the most significant processes in coastal areas, particularly on open shorelines. Coastal zones are experiencing erosion and depositional features due to the action of waves. A tsunami, as we currently understand it, is a sequence of waves brought on by an earthquake, undersea volcanic eruption, landslip, or other sudden disruption.

During December 26, 2004, the Indian Ocean tsunami struck the Arabian Sea shore, causing significant damage in addition to the Bay of Bengal coast in India. The geomorphology and landforms of Kerala's coastline have changed as a result of the devastating tsunami waves. The current study aims to demonstrate how pre- and post-tsunami waves, as well as human activities, caused micro-level shoreline modifications. From a time series of different coastline positions, the rate of shoreline change statistics are computed using the Digital coastline Analysis System (DSAS) extension tool [18]. The program is intended to support rate-of-change computations of the computed data as well as the shoreline change-calculation procedure. The DSAS operation system aids in the completion of a microlevel analysis for a specific shoreline feature in the Kollam region at a given point in time.

2 Regional settings

Kerala is located on the southernmost tip of India and adjoining the coast of Arabian Sea. Kerala coast is divided into three parts, Southern coast, Central coast and Northern coast. Southern coastal area is extended to Thiruvananthapuram, Kollam and Alappuzha. The coastal zone of Kerala is well known for its rich fisheries and placer mineral deposits. Southern coastal Kerala is located on the southernmost tip of Kerala and Kollam coastline length is 45.72km. The present study focuses the very minute area of Kollam district (Figure 1) of Eravipuram coast to Thangasserry beach located at 8°86'64" and 8°88'61" Northern latitude and 76°62'11" and 76°56'91'Eastern longitude and length is 14.1 km. It has a long coastal line with Arabian Sea and Portion of TS canal passes through it. Thangasseri beach has a populated beach area on the shores of Arabian Sea in Kollam coast. The minerals and sand deposits are heavy in Kollam coast, mainly Kollam with white sand beach. The coastal plains with an elevation ranging between 0-6m almost occurs narrow belt of alluvial deposits are seen parallel to the coast. The coastal alluvium and Onattukara soils are purely marine deposits. The coastal plain has a number of backwaters known as kayals. The charnokite group of rocks, migmatite, garnet group of rocks are distributed in the area.

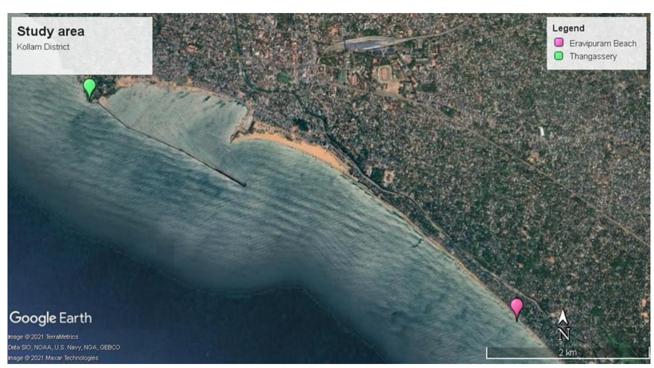

Fig. 1. Study Area of Kollam District [Source: Google Earth Engine]

3 Methods and Techniques

Quantitative techniques were used for the analysis of shoreline change assessment. The multi-temporal satellite images (1973, 1988, 2002, 2018 and 2022) of Land sat 1 to 8 series and Sentinel images (Table 1) were used for analyzing the shoreline changes and DSAS for identifying the rate of shoreline erosion. The following chart (Figure 2) clearly represents the methods and techniques used for the study. Rate of shoreline change is quantified by using End Point Rate statistical analysis method in DSAS.

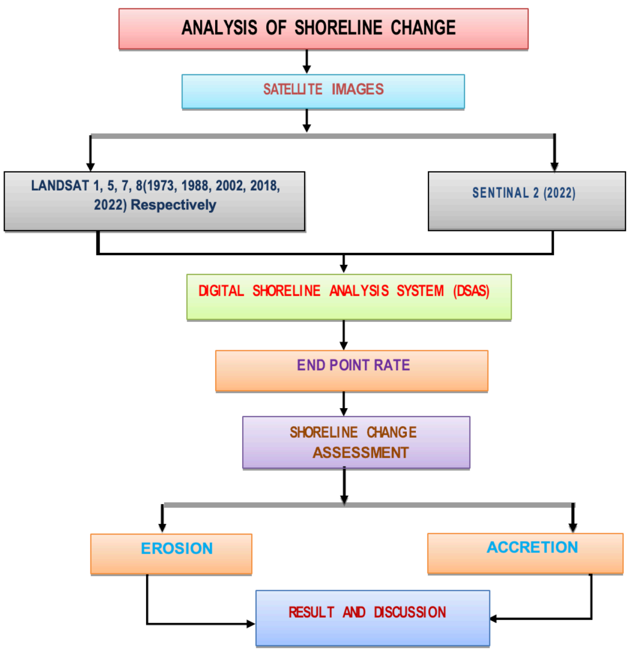

Fig. 2. Methodology Flow chart [Source: Prepared by the researcher]

Table 1. Landsat Imageries and Specifications

Satellite	Sensor	Launch Year	Path / Row	Spatial Resolution
Landsat 1	MSS C1	1973/02/09	155/52	80m
Landsat 5	TM C1	1988/01/19	145/52	28m
Landsat 7	ETM+C1	2002/02/18	145/52	30m
Landsat 8	OLI/TRS C1	2018/02/06	145/52	30m
Sentinel 2A	MSI	2022/01/18	T43 PEN	10m

Source: Prepared by the researcher

4 Result and Discussion

The Digital Shoreline Analysis System (DSAS) is an extension tool of Arc Map is designed to calculate the rate of shoreline change using statistics from a temporal series of multiple shoreline positions. The software is proposed to assist the shoreline change- calculation process and also give rate-of change of information and the arithmetical data important to set up the consistency of the computed results. The most important application of DSAS is that it can operate multiple layers as representation of a particular shoreline feature at a specific point of time. This study envisages on the major and minor shoreline changes in the coastal area of Kollam district of southern Kerala and analyses the natural and anthropogenic activities during the pre and post tsunami.

The rate of shoreline changes analyzed with multi- temporal satellite images of Landsat and Sentinel, from 1973 to 2022. 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 1973 to 2022 is shown in the Figure 3. It is found that the maximum change in shoreline is occurred due to erosion at Thangasserry. The visible shoreline change is figured at Thangasserry and Eravipuram during 1973 and 2022 are expressed through the map.

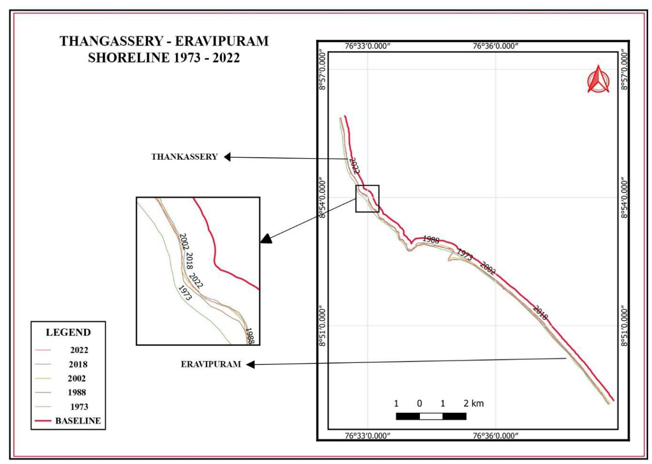

Fig. 3. Map of Thangassery - Eravipuram Shorelines 1973-2022 [Source: Prepared by the investigator]

In order to get a micro level change in the shoreline is done by DSAS assistance. The intersecting point of land and water to be marked as baseline which is the representation of the shape of the coast. The graph itself showing the trend of erosion and accretion from the baseline. The other lines representing different periods (1973-2022) of erosion and accretion in the coast of Thangassery to Eravipuram (Figure 3).

The baseline, which serves as the starting point for all transects cast by the DSAS application is constructed firstly. The transects intersecting each shoreline at the measurement points are used to calculate the rate of shoreline change. Transects are cast perpendicular to the baseline and stored in the geodatabase where the input feature classes (baseline and shoreline) are kept. The shoreline intersection edge, which is the minimum number of shorelines to be intersected and be specified.

It is visible from the images , for the period of 1973, 1988 and 2002, 2018 and 2022 are envisaged that there have been drastic changes occurred in the shoreline of Thankassery coast, before and after tsunami. The reason for the erosion of the shore is due to the force of destructive waves occurred and hit during Tsunami. The wave actions in the shoreline are due to the constraints in the movement of waves at shore. It means that whenever the waves hit the shores it releases their energy and stir up sand in the water column to became stable. Once they break their momentum drives a current pushing water upon the beach against the coastline. One of the reasons for this is due to the construction of shore protection structures such as break water, sea wall which disturbing the shore sediment fluxes. Moreover construction of fishing harbour is also a major reason for shoreline changes in the Thankassery region which drives erosion rate to high.

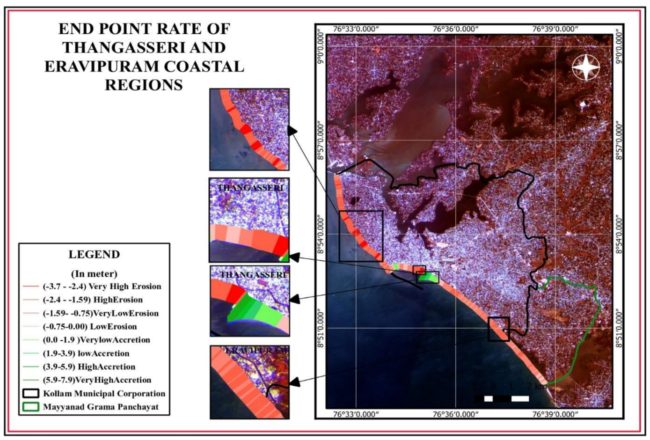

Fig. 4. Map of End Point Rate of Thangassery and Eravipuram Coastal Regions [Source: Prepared by the investigator]

The End Point Rate (EPR) technique (Figure 4) combined with the satellite imageries are accurate and reliable method for shoreline change computation and analysis is done with DSAS. The EPR is computed by dividing the distance of shoreline movement by the time passed between the initial and most recent measurements. Shoreline change evaluations are based on comparing four lines of shore which are extracted from different time period satellite imageries. The long-term shoreline change assessment of Eravipuram and Thangassery coast is studied for a period of 44 years from 1973 to 2022.

From the above (Table 2) clearly explains the categorized EPR values of erosion rate and accretion rate affected in Eravipuram and Thangassery coastal during 1973 to 2022. Shoreline changes are measured by using DSAS method and the calculation is done by End Point Rate statistical analysis.

Table 2. End Point Rate of Thangassery and Eravipuram Coastal Regions in 1973-2022

Satellite	Sensor	Launch Year	Path / Row	Spatial Resolu-tion
Landsat 1	MSS C1	1973/02/09	155/52	80m
Landsat 5	TM C1	1988/01/19	145/52	28m
Landsat 7	ETM+C1	2002/02/18	145/52	30m
Landsat 8	OLI/TRS C1	2018/02/06	145/52	30m
Sentinel 2A	MSI	2022/01/18	T43 PEN	10m

Source: Computed by the Researcher

In the Figure 4, positive sign indicates the accretion, and the negative sign indicates erosion and the shoreline change rate are classified into eight categories as very high erosion, high erosion, very low erosion, low erosion, very low accretion, low accretion, high accretion and very high accretion. From the Figure 4, it is clearly visible that Thangassery coastal region have very high erosion and very high accretion with an eroded rate of -3.7 to -2.4 and an accredited rate of 5.9 to 7.9 respectively. This is mainly due to the unscientific method of constructing sea walls, break water and the construction of fishing harbour. A high accretion value of 3.9 to 5.9 can only see at Thangassery region which results due to the movement of the waves, tides and longshore currents.

Eravipuram coastal area have a high erosion rate of -2.4 to -1.59 compared to Thangassery region, Eravipuram is affecting only high erosion and the map clearly showing, Eravipuram region has a gradual increase in the rate of erosion, also due to unscientific construction of sea walls. It must have to be noted that the Eravipuram coastal region is eroding gradually and having no accretion at all. This kind of differentiation is possible only with the help of DSAS application.

The aftereffects of erosion and accretion are faced by the coastal communities. Mayyanad, a beach tourism spot is known for swimming is closely located near Eravipuram beach and long stretches of white sands and an ideal site for swimming are the major reasons that attract tourists to Mayyanad beach. Tourism activities in the study area is another reason for changing the shorelines. Increasing coastal disasters like cyclone, flash flood, coastal deterioration, saline intrusion is badly affecting the coastal areas and making life vulnerable for coastal communities.

In Thangassery building projects and industries along with harbour construction have negative impact on the stability of the coastal environment. It is also indicated that more human made structures along the coast may create and unstable ecosystem which gradually affect the equilibrium between coastal erosion and accretion.

The study clearly envisages that the continuous shoreline alternations are also contributing more damages in the coastal line in association with climate change and sea level rise.

5 Conclusion

The study examines the rate of shoreline change along of Kerala's southern coast, especially Eravipuram to Thangassery coast. Shore line change rate is calculated by using multi-spectral satellite images (1973, 1988, 2002, 2018 and 2022) and digital analysis method. The calculations are done by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. The ability of DSAS is to calculate the pace of changes is one of the key advantages of employing it in coastal change studies. This study evidently shows that the erosion rate is high after Tsunami period and in the present situation also. The rate of erosion and accretion in Thangassery coastal region is very higher than that of the Eravipuram coastal region. As a complex environment shoreline study focuses on coastal erosion and accretion, changing equilibrium, human interventions, negative impact of climate change, sea level rise and numerous vulnerabilities are affected by coastal communities.

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