A Shoreline Change Analysis Along the Coast Between Kanyakumari and Tuticorin, India, Using Digital Shoreline Analysis System

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Abstract The shoreline is one of the rapidly changing landforms in coastal areas. They are the key element in coastal GIS and provide the most information on coastal land form dynamics. Therefore, accurate detection and frequent monitoring of shorelines is very essential to understand the coastal processes and dynamics of various coastal features. The present study is to investigate the shoreline changes along the coast between Kanyakumari and Tuticorin of south India (where hydrodynamic and morphologic changes occur continuously after the December 2004 tsunami) by using Digital Shoreline Analysis System (DSAS), an extension of ArcGIS. Multidate IRS and Landsat Satellite data (1999, 2001, 2003, 2005, 2007, and 2009) are used to extract the shorelines. The data is processed by using the ERDAS IMAGINE 9.1 software and analyzed by ArcGIS 9.2 workstation. The rates of shoreline changes are estimated by three statistical methods, namely, End Point Rate (EPR), Linear Regression Rate (LRR), and Least Median of Squares (LMS) by using DSAS. The study reveals that most of the study area has undergone erosion. Both natural and anthropogenic processes along the coast modify the shoreline configuration and control the erosion and accretion of the coastal zones. The coastal zones along the estuary have experienced accretion due to the littoral processes. The zones with headlands have more eroded than other zones along the study area. The study also shows that the coastal zones where sand is mined have relatively more rate of erosion than that of the other zones. Improper and unsustainable sand mining may also lead to severe erosion problem along this area. The shoreline change rates are altered by various geological processes along the coast. Thus, the present study implies that proper beach filling and nourishment projects should be made in the study area to save from hazards. It also indicates the advantage and suitability of DSAS to assess the shoreline changes compared with the traditional manual shoreline change analysis and promising its applications for coastal zone management in other regions.

Keywords coastal zone management; erosion; accretion; hazards; beach nourishment

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Introduction

Coastal areas are very important for human beings since the beginning of time. Most of the big cities in the world are situated along coastal areas. About one third of the human populations are living in and around the coastal areas. Due to abundant natural re-
sources, urbanization and population rapidly increases on coastal areas. Various developmental projects are made along the coastal areas, placing great pressure on it, leading to various coastal hazards like sea erosion, seawater intrusion, coral bleaching, shoreline change, etc. Coastal landforms are highly dynamic in nature. They are continuously modified by natural and other manmade processes. The shoreline is one of the most unique features of earth surface. It is one of the 27 features recognized by the International Geographic Data Committee (IGDC). A shoreline is defined as the line of contact between land and water body. It is easy to define but difficult to capture since it is always changing. Accurate demarcation and monitoring of shorelines (seasonal, short-term and long-term) are necessary for understanding various coastal processes. Remotely sensed satellite data is widely used to analyze the shoreline changes. It can provide more information within a short span of time. Several studies using satellite data have proven its efficiency in understanding various coastal processes.

Space technologies have the capability to provide information over a large area on a repetitive basis and therefore very useful in identifying and monitoring various coastal features. Today these technologies are indispensable when developing suitable action plans for development in any coastal area. The advantages of GIS for the integration of thematic information derived from satellite data and other collateral data, such as socioeconomic and cultural data, are significant factors in integrated coastal zone management practices. The information provided in digital format is easily accessible to users and policy makers for various applications and decision-making purposes. The IRS 1C/1D imagery is well suited for generating land-water boundaries because of the strong contrast between land and water in the infrared portion of the electromagnetic spectrum.

After the Indian Ocean tsunami (26 December 2004), different morphological changes and variations in sea level were frequently observed along this coastal area. The recent Indian Ocean Tsunami induced sudden erosion dissimilar to seasonal variations along the southeast coast of India. The tsunami induced large amounts of beach erosion along the study area. Recently, various developmental projects started along this area. Therefore, the present study using remote sensing and GIS will be very useful to assess the impact of hydrological and morphologic factors modifying the shorelines along this area.

1 Geological setting

The study area is the coast between Kanyakumari and Tuticorin extending over a distance of 160 km including different morphological features along the southern coast of Tamilnadu state, India (Fig. 1). For effective spatial data modeling and analysis of shorelines, it is very essential to segment the entire shoreline into several zones or grids. Effective coastal classification is a fundamental precursor to any study of shoreline change. Based on the geological and hydrological aspects, the entire study area has been divided into four coastal zones, namely, Kanyakumari (KAN), Ovari (OVA), Tiruchendur (TRU), and Tuticorin (TUT) by coastal geomorphology, drainage pattern, and diverse energy conditions shown in Table 1. Each zone has further been subdivided into three grids of aerial size about 100 km² (Fig. 1). The Kanyakumari zone is influenced with tourism and developments. The grids of Manappad, Tiruchendur, and Kayalpatnam have headlands. Sand mining is actively pursued along the coasts of Idinthakarai, Navaladi, Ovari, and Periathalai. Breakwaters have been constructed in Kanyakumari, Koottapuli, and Perumanal coasts. The Tuticorin is one of major ports in India. Recently various developmental projects like the Koodankulam nuclear power plant, and Sethu-samuthiram ship canal have also been initiated in the study area.

The southern coastal Tamilnadu is replenished with valuable deposits of heavy minerals. The occurrence of black sands has been reported by many researchers. Moderate to high wave energy condition prevails along the study area, and it is an enriched zone of placer mineral deposits. The reason for the heavy minerals along the study area is not the presence of rivers but because the coastal configuration basinal structure acts as a trap to accumulate heavy minerals transported northward by long-shore currents.
trolled by a major river, the Tambraparni, minor streams, like the Palaiyar, Nambiyar, Hanuman Nadhi, and seasonal streams, like Nilapparai channel and the Puttanar channel. Cliffs are along the Kanyakumari coast, which projects toward the Indian Ocean, forming a promontory. Most of the coastal areas have sandy beaches, but some areas are rocky in nature. The northeast monsoon mainly controls the oceanography of the Indian east coastal region. In addition to northeast monsoon, the Tamilnadu coast is influenced by the southwest monsoon. Along the study area, the wind speed during the southwest monsoon ranges from 36-50 km/hour, and during northeast monsoon, it ranges from 20-80 km/hour. Plunging breakers were mostly observed on the coasts of Kootapuli, Idinthakarai, and Ovari, and spilling breakers were mostly observed on other coasts.

2 Data and methods

In this present study, multdate IRS and Landsat satellite data (1999, 2001, 2003, 2005, 2007, and 2009) are used as primary data for extracting the shorelines. The Survey of India (SOI) Topographical maps (1:50000 scale) are used for the base map. Low-tide satellite data is very important for shoreline mapping. Therefore, in order to eliminate the influence of tidal variations and to get a clear demarcation of both low and high water levels using satellite data during low tide for the same period, district maps and other information obtained during the GPS field surveys are also used as secondary data.

The raw satellite images usually contain many defects, like radiometric distortion, geometric distortion, presence of noise, etc., due to variations in the altitude, attitude, and velocity of the sensor platform. Thus, they cannot be used as map base without corrections. After performing preprocessing operations, a satellite image was georeferenced and projected with polygonic projection using WGS 84 as datum in the ERDAS IMAGINE 9.1 software. More than 25 Ground Control Points (GCP) collected from toposheets were used during this geometric correction process with third-order polynomial geometrical modal. The GCP's obtained were also verified by using the GPS survey, and the Root Mean Square (RMS) error was kept to less than 0.005 of a pixel. The image was then resampled by the nearest neighbor method. A geometric correction is essential for applications, such as change detection, resolution merge, mosaic, and layer stacking purposes and should be highly accurate, since any misalignment of features at the same location leads to large errors. The current process of manual point measurement can be prohibitively labor intensive for large applications, and it does not enforce subpixel level correlation between images due to the limitations of human visual interpretation.
The IMAGINE Auto-Sync workstation uses an Automatic Point Matching (APM) algorithm to generate thousands of tie points and produces a mathematical model to tie the images together. The resulting workflow significantly reduces or eliminates manual point collection. For near shore areas, however, where shoreline changes occur, it is potentially possible that the Auto-Sync function will force two laterally displaced shoreline features to the same ground control points (i.e., they are interpreted by the function as the same geographic location) and Auto-Sync function will mistakenly georeference the two images. In-order to eliminate this problem, all automatically generated GCP’s are carefully verified, and the points present along the shorelines are removed. Only the control points from the stable ground features are taken and processed using IMAGINE Auto-Sync workstation. The remaining images were georeferenced for a better output with higher accuracy in comparison to the previous methodology.

The images were subjected to a noise reduction technique segregating the noise from the data. Many semiautomatic or automatic segmentation techniques are applied to extract the shoreline from a variety of remote sensing data, but there is no single method that can be considered good for all images. In this present study, the exact land-water boundary was obtained by using a nonlinear edge-enhancement technique with Sobel operator (3×3 kernal matrix). These operations applied to image data to produce an enhanced image output for subsequent visual interpretations. The enhancement techniques improved feature exhibition and increased visual distinctions between features contained in a scene. This technique gives a clear demarcation of the land-water boundary. Then, the shorelines were carefully digitized and exported to shape-file format for further analysis in ArcGIS 9.2. The extracted shorelines were analyzed by using Digital Shoreline Analysis System (DSAS) an ArcGIS extension.

The shoreline changes and dynamics can be analyzed by variety of methods. The conventional mapping and analyzing of shoreline change subdivides the available shorelines into smaller segments by creating transects at right angles to a master shoreline, which is usually chosen from among the available shoreline models, based on several factors, such as higher positional accuracy. Shoreline changes along these transects are computed and further used to predict future changes. This method has been adopted over the years to establish the correspondence between shoreline models acquired at different times to predict shoreline change. Rates of change are then employed to summarize historical shoreline movements and to predict future positions based on the perceived historical trends. The method commonly used, especially by coastal land planners and managers to predict future shoreline-changes, is extrapolation of a constant rate of change. This method makes use of successive shoreline data available over time, providing the ability to assess future shoreline changes bay review of spatio-temporal shoreline changes. In this present study, the shoreline changes along the study area have also been analyzed using Digital Shoreline Analysis System (DSAS).

Shoreline change rates have been extensively overviewed by many researchers. Most shoreline change rate methods assume shoreline change is linear through time, with any nonlinearity attributed to mapping and measurement errors. Questions about the appropriateness of linear models are raised since shorelines do not recede or accrete in a uniform manner. In this present study, shoreline change rates were estimated with the DSAS v3.2, an extension that enhances the normal functionality of ArcGIS software developed by the US Geological Survey in cooperation with TPMC Environmental Services. The extension leads a user through the major steps of shoreline change analysis and allows them to calculate the shoreline rate-of-change statistics from a time series of multiple shoreline positions. It contains three main components that define a baseline, generate orthogonal transects at a user-defined separation along the coast, and calculates rates of change (linear regression, endpoint rate, average of rates, etc.) using several models. The extension utilizes avenue code to develop transects and rates and uses the avenue programming environment to automate and customize the user interface. Baselines were constructed seaward of, and parallel to, the general trend of all the shorelines. Transects with a spacing of
100 m apart are used to estimate the different shoreline change rates.

The End Point Rate (EPR), Linear Regression Rate (LRR), and Least Median of Squares (LMS) are estimated and analyzed. The three methods have been described as follows:[30, 40] The EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements (i.e., the oldest and the most recent shoreline). The major advantage of the EPR is its ease of computation and minimal requirements for shoreline data (two shorelines). The major disadvantage is that in cases where more than two shorelines are available, the information about shoreline behavior provided by additional shorelines is neglected. Thus, changes in sign or magnitude of the shoreline movement trend or cyclicity of behavior may be missed. LRR can be determined by fitting a least squares regression line to all shoreline points for a particular transect. The rate is the slope of the line. The advantages of linear regression include the following: (1) All the data are used, regardless of changes in trend or accuracy. (2) The method is purely computational. (3) It is based on accepted statistical concepts. (4) It is easy to employ. LMS is determined by using an iterative process that calculates all possible values of slope within a restricted range of angles. Finally, all the shoreline change rates of the different zones are analyzed.

3 Results and discussion

The present study clearly indicates that the shoreline change depends on both natural coastal processes and anthropogenic activities. Figs.2(a-l) shows the shorelines, baseline, and transects along each grids of all the coastal zones. The variation of different shoreline change rates along the different transects of all the grids are also shown in the above figures. The four statistical methods EPR, JKR, LRR, and LMS of the shoreline change rates are identical in most regions of the various grids. It can be seen that the positive and negative rates of change in the figure reflect the corresponding accretion and erosion. The present study indicates that the three statistical methods (EPR, JKR, LRR, and LMS) for shoreline change rates are almost identical in many regions of the coastal zones. The figure shows that the positive and negative rates of changes correspond to shoreline accretion and erosion.

3.1 Shoreline change rates

These shoreline change rate studies indicate that the Kanyakumari coastal zone has experienced more erosion. The shoreline along the western side of the Manakudy estuary (transects 1-40 in grid 1) retreating at a rate of 1-3 m/year. The LRR and LMS values are almost identical, whereas the JKR rate is quite different and may be due to the change in trend in the southern side of Manakudy estuary. Negligible erosion was noticed along the Manakudy estuary. The eastern part of the estuary is retreating at a rate of 3-5 m/year. The urban coast of Kanyakumari (grid 2) has also experienced erosion, and there the shoreline is retreating at a rate of 1-3 m/year. The sudden positive in shoreline change rate (transects from 135-145) indicates beach nourishment activities and the development of Jetties along ‘Muttam’ fishing harbor. The eastern side of the Kanyakumari coast has experienced erosion, and the shoreline is retreating at a rate of 1-3 m/year. The Perumanal coast (grid 3) has experienced more accretion from transects 262-362. The entire coast in grid 3 has been accreting at a rate of 1-5 m/year. During monsoon, the sediments from the western part of coastal zone are eroded and littorally drifted by the currents and waves. These sediments are also deposited along the Perumanal coast by the littoral currents. The Ovari coastal zone has experienced both erosion and accretion. However, accretion dominates in most of the areas. The shoreline along the Idinthakarai coast (grid 4) has experienced both erosion and accretion; however, erosion dominates in this grid. Accretion has been noted from transects 440-470. In Navaladi and Ovari (grid 5), the entire coastal area has experienced accretion, and the shoreline is advancing at a rate of 1-3 m/year. The EPR, LRR, and LMS indicate the advancement of shorelines, while the JKR indicates that the shoreline is retreating at smaller rates. Recalling that during the period 1969-1999, this coast experienced more accretion and is presently under going severe erosion. The lower erosion rates of JKR indicate that the coast of
Fig. 2  The variation of shoreline change rates along each grid of all the coastal zones
Ovari and Navaladi are presently undergoing erosion. The Periathalai coast (grid 6) has experienced more accretion. The peak at transects from 685-687 indicates the advancement of shoreline of 5 m/year along the breakwater in this zone (Fig. 3). The JKR rate indicates that the southern side of the breakwater has experienced erosion. The study also reveals that the northern side of the breakwater is advancing more than the southern side.

The shoreline along the Tiruchendur coastal zone is mostly retreating. This study indicates that the southern part of the Manappad headland (grid 7, transects 748-825) is advancing at a rate of 1 m/year, whereas the northern part is quickly retreating at a rate of 2-3 m/year. It was also noted that a sudden change occurred along the headland of Manappad. In this grid, the EPR, LRR, and LMS are almost identical, whereas the JKR rate is different, and it reveals a decrease of accretion along the southern side and erosion in the northern side of the Manappad headland. It was observed that during the period 1969-1999, the southern part accreted and the northern part eroded. During 1999-2006, the southern part eroded, while some accretion was noted along the northern part of the headland. The formation of a small spit along the northern part of the headland (Fig. 4) also implies sediment transport and shoreline changes. The Tiruchendur coast (grid 8) has been retreating at a rate of 1-2 m/year. An accretion was also noticed along the northern side (transects 1000-1010) of the Tiruchendur headland. The Kayalpatinam coast (grid 9) is also retreating at a rate of 1-2 m/year. During the period 1969-1999, the coast experienced erosion, but during 1999-2006, accretion was noticed along this coast. The JKR shoreline change rate along Kayalpatinam implies that, presently, the shoreline is advancing at a rate of 1-2 m/year.

The shoreline along the Tuticorin coastal zone is advancing at higher rates. The Punnakayal coast (grid 9) has experienced both erosion and accretion. The Thambraparani estuary is a major supplier of sediment present in this coastal zone. The study implies that the shoreline along the southern part of the estuary (transects 1126-1196) is retreating at a rate of 2 m/year, whereas the northern part of the estuary (transects 1200-1236) is advancing more at a rate of 2-6 m/year. The coast of Tuticorin south is also advancing more at a rate of 2-6 m/year. It should be noted that, during the monsoon, large quantities of sediments are discharged along the estuary. These sediments are littorally drifted and deposited along the northern side. The rapid changes or variations in shoreline change rate along the Tuticorin coasts (grids 11, 12) indicates the dynamics of shoreline due to presence of mud flats, salt pans, and recreational activities along the zone.

3.2 Factors modifying the shorelines

The shoreline change is caused by a complex interaction of various natural- and human-induced coastal processes. The natural processes due to geology and geomorphology, the combined action of waves and currents, variations in sea level, tectonics, and storms modify the shorelines. The human activities that could intensify the coastal erosion include manipulation of hydrological cycles mainly through dam construction; buildings on beaches; coastal structures such as harbors, beach-protecting structures, and jetties; mining of beach sand and live coral; destruction of protective coral reef systems; and destruction of coastal vegetation.
3.2.1 Coastal geology and geomorphology

The coastal geology and geomorphology plays a vital role in modifying the shorelines. The various coastal landform features, such as headland and bays, beaches, mud flats, estuaries, and sand dunes along the study area were involved in the shoreline changes. The present study reveals that the coastal zones of Kanyakumari and Ovari are under severe threat of coastal erosion. The Kanyakumari coastal zone (Gird No.2) has an exposed rocky coast and narrow continental shelf. Much erosion has been noted along this coast. The high wave energy acting on the soft part of the rocky coasts produces more erosion to form cliffs. The waves also modify the shoreline along the coast of Kanyakumari. Similar effect has also been observed in the Kenyan coast.[41] The Ovari coastal zone is experiencing severe coastal erosion due to low lying sandy beaches and dunes, which enhance the effects of coastal erosion. The Tiruchendur coastal zone has headlands and bays with both erosion and accretion resulting along the coast. The Tuticorin coastal zone has curved sandy beaches and estuaries that easily traps sediments and leads to accretion.

3.2.2 Natural causes and conditions

Natural processes and climatic conditions are important when determining the nature of wave impacts responsible for sediment transport, erosion, and accretion and shoreline changes. Natural processes are constantly changing resulting in alternating periods of accretion and erosion. These processes are influenced not only by daily or hourly changes in tides, etc., but also over longer timescales as sea level and climate change.

(1) Sea level changes. The changes in sea level may also induce the erosion or accretion along coasts. The present study reveals that the Tuticorin coastal zone has been advancing at a rate of 2-6 m per year. A long-term geological process of utmost importance to a shoreline is relative sea-level change, which can occur as the result of a change in water volume of the oceans or the subsidence or emergence of the land by geologic processes. In the Tuticorin coastal zone, relative change in the sea level might be involved in modifying the shorelines. Relative sea level change puts the shoreline out of equilibrium with the sea-level triggering processes that tend to restore that equilibrium. These processes can cause the shoreline either to erode or accrete. A lowering of sea level or an increase of the land elevations due to tectonic changes leads to a relative sea level drop and the appearance of a shoreline of emergence.[42]

(2) Shortage of sediments. Erosion and inundation brought about by river flows, tides, winds, and rain are among the most important natural processes that determine the shape and dynamic character of the coastline. Coastal features, such as sand dunes and beaches, mangroves, and mudflats, are formed by the deposition of sediments. Throughout most of coastal region, growth and its related sedimentary processes have been and are some of the principal contributors to the coastal geomorphology. The Indian Ocean Commission Publication Manual clearly emphasizes that the present shortage of sediment on the shoreline due to natural reasons is one of the causes of erosion in the islands of the Indian Ocean.[43] During the period from 1969-1999, the Ovari coastal zone experienced more accretion due to excess amount sediment discharged through the rivers. However, the contrary is now happening, there is a natural shortage of sediment. Sediment discharges from rivers are considerably reduced due to the construction of dams, developmental activities and encroachments. This makes the sandy beaches along the zone more vulnerable to erosion.

3.2.3 Waves, currents, and sediment transport

Waves are the prime movers for the littoral processes at the shoreline. The dynamics and kinematics of water waves are discussed in several researches.[42, 44] The long-shore sediment transport rate is the major factor influencing on the evolution of the shoreline change.[45] Littoral transport plays a major role in the development of certain shoreline features like spits and bars and is causing considerable coastal erosion and accretion.[46-48]

The coastal zones of Tuticorin-south, Kayalpatnam, have accretion due to the littoral drift of sediments transported through the Tambraparani River. During north-east monsoon, the sediments from the river are drifted by the littoral processes toward the south direction. These sediments are deposited along
the coast of Kayalpatinam. During the south-west monsoon, the sediments from the river are drifted by the littoral processes towards northern direction. Longshore sediment transport Rates (LSTR) in Idinthakarai, Navaladi, and Ovari along the Indian east coast are estimated as high.\(^{49, 50}\)

3.2.4 Human interventions and anthropogenic activities

Nowadays, human interventions and anthropogenic activities also have great impact on shoreline changes. The anthropogenic activities contributing to shoreline change could broadly fall into four main categories as described below:

(1) Obstruction of sediment supply or modification of water flow. Reduced sediment supply (caused by offshore extraction, protection of eroding shoreline and damming of sediment rich rivers) has contributed to the further loss and degradation of coastal habitats including beaches and mangroves. The construction of coastal structures, such as groins and jetties Kanyakumari, Koothapuli, Periathalai, and Tuticorin, may interfere with the process of long-shore drift, modifying the sediment budget and exacerbating erosion of the adjacent beach or beach head in a down drift direction. The construction of dams on rivers leading to the ocean has reduced sediment supply to the coast through trapping.

The present study indicates that the Kanyakumari zone is undergoing more erosion due to natural geological and hydrological processes along the coast. The Kanyakumari coast faces problems due to tourism and other developmental projects along the coast. The construction of artificial barriers like breakwater and Jetties enhances the erosion along the Kanyakumari coast.\(^{51-53}\) The photograph in Fig. 5 shows construction work along the coast of Kanyakumari, which may also induce erosion at the nearby area of the coast.

(2) Littoral sediment transport and coastal sand mining. The coasts of Kanyakumari, Navaladi, Idinthakarai, and Ovari are mined for sand. The high LSTR also indicates the severe erosion along these coasts. Though banned in most parts of the study area, beach sand is still being mined for construction and other purposes.

Fig. 5 Constructions along the Kanyakumari Coast

Littoral transport plays a major role in the development of certain shoreline features, like spits and bars, and is causing considerable coastal erosion and accretion.\(^{54}\) The coastal zones of Tuticorin-south, Kayalpatinam, have accretion due to the littoral drift of sediments transported through the Tambraparni River. During the northeast monsoon, littoral processes drift river sediments in a southerly direction. These sediments are deposited along the Kayalpatinam zone. During the southwest monsoon, littoral processes drift sediments from the river toward the north. The coasts near Ovari and Periathalai along the study area are exposed to severe coastal erosion during the months of June and November due to a high wave climate.\(^{55}\) These coasts have high LSTR and are heavily mined for heavy minerals. The mining industrialists do not carry out any reclamation or refilling activities. This may contribute to severe erosion along the coast. Unplanned excavation can lead to severe erosion problems arising from either the net loss of sand itself or via creation of erosional “hot spots” resulting from the focusing of wave energy on specific points along a shoreline. These points can be identified using traditional beach surveys or predicted using numerical models of wave transformation.\(^{56}\) The importance of sustainable sand mining along coastal areas has been analyzed by many researchers.\(^{57-59}\) The concept of sustainable management should be implemented in the management of the near-shore coastal sand mining industry. These coasts have a high erosion hazard due to anthropogenic activities. It divulges the fact that the presence of (barrier) islands, river input, and wave patterns dictate the rate of erosion. It is also evident that if the river input gains over the erosion activity, the beach could survive without much threat to its volume.
(3) Removal of vegetation and natural protections. There are several factors that protect shorelines from erosion and help to preserve our coastal environment. They are sand dunes, coral reefs, vegetation cover, etc.\(^{[60]}\) The small sand dunes along the Ovari coastal zone have been flattened for various developmental projects and agriculture. These natural protections are greatly affected by the human-induced activities with consequences for coastal erosion.

4 Conclusion

The present DSAS shoreline change analysis indicates that erosion is predominant in the study area. Both natural and anthropogenic processes along the coast modify the shoreline configuration and control the erosion and accretion of the coastal zones. The coastal zones of Tuticorin-south, Kayalpatinam, have accretion due to the littoral drift of sediments transported through the Tambraparni River. The coastal zones along the headlands have much erosion. The zones with sand mining have a relatively higher rate of erosion than that of other zones. The mining industrialists do not carry out any reclamation or refilling activities along the study area. Unplanned excavation can lead to severe erosion problems arising from either the net loss of sand itself or via creation of erosional “hot spots” resulting from the focusing of wave energy on specific points along a shoreline. Improper and in-sustainable sand mining leads to severe erosion problem along this area. The concept of sustainable management should be interpreted in the management of the near shore coastal sand mining industry.

Thus, the present study clearly focuses the influences of both natural and anthropogenic coastal processes on the study area. It also recommended that proper beach filling and nourishment projects be made along the coast to save the coastal area from severe hazards. Other statistical methods to evaluate coastal areas and calculate metrics, such as variances, standard deviations, and intervals of confidence, will be the focus of future studies.

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