



Geospatial assessment of shoreline dynamics in Chengalpattu district, northeastern coast of Tamil Nadu, India

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Abstract

Coastal areas are among the most dynamic and sensitive environments on earth, shaped continuously by the interaction of land, sea, and atmospheric processes. The shoreline, which forms the interface between land and ocean, is particularly vulnerable to changes caused by natural phenomena such as wave action, tides, and cyclones, as well as by human interventions like coastal infrastructure development. Understanding these changes is critical for managing coastal resources and mitigating hazards. This study evaluates shoreline change along the coastal taluk of Chengalpattu district, Tamil Nadu, from 2009 to 2025 using geospatial techniques. Shorelines were extracted from Google Earth Pro and analyzed using the Digital Shoreline Analysis System (DSAS) in ArcGIS through key statistics methods such as Linear Regression Rate (LRR), Net Shoreline Movement (NSM), and End Point Rate (EPR). The result reveals that Cheyyur taluk predominantly experienced accretion, especially near the river mouth and harbour regions, with a mean LRR of 1.47 m/year. Tirukalukundram taluk exhibited a general erosion trend, with a mean LRR of -0.40 m/year, particularly in infrastructure-heavy areas such as Kalpakkam. Tiruporur taluk exhibited mixed trends with localized erosion near backwaters and development zones and a nearly neutral mean LRR of 0.06 m/year. Localized hotspots of severe erosion indicate increased susceptibility, especially in light of recent cyclonic storms, even though the district-wide average suggests mild accretion. These findings point to the need for localized, science-based coastal management strategies to enhance resilience against future coastal hazards.

Keywords: Shoreline change; erosion & accretion, digital shoreline analysis system, Chengalpattu district, Linear Regression Rate

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1 Introduction

Coastal regions have long been significant for human settlement and development. A majority of the world's major cities are located along the coast, and approximately one-third of the global population resides in coastal zones (Cosby et al., 2024). Urbanization and population growth are accelerating in these areas due to the abundance of natural resources. However, coastal regions are increasingly under stress from various development projects, leading to a range of coastal hazards such as shoreline alteration, sea erosion, seawater intrusion, and coral bleaching (Sheik and Chandrasekar, 2011).

Shoreline refers to the actual physical meeting point of land and water (Nath et al., 2023). It is regarded as

one of the most dynamic areas along the coast, and anthropogenic and physical forces are primarily responsible for shoreline changes (Chen et al., 2005). It experiences both short-term and long-term changes frequently due to hydrodynamic (such as river cycles and sea level rise), geomorphological (such as barrier island formation and spit growth), and other causes (such as abrupt and quick seismic and storm occurrences) (Scott, 2005). Since it is constantly changing, it is easy to define yet challenging to capture. To comprehend different coastal processes, shorelines must be accurately demarcated and monitored on a seasonal, short-term, and long-term basis (Sheik and Chandrasekar, 2011). The direct result of shoreline changes is erosion or accretion, which involves the loss or gain of valuable land masses (Rajawat et al., 2014). One of the most crucial factors in

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identifying coastal erosion and deposition and studying coastal morphodynamics is shoreline computation (Armenio et al., 2019). Shorelines are one of the 27 most important features that need to be mapped and observed, according to the International Geographic Data Committee (Natesan et al., 2013). The dynamic interactions between and among waves, tides, rivers, storms, tectonic processes, and physical processes determine shoreline features (Passeri et al., 2015). Erosion makes coastal areas more vulnerable, which can be dangerous for human activity near the coast. Additionally, coastlines are becoming more sensitive and prone to change due to the rising frequency of coastal disasters (Saxena et al., 2013). The growth of residential neighborhoods, industries, tourist attractions, ports, sand mining, groins, seawalls, breakwaters, jetties, and coastal deforestation are just a few examples of the significant changes brought about by growing human activity along the coast (Velsamy et al., 2020).

To understand the dynamics and evolution of coastal areas, it is crucial to understand shoreline change. Additionally, stakeholders can improve their efforts to prevent economic, social, and physical losses as well as the risk of coastal erosion (Baig et al., 2020). Satellite remote sensing data development provides valuable tools for mapping and monitoring a large area at a lower cost and in less time than traditional methods (Roy et al., 2018). Wave action and alongshore currents cause coasts to accrete and erode, and shoreline changes in coastal areas can be easily identified and calculated using geospatial techniques and automated calculations by the ArcGIS extended tool. Additionally, the rate of shoreline change data is computed from a time series of different coastline positions using the Digital Shoreline Analysis System (DSAS) extension tool. For large-scale data collection, the U.S. Geological Survey's Coastal Change Hazards project mainly relied on DSAS because it provides a complete suite of regression rates in an easy-to-use and consistent way. Furthermore, the program is recommended to support the shoreline change computation process by offering rate-of-change statistics and the mathematical data required to demonstrate the consistency of the computed results (Baig et al., 2020).

Chengalpattu district came into existence on 29/11/2019, when it was carved out of the erstwhile Kancheepuram district. Being geographically adjacent to Kancheepuram, a regional center of culture, and having been a part of the Kancheepuram district until recently, Chengalpattu district has seen nearly every stage of history that Kancheepuram has. Fishing is the one of the major occupations in Chengalpattu district. The 57 kms of coastal belt of Chengalpattu district with marine fishing villages from Kannathur reddy kuppam to Kottaikadu is characterized by the availability of a wide array of marine species and thus marine fisheries is considered as most important livelihood in the coastal area. The district's coastline also supports livelihoods, through tourism, and agriculture, while also hosting ecologically sensitive habitats such as backwaters. However, this coastal zone is increasingly exposed to hazards such as erosion, cyclonic storms, and unregulated development, all of which threaten both natural systems and human settlements. The effects of

recent cyclones, such as Nivar (2020) and Mandous (2022), have further highlighted the vulnerability of this regions coastline.

Several earlier studies have explored shoreline dynamics along various parts of Northeast coast. For example Sheik and Chandrasekar (2011) analyzed shoreline changes between Kanyakumari and Tuticorin using DSAS, while Natesan et al. (2015) provided a long-term shoreline change assessment along the Tamil Nadu coast, highlighting coastal vulnerability. District wise coastal assessments of Tiruvallur, Chennai, and Kancheepuram including portions of the present-day Chengalpattu district were carried out by Jayakumar and Malarvannan (2016). However, studies focusing especially on Chengalpattu are very less so here we attempted to mark out the rate of shoreline change in Chengalpattu district, Tamil Nadu, from 2009 to 2025 using ArcGIS and the DSAS techniques, and the Linear Regression Rate (LRR) method for calculations.

2 Study area

The present study was carried out in Chengalpattu district, Tamil Nadu which is often referred as 'Gateway of Chennai' (Fig. 1). Comprising the coastal taluks of Thiruporur, Tirukalukundram, and Cheyyur, the district has a coastline length of 57 km and has a total area of 2945 km² which lies between latitudes 12°14'00" N and 13°02'00" N and longitudes 79°31'30" E and 80°15'00" E. The coastal area of the district comprises 33 revenue villages engaged in fishing, agriculture, and tourism. Beyond fishing and tourism, coastal villages may also be involved in salt manufacturing and other coastal-related industries. Additionally, coastal villages like Kovalam are known for their scenic beauty and attract tourists with activities like catamaran rides and diving.

3 Methodology

3.1 Data collection

Shoreline change detection requires continuous data, but obtaining high-resolution satellite images over a range of periods can be expensive and time-limited. Interestingly, some high-resolution images for specific years are freely available on the Google Earth (GE) platform (Table 1). As a result, the use of GE in scientific studies has grown as it has been acknowledged as a useful tool in research and education over the past few decades (Warnasuriya et al., 2020).

Table 1. Details of shoreline data used.

Sl.No	Date of Acquisition	Length (km)
1	14/09/2009	77.63
2	13/08/2015	77.76
3	12/12/2020	76.63
4	11/03/2025	83.56

The shoreline of the study area was drawn along using a manual free-hand digitizing method using the "Path" tool for each year (2009–2025) at eye altitudes ranging from

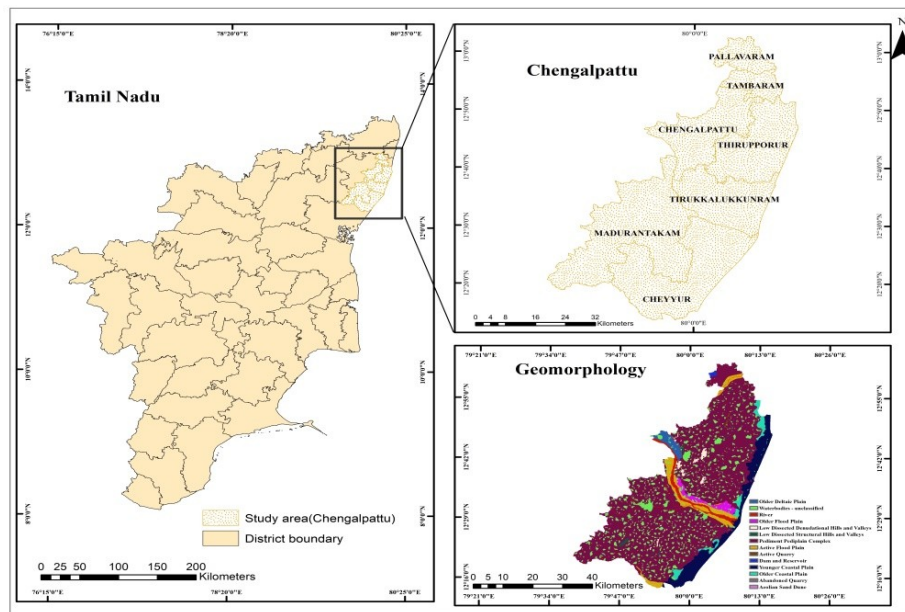


Fig. 1. Study area showing geomorphology map of Chengalpattu.

30 m to 100 m from various satellite images on the GE Pro platform. A single user created shorelines for four different years at the same location for each eye altitude to ensure consistency and accuracy in digitization.

3.2 Data processing and analysis

Each digitized shoreline was initially saved as a Keyhole Markup Language (KML) file using Google Earth Pro (Fig. 2). These KML files were then converted to shapefiles using ArcGIS 10.8.1 and managed within a personal geodatabase. Before merging the shorelines, each must include specific attributes including a unique object ID for each transect, the shape and length of the coastline acquired from Google Earth Pro, and the corresponding date (day, month, and year). After ensuring these attributes are present, the shorelines are merged and projected into UTM (Universal Transverse Mercator) zone 44N.

3.3 Creation of baselines and transects

The merged shorelines were then buffered at a predetermined distance, resulting in an output that serves as the baseline in the Digital Shoreline Analysis System (DSAS). The baseline was established at a distance of 100 m to act as the reference point for all transects. These transects intersect each shoreline at designated measurement points, which are used to assess shoreline change rates. 50 m interval transects were cast for each baseline using the ‘Smooth Baseline Cast’ method (smoothing distance is 500 m) from the DSAS tool in ArcGIS software, as this close transect spacing reflects even slight changes.

DSAS is a statistical tool in ArcGIS to determine the rate of change for any given input. The program generates transects perpendicular to a user-defined baseline at specified intervals, using multiple shoreline positions to compute rate-of-change statistics from their intersections (Mahapatra et al., 2014). The resulting rates are solely deter-

mined by the input parameters used in the computation. To determine these rates, DSAS uses various statistical techniques. The Linear Regression Rate (LRR) method is utilized for long-term investigations, while the End Point Rate (EPR) approach works well for short-term studies. In this study, the Linear Regression Rate (LRR), Net Shoreline Movement (NSM), and End Point Rate (EPR) are used to calculate the erosion or accretion rate per year.

3.4 Linear Regression Rate (LRR)

A LRR is a rate-of-change statistic calculated by fitting a least-squares regression line to each coastline point for a particular transect. The slope of this line represents the rate of change. The key characteristics of the linear regression method include (1) it is entirely computational, (2) based on recognized statistical ideas, (3) utilizes all the data regardless of changes in trend or accuracy, and (4) is simple to apply (Roy et al., 2018). The shoreline continues to change because of natural and man-made causes (Velsamy et al., 2020). Erosion and accretion are two significant problems with shoreline management that arise from these influences (Kiran et al., 2016). In LRR analysis, negative values indicate erosion, a positive value signifies accretion, and zero denotes a stable and moderate shoreline.

3.4.1 Net Shoreline Movement (NSM)

The net shoreline movement (NSM) is the distance between the oldest and the youngest shorelines for each transect. In this study, NSM was calculated for the period from 2009 to 2025.

3.4.2 End Point Rate (EPR)

The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline.

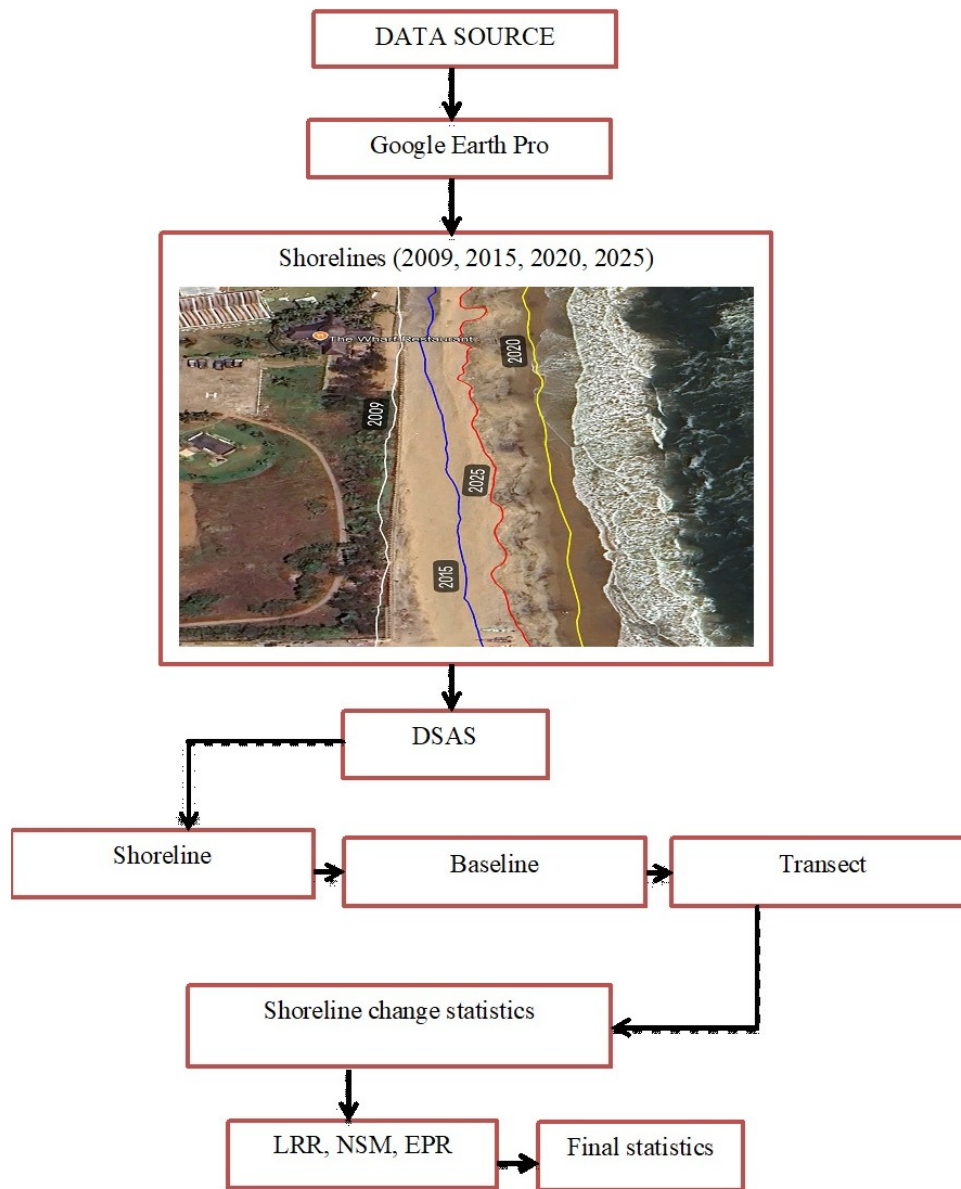


Fig. 2. Flowchart of methodology adopted for the study.

4 Results and discussion

This study examined the shoreline changes along the coastal areas of Chengalpattu district from 2009 to 2025. In the study area, the LRR value showed a minimum of -7.42 and a maximum of 10.82. The negative value indicates erosion, and the positive value indicates accretion. The average LRR value of the study area is 0.50, which indicates a general trend of accretion in the study area (Fig. 3). The minimum and maximum EPR are -8.17 (strong erosion) and 11.61 (strong accretion), respectively. However, the overall mean EPR is 0.50, showing accretion-dominant coasts (Fig. 5). The overall mean NSM is 8.99, with a maximum value of -126.5 and a minimum value of -179.83 (Fig. 4). There is also an increase in shoreline length of 2025 compared to the previous years. This change is due to coastal processes such as erosion, accretion and tidal actions that make the coastline more irregular and complex throughout the years.

4.1 Cheyyur Taluk

Cheyyur taluk is experiencing both erosion and accretion, with a minimum LRR value of -5.4 m per year, indicating significant erosion, and a maximum of 10.82 m per year, indicating significant accretion. The average LRR of Cheyyur taluk was 1.47, which indicates a general trend toward accretion. High accretion is concentrated in areas of the Palar River mouth, as the value is 10.82 m per year (Fig. 6). The high accretion in this area is partly due to river sediment accumulation on the shore. There is also a considerable amount of accretion in places with groins and breakwaters. It is also probable that human activities are in some ways accelerating this process, as there are active harbours (Thazhuthalikuppam) and prawn hatcheries in the area; natural sedimentation and human activities influenced these shoreline dynamics (Fig. 6).

Out of these erosive points, erosion is mainly concentrated in the backwater area, such as the Alambarai back-

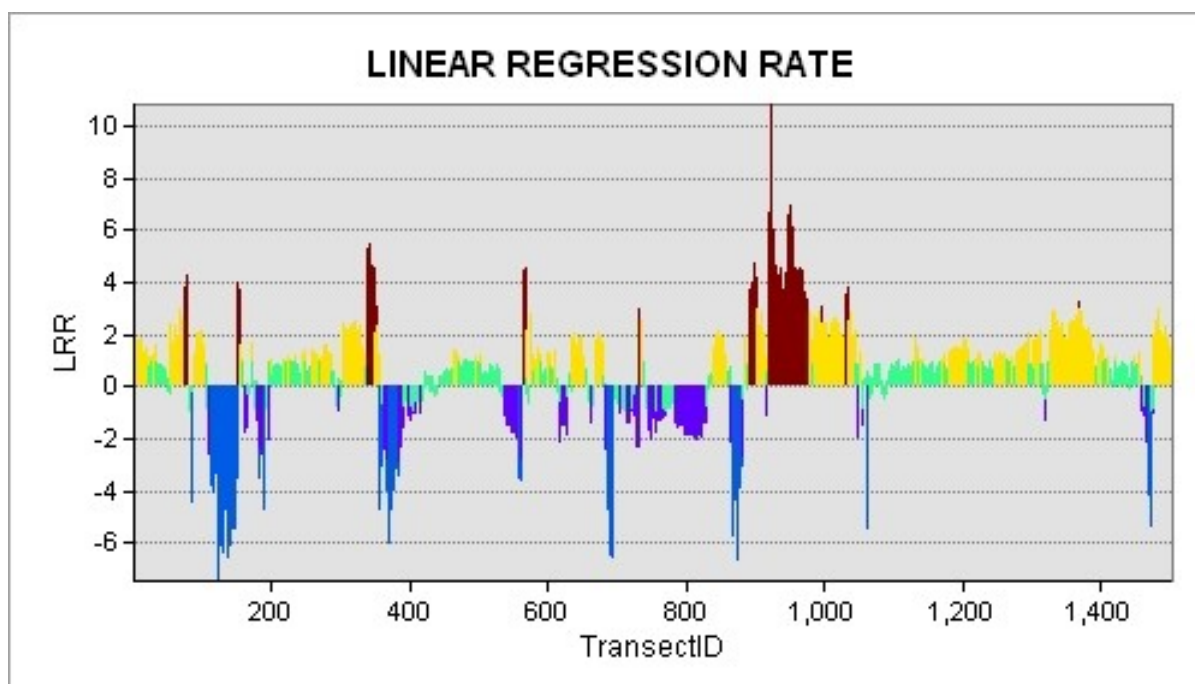


Fig. 3. Graph showing LRR of the study area.

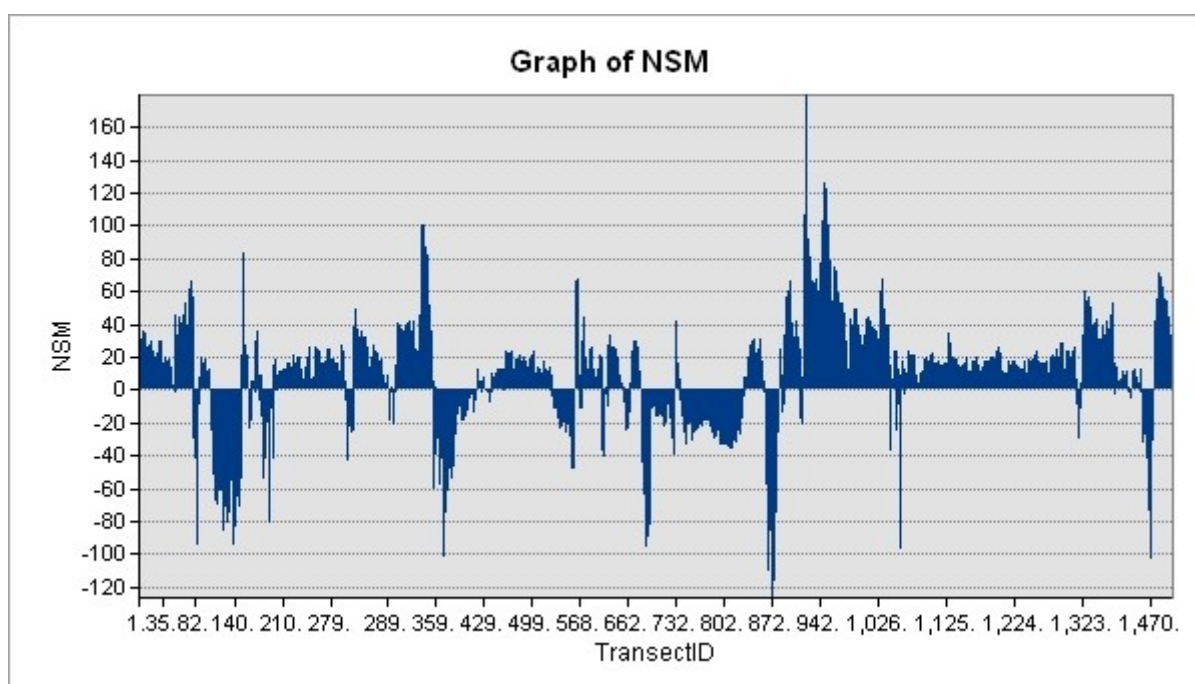


Fig. 4. Graph showing NSM of the study area.

waters, with an erosion rate of -5.4 m/year (Fig. 6). They are prone to erosion mostly because of tidal action, low sediment availability, and the peculiar dynamics of backwaters. NSM values vary from -102.76 m to 179.83 m, and the mean NSM stands at 24.74m, showing that although certain parts of the coast are suffering from heavy erosion, others have witnessed considerable accretion during the study period. Likewise, the EPR has varied from -6.63 m/year to 11.61 m/year, with the mean EPR standing at 1.59 m/year.

4.2 Tirukalukundram

Tirukalukundram taluk is experiencing both erosion and accretion, with a minimum linear regression value of -6.71 m per year indicating significant erosion and a maximum of 4.5 m per year indicating significant accretion (Fig. 7). The average LRR of Tirukalukundram taluk was -0.40, which indicates a general trend toward erosion. This area has two nuclear power plants as well as the famous tourist site,

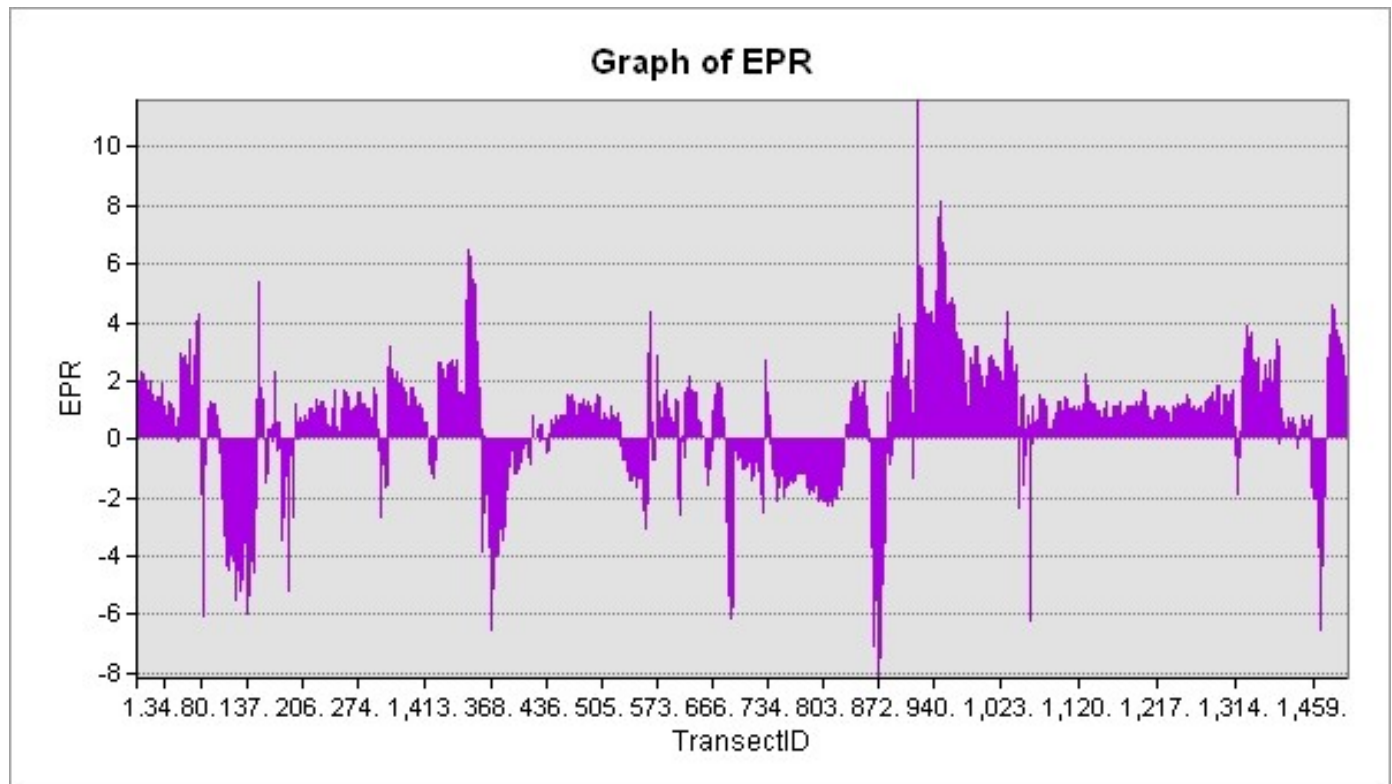


Fig. 5. Graph showing the EPR of the study area.

the Mahabalipuram Shore Temple. There are other populous fishing harbours in this area, such as Meyyur Kuppam Harbour. Areas with harbours and those near the shore, temples, and atomic power plants suffer from more erosion because of the existence of groins and breakwaters that are built to protect these structures. The sea builds breakwaters, and significant accretions occur in the nearby areas. These breakwaters are built to lower the height of incoming waves into smaller transmitted waves; breakwaters are utilized all over the world to prevent beach erosion. Furthermore, breakwaters can effectively be utilized to protect the harbour basin's tranquillity, reduce silt deposition that could contaminate the water at the harbour entrances, and serve as a sanctuary for marine life (Safari, 2018). Human activities that alter coasts, including building groins, seawalls, or breakwaters, are likely to spread the issue to nearby shorelines. Installing shore protection measures in one place may have effects that go beyond the project site and affect a wider stretch of the shoreline on both sides of the project site (Kiran et al., 2016). The highest erosion of -6.71 m per year is experienced in Kalpakkam. Kalpakkam is known for its nuclear plants and affiliated research installations (Fig. 5). These include the Madras Atomic Power Station (MAPS), a nuclear power plant; the Indira Gandhi Centre for Atomic Research (IGCAR), an affiliate of the Department of Atomic Energy (DAE); and the Bhabha Atomic Research Centre (BARC). A high accretion rate of 4.5 m per year is in the nearby region of the Mahabalipuram shore temple (Fig. 5). NSM in Tirukalakundram taluk is a minimum of -126.5 and a maximum of 67.02 a mean of -7.92, which indicates erosion in that region, and EPR is a minimum of -8.17 and a maximum of 4.33, with a mean of -0.51,

also indicating erosion. The impact of Cyclone Mandous in December 2022 further highlighted the region's vulnerability.

4.3 Tiruporur

In Tiruporur taluk, erosion and accretion are both occurring; a LRR value of -7.45 m/year indicates significant erosion, while a value of 5.47 m/year indicates significant accretion. Tiruporur taluk's average LRR was 0.06, indicating a general trend toward both accretion and erosion. The Muttukad backwater experiences major erosion at a rate of -7.45 m/year (Fig. 8). Due to tourism activity and high population, the Kovalam harbour beach area faces both erosion and accretion, with LRR varying from -6.2 to 4.5 m per year (Fig. 8). These changes indicate the impact of human pressure and land use changes on shorelines. The Nemmeli region consists of both a desalination plant and a new water plant facility, and also coastal protection structures like groins and breakwaters are built in the vicinity. Shoreline analysis reveals that areas adjacent to these structures exhibit erosion, and the shoreline near the new water plant is experiencing accretion.

The NSM ranges from a minimum of -102.68 m to a maximum of 100.46 m, with an average of 3.42 m, indicating that while some areas have experienced significant shoreline loss due to erosion, others have observed notable accretion during the same study period. Similarly, the EPR fluctuates between -6.63 m per year and a maximum of 6.49 m per year, with a mean of 0.22 m per year. These values indicate that the general trend is one of gentle accretion, but this conceals significant localized erosion in some reaches.

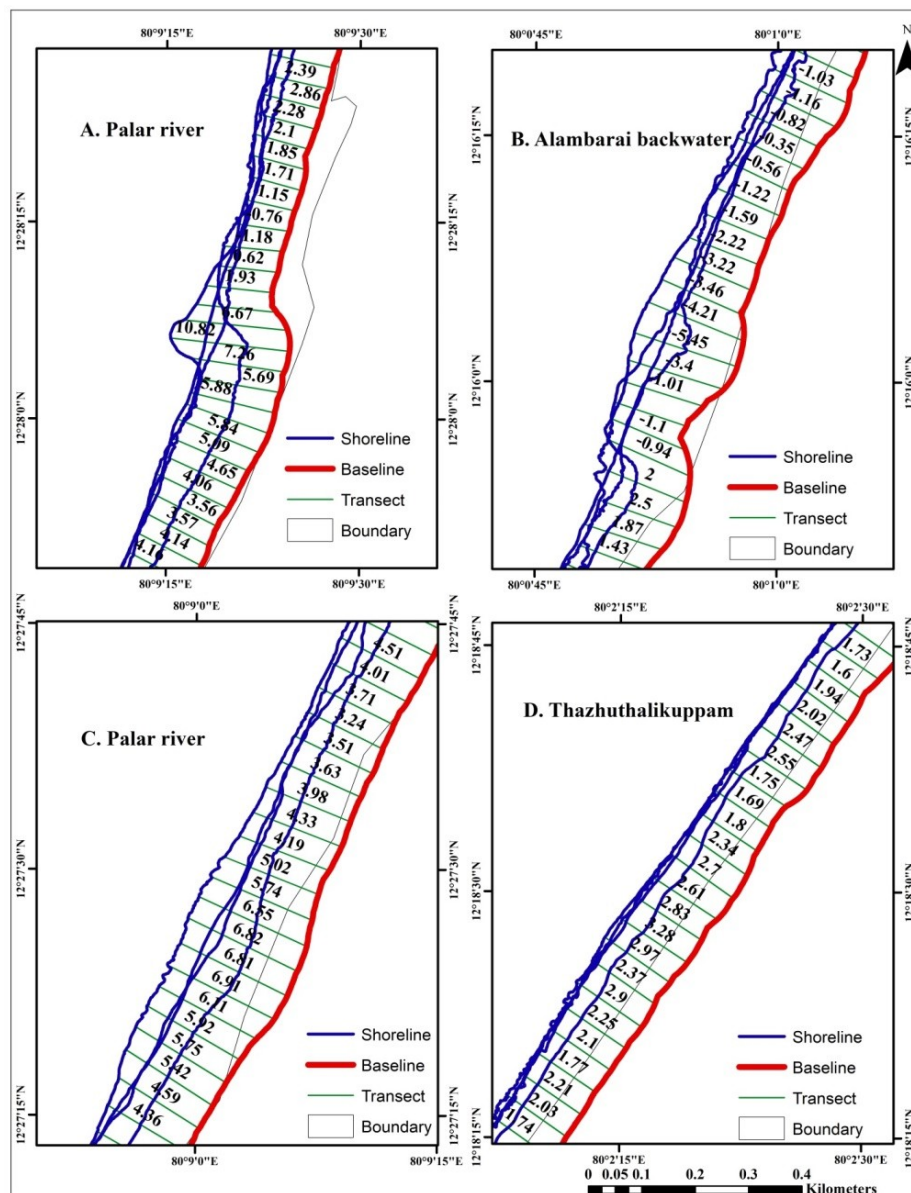


Fig. 6. LRR of A. Palar river, B. Alambarai backwater, C. Palar river, D. Thazhuthalikuppam.

These weaknesses were tragically exposed during Cyclone Nivar in November 2020, which caused severe floods and significant damage to various sectors, including agriculture and fishing. The event highlighted the region's increased susceptibility to climate-related hazards, particularly in regions where erosion has already weakened the terrain.

This study comprehensively assessed the shoreline changes in the coastal areas of Chengalpattu district from 2009 to 2025 using the LRR method. The results indicate an intricate pattern of erosion and accretion subjected to natural forces as well as human activities such as the construction of groins, breakwaters, harbours, and other industrial structures. Cheyyur taluk exhibited overall positive accretion trends, particularly towards river mouths and harbours, while Tirukalukundram taluk showed a strong erosion trend exacerbated by high infrastructure development around Kalpakkam. Tiruppur taluk showed diverse trends, with severe erosion in development-associated tourism areas of Muttukad and Nemmeli but some pockets of accre-

tion. The overall values for Chengalpattu reveal significant coastal instability that directly increases vulnerability to cyclones. Areas with severe erosion have weakened natural defences like beaches and dunes, making them more susceptible to cyclone-induced storm surges and flooding. Conversely, zones of rapid uplift may alter coastal topography in ways that disrupt natural drainage patterns, potentially amplifying cyclone-related flooding. The overall positive mean values mask critical local variations, meaning that while some areas gain protection from new sediment deposits, others face increasing exposure to cyclones. This uneven shoreline behaviour is particularly concerning as climate change intensifies cyclone frequency and strength in the Bay of Bengal region. The erosion hotspots could experience catastrophic land loss during future cyclones, while accretion areas might see sudden sediment redistribution that alters storm surge pathways. These results emphasize the necessity to combine scientific approaches to shoreline monitoring with coastal sustainable zone management to

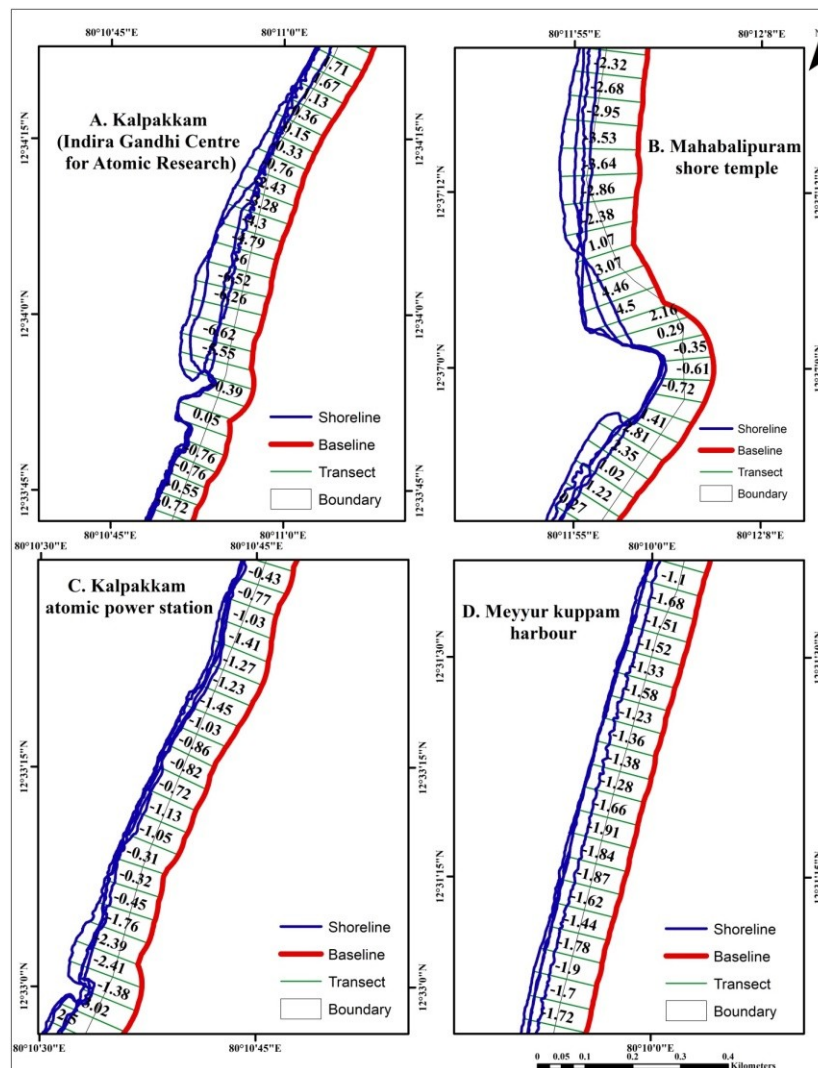


Fig. 7. LRR of A. Kalpakkam, B. Mahabalipuram shore temple, C. Kalpakkam atomic power station, D. Meyyur Kuppam harbour.

reduce the impacts of unplanned development while preserving coastal ecosystems.

5 Conclusion

This study offers important details about the evolving shoreline dynamics of the Chengalpattu district, highlighting the diverse patterns of erosion and accretion along its coastal taluks with LRR values ranging from -7.42 to 10.82 m per year and an average LRR mean 0.50 per year indicating an overall trend of mild accretion in the district. The NSM ranged from -126.5 m (severe erosion) to 179.83 m (strong accretion), with mean NSM of 8.99 m, indicating a general but uneven trend of shoreline advancement over the study period. Also the EPR ranged from -8.17 m/year to 11.61 m/year, reflecting mild average accretion when observed at the district scale. The use of DSAS and geospatial analysis revealed that regions like Cheyyur are undergoing substantial accretion, while others, such as Tirukalukundram, face ongoing erosion driven by both natural processes and human interventions. Tiruporur, meanwhile, reflects a transitional coastal landscape where shoreline changes are

closely tied to urban development, tourism, and coastal infrastructure. These localized variations stress the importance of moving beyond general assessments and adopting site-specific coastal management strategies. The presence of erosion hotspots in densely developed or environmentally fragile areas is particularly alarming in light of intensifying climatic events such as cyclones.

Proactive coastal planning rooted in continuous monitoring, regulated development, and ecosystem-based approaches is essential to safeguard both the environment and the livelihood of coastal communities. The coastline configuration is altered by both natural and man-made causes, such as littoral drift, tidal action, and the installation of seawalls, groins, or breakwaters. To enable appropriate management plans and control of the coastal areas in Chengalpattu as well as other coastal areas of India with comparable geographic characteristics, the study might be more helpful to coastal engineers, planners, and coastal zone management authorities. Integrating shoreline change analysis into district-level planning and disaster preparedness frameworks can significantly reduce the long-term risks associated with coastal hazards.

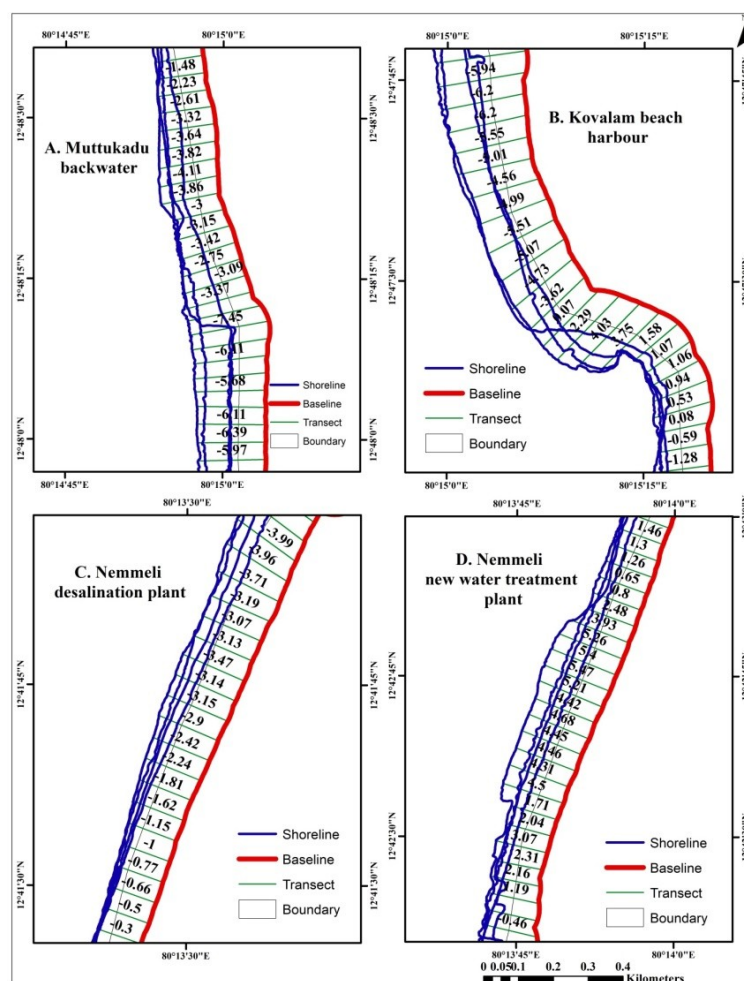


Fig. 8. LRR of A. Muttukadu backwater, B. Kovalam beach harbour, C. Nemmeli desalination plant, D. Nemmeli new water treatment plant.

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Conflict of Interest

The authors declare no conflict of interest.

CRedit statement

PP: Data collection, analysis, interpretation, writing. **AV:** Study design, interpretation, writing. **BKR:** Study design, interpretation, writing. **SP:** Interpretation, Critical revision. **AS:** Interpretation, Critical revision. **JA:** Interpretation, critical revision of the manuscript, **NJ:** Critical revision.

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