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Integrated spatio-temporal analysis of coastal shoreline dynamics of Kozhikode district, southwest India, using remote sensing and Digital Shoreline Analysis System (DSAS)

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ABSTRACT

A comprehensive analysis of long-term shoreline alterations is crucial for effective coastal zone management and for strategizing future coastal development. The current investigation examines a prolonged period (1990–2015) of shoreline transformations along the coastline of Kozhikode district, Kerala, India, employing geo-informatics methodologies. The High Water Line (HWL) was identified as the delineation of the shoreline, which was ascertained through remote sensing technologies and subsequently vectorized. The shoreline has been updated to encompass river creeks and their mouths. The Digital Shoreline Analysis System (DSAS), a tool developed by the United States Geological Survey (USGS) as an extension of ArcGIS, was utilized to ascertain the rate of shoreline change. The Linear Regression Rate method was employed to derive the shoreline change rate. The current DSAS shoreline change analysis revealed that approximately 59.24% (45.5 km) experienced erosion, 0.13% (9.98 km) remained stable, and 40.63% (31.20 km) experienced accretion during the period from 1973 to 2020 within the study area. The coastal taluk exhibiting the most significant erosion in Kozhikode district is Vadakara (Zone I). The rate of erosion is notably higher in Vadakara taluk (82%) compared to Quilandy taluk (53%). The lack of seawalls and other protective shoreline structures has contributed to an increased rate of erosion. Accretion is predominantly observed in the vicinity of harbor areas. The geomorphological characteristics and the presence of resilient rock formations, such as charnockite, along the shoreline also affect the dynamics of erosion and accretion. This study has been conducted at the taluk level in Kozhikode district, providing critical data that can assist coastal managers and researchers in fostering sustainable practices in coastal zone research, management, and planning.

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1. Introduction

The shoreline is the most dynamic and constantly changing zone on Earth (Dolan et al., 1980; Boak and Turner, 2005; Mahapatra et al., 2013). This interface between land and sea is being shaped by natural processes like waves, nearshore currents, tidal fluctuations, sediment transport and extreme events (Mukhopadhyay et al., 2012) which, collectively influence the shoreline morphology. Anthropogenic interventions also affect the sustainability of the shoreline (Rafeeque et al., 2022).

Shoreline changes manifest primarily as erosion or accretion. Erosion involves the removal of land, which can threaten coastal infrastructure, habitats, and human settlements. Accretion, on the other hand, refers to the buildup of land through the deposition of sediments, which can create new landforms and habitats (Rajawat et al., 2014). Both processes are critical as they directly affect the availability and stability of coastal land, impacting ecological systems and human activities. Mapping and monitoring of shorelines are essential tasks for coastal zone management. By employing various techniques such as satellite imagery, aerial photography, and in-situ measurements, scientists and managers can track changes in the shoreline with precision. This information is vital for understanding coastal morphodynamics (Sherman and Bauer, 1993).

Effective shoreline management is crucial for sustainable coastal zone development. It involves implementing strategies to mitigate erosion, protect coastal ecosystems, and manage human activities in a way that balances economic, environmental, and social needs. Understanding the dynamics of the shoreline enables policymakers to make informed decisions, ensuring the long-term health and resilience of coastal areas (Zuzek et al., 2003). Coastal erosion and accretion have reflective social and economic implications, particularly erosion, which garners significant attention due to the loss of valuable land masses (Chowdhury and Tripathi, 2013). Coastal regions experiencing accretion are less vulnerable compared to areas with erosion. Accretion expands land areas, while erosion pushes the shoreline inland, increasing the risk of coastal hazards for nearby populations (Jana and Hegde, 2016). The satellite remote sensing technology has revolutionized the mapping and monitoring of large coastal areas, offering a cost-effective and time-efficient alternative to traditional methods (Nayak, 2000; Mahapatra et al., 2014). Various techniques have been developed to extract shoreline information from satellite images (Mahapatra et al., 2014; Liu and Jezek, 2004; Goncalves et al., 2015). Recent advancements in satellite image processing, coupled with Geographic Information Systems (GIS), provide enhanced capabilities for automatic and semi-automatic shoreline identification and extraction. These methods utilize band ratios, single band thresholds, and various indices such as the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) (Mukhopadhyay et al., 2012; Goncalves et al., 2015; Altinuc et al., 2014; Guariglia et al., 2006). The near-infrared (NIR) and mid-infrared (MIR) wavelength bands are particularly effective in providing high contrast between land and water, aiding in accurate shoreline delineation (Jensen, 2000).

Several researchers have employed Landsat satellite images to detect and extract shorelines using diverse image analysis techniques. These include density slicing (Braud and Feng, 1998; Frazier and Page, 2000), NDVI (Ryu et al., 2002), and supervised and unsupervised classification methods (Guariglia et al., 2006; Ustun et al., 2004; Roy et al., 2018, Baig et al., 2020; Logesh et al., 2021). The study by Dhanil Dev et al. (2023) analyzes shoreline changes and land use shifts around Ponnani Fishing Harbour, in the Kerala coast of southern India using DSAS, GIS, and remote sensing, revealing significant erosion in the southern sector due to harbour construction and predicting further coastal retreat by 2030 and 2040. The examination of long-term alterations in shorelines is critically significant for the formulation of adaptive shoreline management strategies. The assessment and management of shoreline modifications have emerged as paramount concerns in various states and countries, given that the majority of the population inhabits coastal areas. The systematic monitoring of shoreline changes is imperative prior to any coastal development initiatives, as well as for the appraisal of hazard zonation, erosion/accretion zones, and morphodynamic investigations.In the present study, the shoreline changes along the Kozhikode coast were analyzed using the Digital Shoreline Analysis System (DSAS) version 5.1, an extension to ESRI ArcGIS (Thieler et al., 2009; Himmelstoss et al., 2018; Himmelstoss et al., 2024).

The Kozhikode district coast, also known as the 'Malabar Coast of India' is a densely populated and considered a hub of both urban and rural settlements (CGWB, 2013). Many of the beaches in Kozhikode districts are popular tourist destinations. Based on the higher Coastal Vulnerability Index (CVI) values, Naga Kumar et al. (2022) reported that more than a third of the Kozhikode coast is under high risk to coastal hazards. Similarly, the study by Rafeeque et al. (2022) reported that intense human interventions have harmfully affected the sustainability of the Kozhikode coastal line. As a fast-growing urbanized coastal city of the state, the Kozhikode district's coastline needs to be protected. There has been an increasing demand from the coastal community for coastal protection measures. Therefore, this study aims to: (1) identify areas experiencing significant coastal erosion, (2) quantify the rates of shoreline changes along the study area, and (3) classify coastal stretches based on the rates of shoreline changes into categories of erosion, accretion, and stability. This study will provide valuable insights into the long-term coastal dynamics within a segment of the Kerala coastal region, which has experienced considerable industrialization. It will also contribute to the formulation of coastal erosion risk management strategies, the sustainable development of coastal zones, and assisting coastal researchers and decision-makers in their future endeavors.

2. Study Area

Coastal local bodies in Kozhikode district of Kerala is selected for the present study, which is one of the fourteen districts as well as one of the nine coastal districts in the state of Kerala, Southwest coast of India (Fig. 1). The district is bounded by Mahe district of Union Territory of Pondicherry and Kannur district of Kerala in the north, Wayanad district in east, Malappuram district in the south and Lakshadweep Sea (Arabian Sea) in the west. It lies between 11°08' and 11°50' N and 75°30' and 76°8'E. Administratively, the district is divided into 4 taluks (subdivision of district), 12 block panchayats, 2 Municipalities, 1 Corporation and 77 panchayats (Sreepadi, 2021). Among the four taluks of Kozhikode district, three were chosen for shoreline change analysis as they share coastline boundary of the district (approximately 76 km). These taluks, namely Vadakara, Quilandy and Kozhikode have been designated as Zones I, II and III respectively which shares a coastal line boundary with the Lakshadweep Sea. Six rivers, form north to south, namely Mahe, Kuttiady, Korapuzha, Kallayi, Chaliyar, and Kadalundy open to the sea along the coast of Kozhikode district.

Kozhikode has a tropical monsoon climate (Koppen climate classification *Am*). The minimum temperature ranges between 22 and 25.8° C and the maximum between 28.2 and 32.9° C. The temperature reaches its peak in the month of April and attains minimum in January. A brief spell of pre-monsoon mango showers hits the area most of the time during April. However, the primary source of rain is the southwest monsoon that sets in the first week of June and continues until September. Kozhikode district experiences an annual average rainfall of 3063 mm. The high rainfall areas in the district are Kakkayam dam site and Kakkayam Power House. Kakkayam dam site has been experiencing more than 4500 mm of annual rainfall since 2000. It has been noticed that rainfall displays an increasing trend towards northeastern areas of the district. There are four seasons – summer, southwest tropical monsoon period, northeast tropical monsoon period and winter. The SW and NE monsoons mainly contribute to rainfall in the area with 82.77% of the rainfall. The month of June experiences maximum rainfall. The months of July, August and October also receive heavy rainfall. The agricultural activity of the district depends on the onset of SW tropical monsoon.

Topographically, Kozhikode district is divided into three distinct regions: the sandy coastal belt, the rocky highlands formed by the Western Ghats, and the laterite midlands. According to the District Handbook of Kozhikode (2011), the sandy coastal belt covers an area of 362.85 square kilometers within the elevation less than 7.6 m from the mean sea level (MSL). The laterite midlands span 1,343.50 sq. km with the elevation in between 7.6 to 76 m from MSL, and the rocky highlands encompass 637.65 sq. km with an elevation above 76m from MSL. This distribution indicates that 26.8% of the total area consists of coastal lands, 57.65% comprises midlands, and the remaining portion is made up of highlands.

The shoreline of Kozhikode coast is generally straight with minor undulations near Kadalur in Quilandy. From Kadalur to Beypore, the shoreline appears mostly linear. Major geomorphic units identified in the coastal areas include beaches, sand bars, shore platforms, lateritic hills, and valleys (Ahmad, 1972). The Naduvattam-Panniyankara area in Kozhikode is a typical sandbar region with

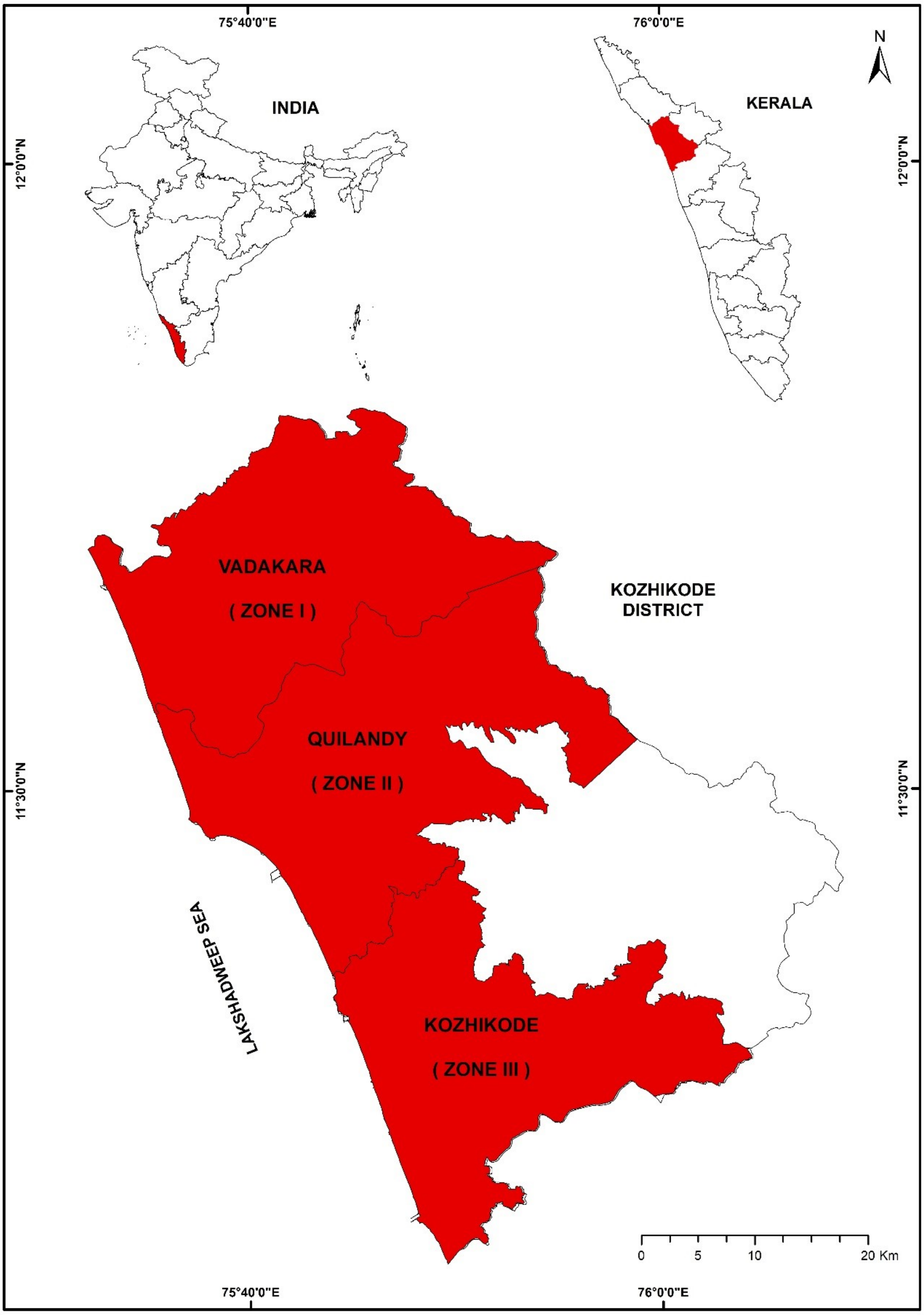

Fig. 1. Location of the study area.

small valleys.

Two major types of shorelines are identified along the Kozhikode coast: cliffed and neutral (Nair, 1987). The cliffed shoreline features cliffs bordered by gently sloping platforms extending across the shore, formed due to cliff recession by wave attack. These platforms

Table 1. Details of the satellite images used for the study.

Sl.No.	Satellite/Sensor	Date of Acquisition	Path/Row	Source
1	LANDSAT 1-5 MISS C2L1	10-FEB-1973	155/052	USGS
2	LANDSAT 4-5 TM C2L1	17-DEC-1990	145/052	USGS
3	LANDSAT 7 ETM + C2L1	20-DEC-2000	145/052	USGS
4	LANDSAT 7 ETM + C2L1	03-MAR-2010	145/052	USGS
5	LANDSAT 8-9 OLI/TIRS C2L2	22-MAR-2020	145/052	USGS

extend from the high tide level at the base of the receding cliffs to the low tide level in the nearshore zone and are intertidal shore platforms. Such platforms are found on laterites around Quilandy west and north of Azhiyur near Mahe. The shoreline between Elathur and Beypore falls under the neutral category. Wave activity is significant during both the southwest and northeast monsoons, but extreme wave conditions occur during severe tropical cyclones and storm surges. These extreme conditions are likely to impact the coastal area under study, making it susceptible to coastal erosion and accretion. Geologically, the shoreline patches of Kozhikode district are filled with sand and silt. Charnockite group rock formations are found in the Beypore, Faroke, and Puthiyangadi regions. In the northern parts, lateritic cliffs overlie crystalline Precambrian rocks. Tropical cyclone "Tauktae" formed in the Arabian Sea on May 14, 2021, and, brought heavy rainfall and caused severe damage to the coastal regions of the Kozhikode district (CWRDM, 2021).

3. Material and methods

Between 1973 and 2020, multi-temporal images from Landsat sensors, for the years 1973, 1990, 2000, 2010 and 2020, were used to detect shoreline changes (as detailed in Table 1) in the Kozhikode district.

Landsat data have proven to be exceptionally valuable for coastal zone management studies since the 1970s due to their synoptic and repetitive data coverage, as well as their multi-spectral resolution capabilities. These capabilities enable the observation and measurement of geophysical characteristics of both land and sea surfaces, allowing researchers to distinguish and analyze these characteristics effectively (Moore, 2000; Woodcock et al., 2008; Mishra et al., 2019). All the satellite images in this study are projected in the Universal Transverse Mercator (UTM), Zone 43 N with World Geodetic System 1984 (WGS 84) datum.

To analyze the shoreline changes along the coastal tract of Kozhikode, a systematic process was followed, as illustrated in Fig. 2. This process involved the following key steps:

1. ***Digitization of Satellite Images:*** The shorelines from multiple dates (1973–2020) were extracted through the digitization of satellite images. This process involved converting the visual data from the images into digital form, specifically shapefiles, which are used for further analysis. To ensure precision, the delineated shoreline undergoes a smoothing procedure and is subsequently enhanced utilizing satellite imagery. This enhancement is imperative in certain regions where the shoreline may not have been accurately delineated due to image distortions. The final, revised shorelines are exported into shapefiles corresponding to distinct years—specifically, 1973, 1990, 2000, 2010, and 2020. These shapefiles constitute a significant archive for the examination of shoreline transformations over temporal scales and facilitate diverse applications in coastal management and environmental assessment.
2. ***Input into DSAS Tool:*** The digitized shoreline shapefiles were then input into the Digital Shoreline Analysis System (DSAS 5.1) tool. The DSAS tool is a widely used application for calculating shoreline change rates.
3. ***Baseline Creation:*** A baseline was created by buffering the coastal area by 300 meters. This baseline serves as a reference point for measuring shoreline changes.
4. ***Transect Generation:*** Using the DSAS tool, transects (lines perpendicular to the shoreline) were generated with a length of 1 km and a spacing of 100 meters along the coastline. These transects help in studying the changes that have occurred along the Kozhikode coast.
5. ***Shoreline Change Rate Calculation:*** The shoreline change statistics were calculated using different methods, including:
   - ***Linear Regression Rate (LRR):*** This method calculates the rate of change by

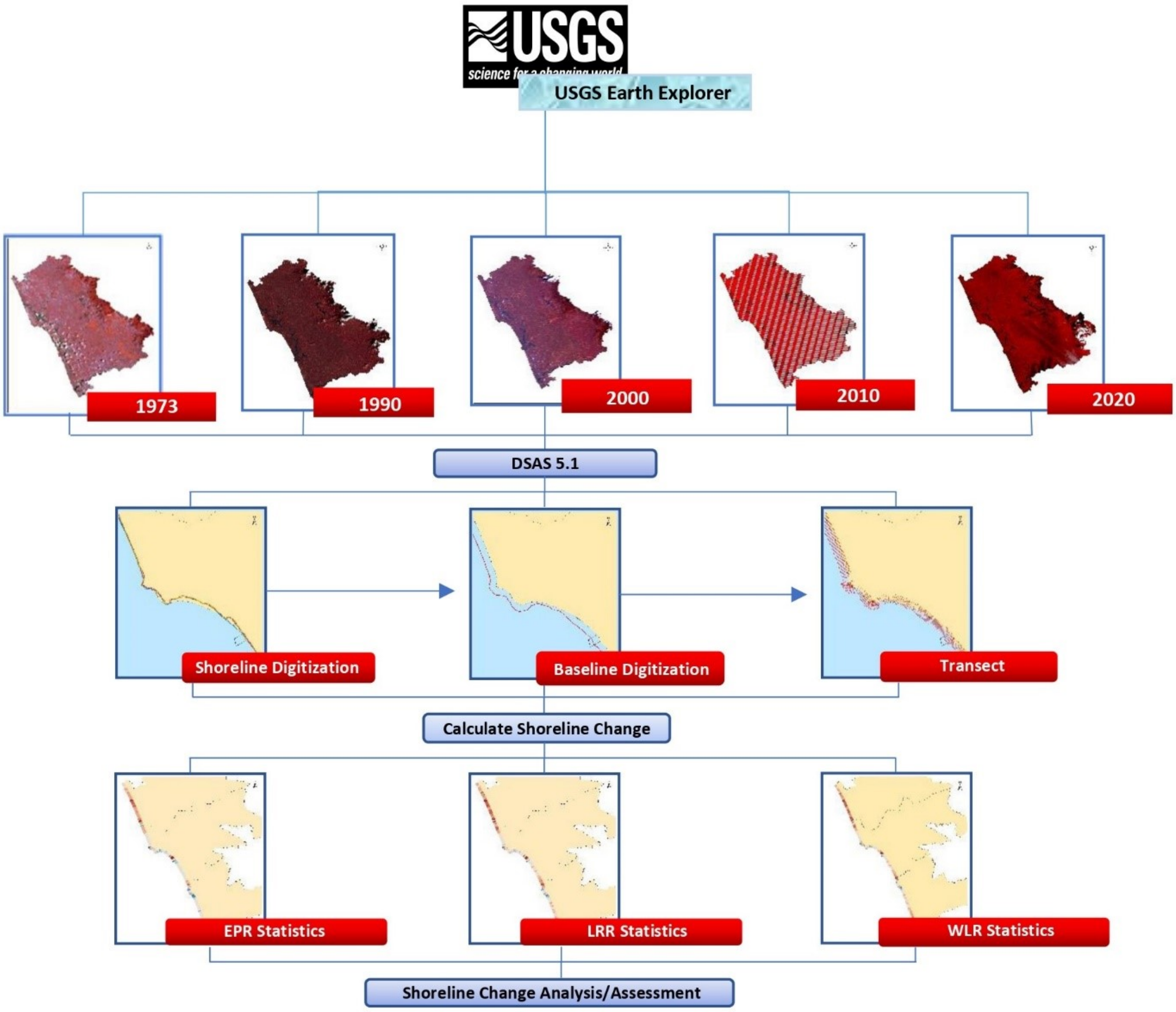

Fig. 2. Flow chart of the methodology adopted in this study.

fitting a linear trend to the shoreline positions over time.

- ***Weighted Linear Regression:*** Similar to LRR but gives different weights to different shoreline positions based on certain criteria.
- ***End Point Rate (EPR):*** This method calculates the rate of change by measuring the distance between the oldest and the most recent shoreline positions and dividing it by the time elapsed.

6. ***Preparation of Decision Matrix:*** Based on the calculated results and outputs, a final decision matrix was prepared. According to the computations conducted, the statistical dataset has been integrated with the transect line utilizing the transect identifier, in addition to being amalgamated with the administrative boundary to acquire taluk-specific statistics. The shoreline regions have been divided into five unique categories based on the rates of coastal change determined by LRR values, namely high accretion (>5 m/y), low accretion (0.5–1 m/y), stable (0.5 to -0.5 m/y), low erosion (-0.5 to -5 m/y), and high erosion (> -5 m/y) areas. This matrix provides a comprehensive summary of the shoreline changes and helps in making informed decisions regarding coastal management.

By following this detailed process, it was able to effectively analyze the shoreline changes along the Kozhikode coast, providing valuable insights for coastal zone management and planning. The results, visualized in Fig. 3a, Fig. 4a and Fig. 5a, offer a clear representation of the shoreline dynamics over the study period.

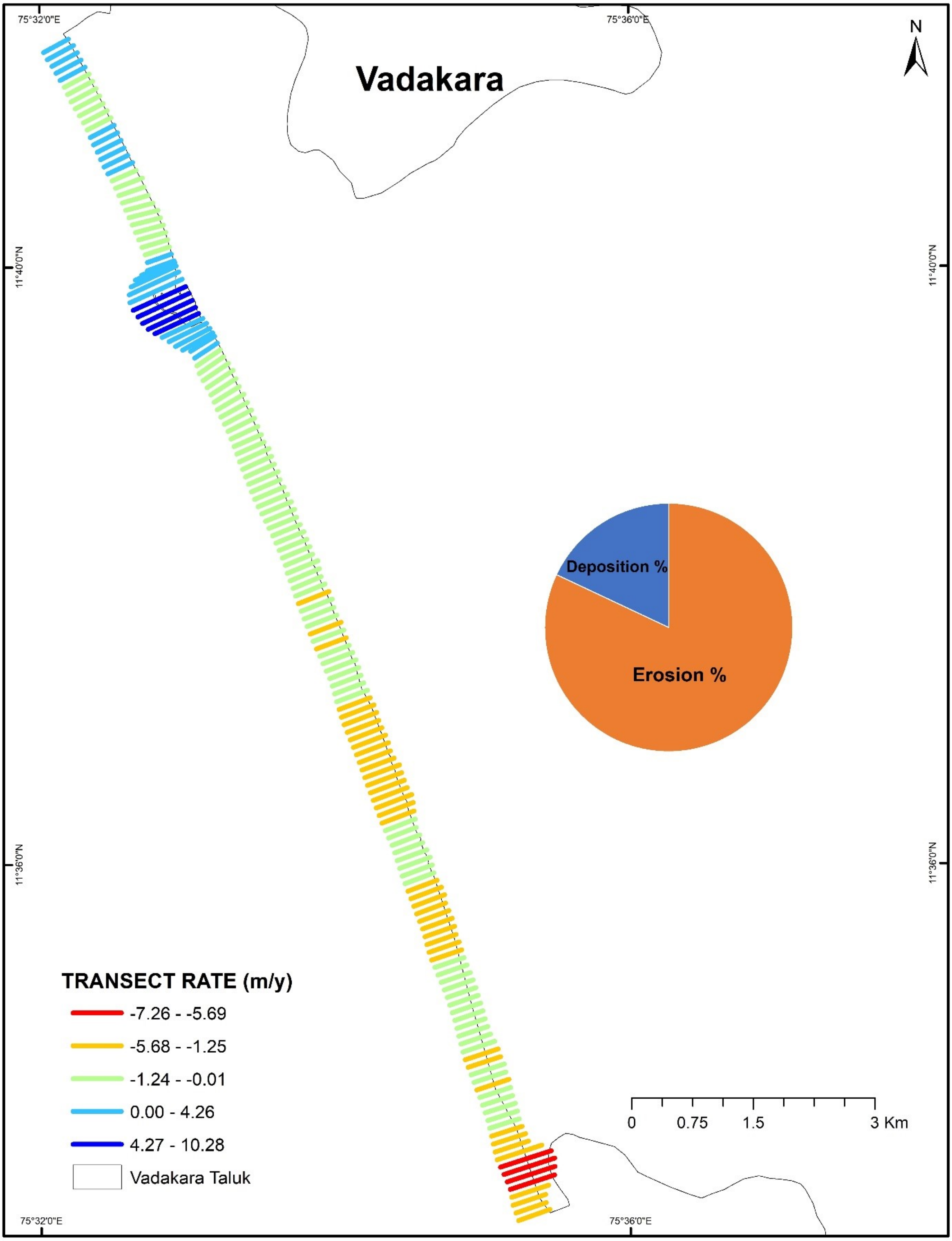

Fig. 3a. Shoreline change category map of Zone I (Vadakara taluk).

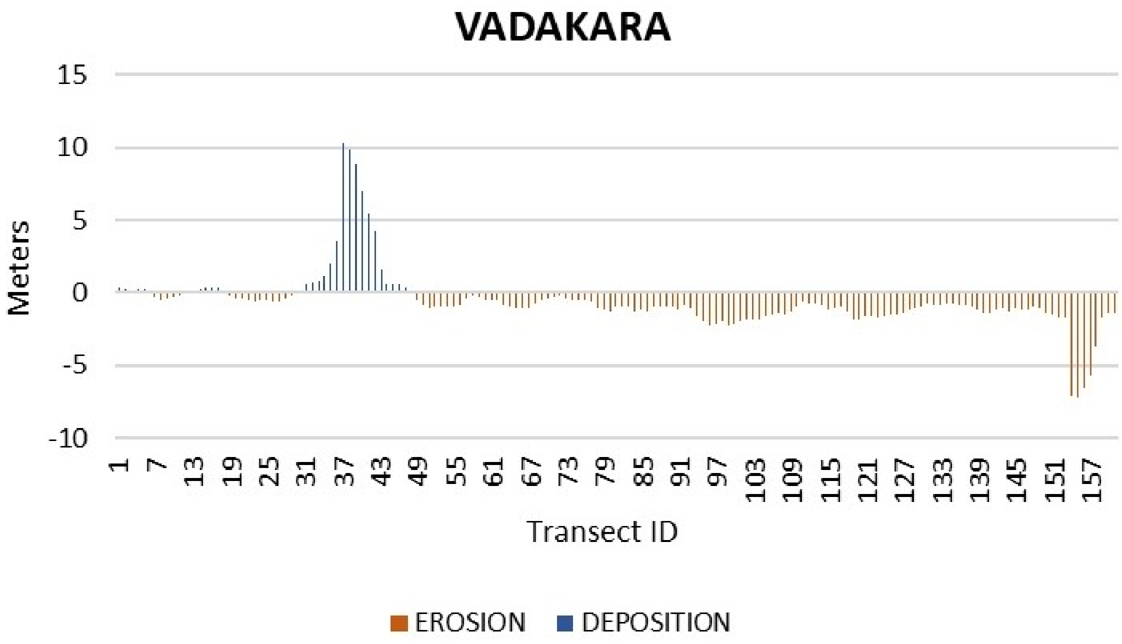

Fig. 3b. Graphical representation of shoreline change along the Zone I (Vadakara taluk).

4. Results and Discussion

The shoreline changes study reveals that a significant portion of the coastal areas (59.24%) are vulnerable to erosion. Detailed shoreline changes are provided in Table 2 and in Fig. 3a, Fig. 4a, and Fig. 5a. The taluk-wise descriptions are outlined as follows.

4.1. Vadakara taluk

Vadakara taluk is located in the northern part of the Kozhikode district covering an area of 576 sq.km (Fig. 1). To the north, it borders the Thalasseri taluk of Kannur district; to the south, Quilandy taluk; to the east, the Mananthavady taluk of Wayanad district; and to the west, the Arabian Sea. The coastal area spans approximately 16 km. The results indicate that a significant portion of the coastal stretch of Vadakara taluk is vulnerable to erosion, with about 81.99% affected (Table 2 and Fig. 3a & Fig. 3b). The erosion rate is particularly high, reaching between 6 to 7 m/year along the estuary of the Kuttiyadi River. Minimal deposition is observed, accounting for only 18.01% of the coastal track (Table 2). The areas of observed accretion are primarily concentrated in the northern part of the taluk, particularly along the southern stretch of the Mahe River near Mahe Harbour and Chombala Harbour, where accretion rates range from 4 to 10 m/year (Fig. 3a & Fig. 3b).

4.2. Quilandy taluk

Quilandy taluk, covering 576 km^2, is located in the central part of the Kozhikode district (Fig. 1). It is bordered by Vadakara taluk to the north, Kozhikode and Thamarassery taluks to the south, Vythiri taluk of Wayanad district to the east, and the Arabian Sea to the west. This taluk has the longest coastal stretch (31 km^2) compared to the other two taluks (Fig. 1 and Fig. 4a). The study indicates that erosion (52.58%) and accretion (47.42%) are relatively similar in range within Quilandy taluk (Table 2). Both processes are most prominently observed along the central part of the taluk (Fig. 4a, Fig. 4b). Erosion is particularly severe in the Parapally Beach to Quilandy region, with rates ranging from 3.58 to 7.18 m/year. The southern part of the Quilandy shoreline is also highly vulnerable to erosion (Fig. 4a, Fig. 4b). In contrast, accretion is most significant in the central part of the taluk, particularly from Thikkodi to Moodadi, with notable accumulation along Kodikkal Beach, where rates range from 2.58 to 6.35 m/year. The presence of hard rocks such as charnockite along this shoreline reduced the encroachment rate.

4.3. Kozhikode taluk

Kozhikode taluk is situated in the southern part of the Kozhikode district (Fig. 1), covering an area of

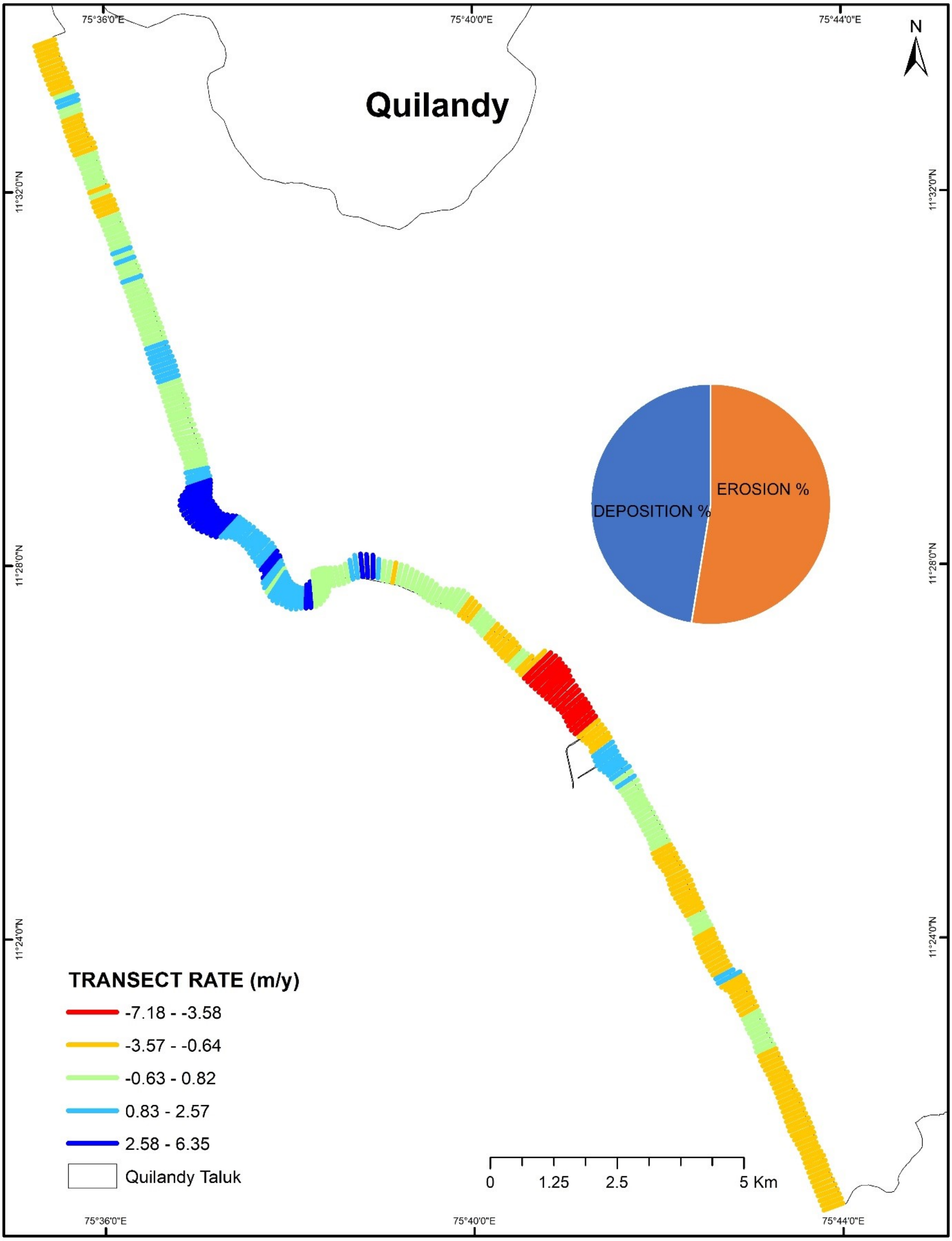

Fig. 4a. Shoreline change category map of Zone II (Quilandy taluk).

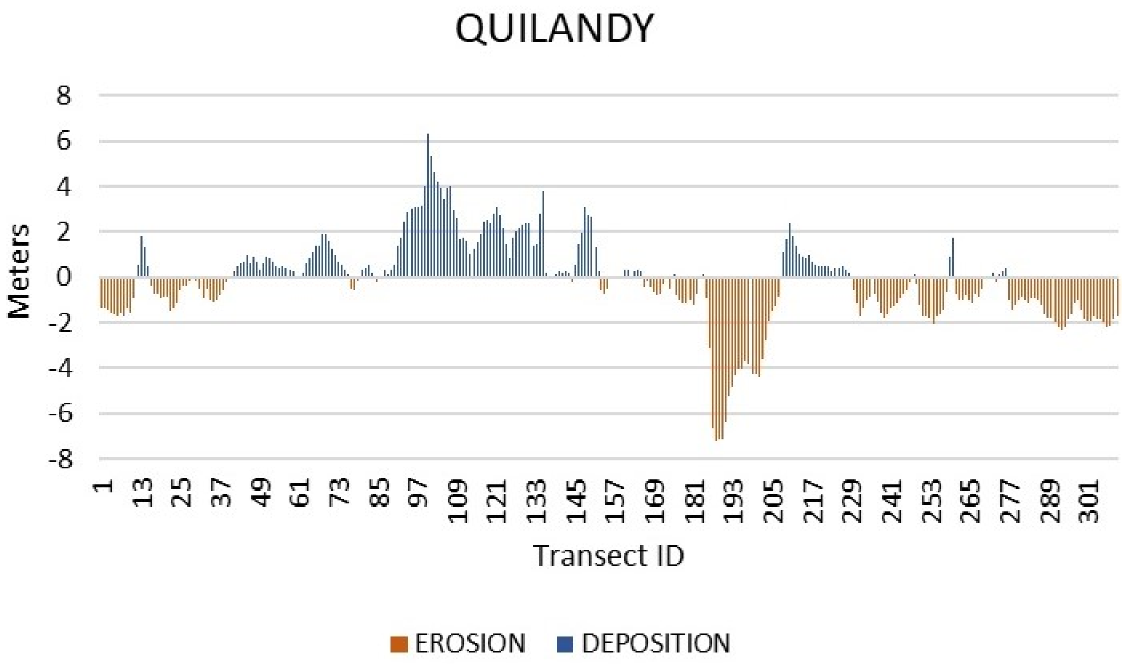

Fig. 4b. Graphical representation of shoreline change along the Zone II (Quilandy taluk).

23.33 sq km. To the south lies Malappuram district, while Quilandy taluk is to the north. The eastern border is defined by Thamarassery taluk, and the Arabian Sea lies to the west. The coastal area spans approximately 29 km (Fig. 1 and Fig. 5a). The shoreline change study reveals that the length of eroding coastline in Kozhikode taluk is 53.87% (Table 2), primarily affecting the central to southern regions (Fig. 5a, Fig. 5b). Erosion is particularly severe along the Kadalundi area, with rates ranging from 1 to 2 meters. In contrast, the length of the accreting coastline is 45.79%, mainly observed in the northern part of the taluk, from the estuary of the Korapuzha River to Puthiyappa Harbour, with rates ranging from 1.8 to 7 m/year (Fig. 5a, Fig. 5b). Accretion is most pronounced along Beypore Beach, where it ranges from 4.79 to 10.27 m/year. Approximately 0.34% of the coastline remains stable (Table 2).

The result was validated using the coastal erosion map of Kozhikode district published by the Irrigation Department, Government of Kerala. The study suggests that, in general, the northern part of Kozhikode district is more prone to erosion, while the southern part is more prone to accretion. The analysis data suggests that about 59.24% (45.5 km) was eroded, 0.13% (9.98 km) was stable and 40.63% (31.20 km) was accreted during 1973–2020 along the study area. According to Selvan et al. (2020), 34% of Kerala's coast is in a stable state, 21% is accreting, and 45% is in an erosive state. The LRR (Linear Regression Rate) value indicates that the erosion rate is comparatively higher in Vadakara taluk (82%) and lower in Quilandy taluk (53%). The highest intensity of erosion is observed at the estuary of the Kuttiyadi River (6 to 7 m/year) in Vadakara taluk and from Parapally Beach to the Quilandy region (3.58 to 7.18 m/year) in Quilandy taluk. However, the shorelines of Kozhikode taluk were comparatively less vulnerable to the encroachment. The study suggests that the erosion is mainly concentrated along river estuaries, such as Kadalundi and Kuttiyadi, due to reduced fluvial inflow. The absence of seawalls and other protective shoreline structures has led to an increased erosion rate along the Parapally Beach to Quilandy region. The accretion rate is comparatively higher in Quilandy taluk (47.4%) and lower in Vadakara taluk (18.01%). Accretion is most prominent along Beypore Beach (4.79–10.27 m/year) near the river mouth of the Chaliyar River in Kozhikode taluk. The study shows that the accretion rate is dominated along the harbor areas as well as river mouths such as Korappuzha River, Chaliyar River, Mahe River, etc. This observation is supported by the study result of Rafeeque et al. (2022). They reported an accretion of 2.5–5 km along the Beypur–Kallayi sector, 1–2 km along Kallayi–Korappuzha sector and

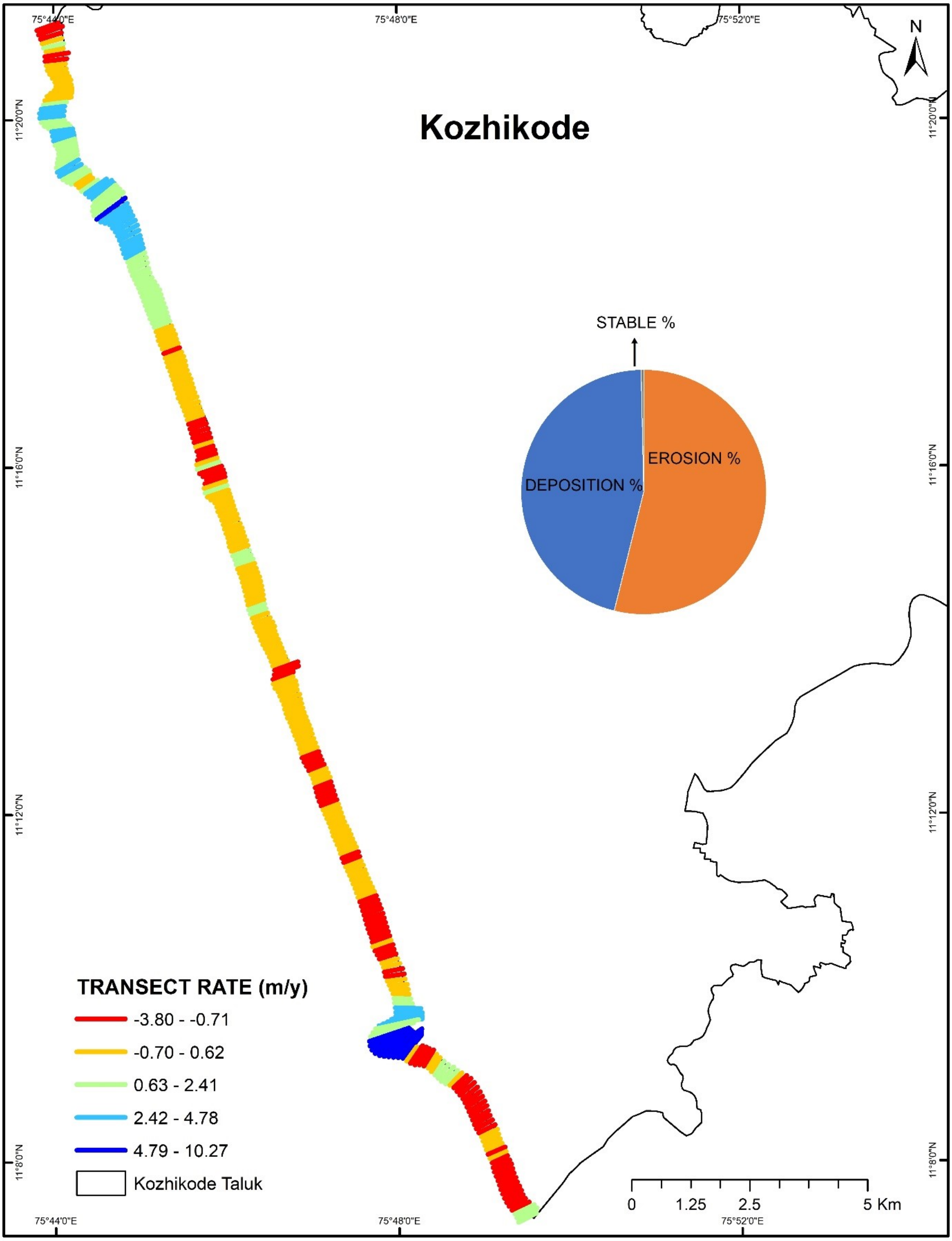

Fig. 5a. Shoreline change category map of Zone III (Kozhikode taluk).

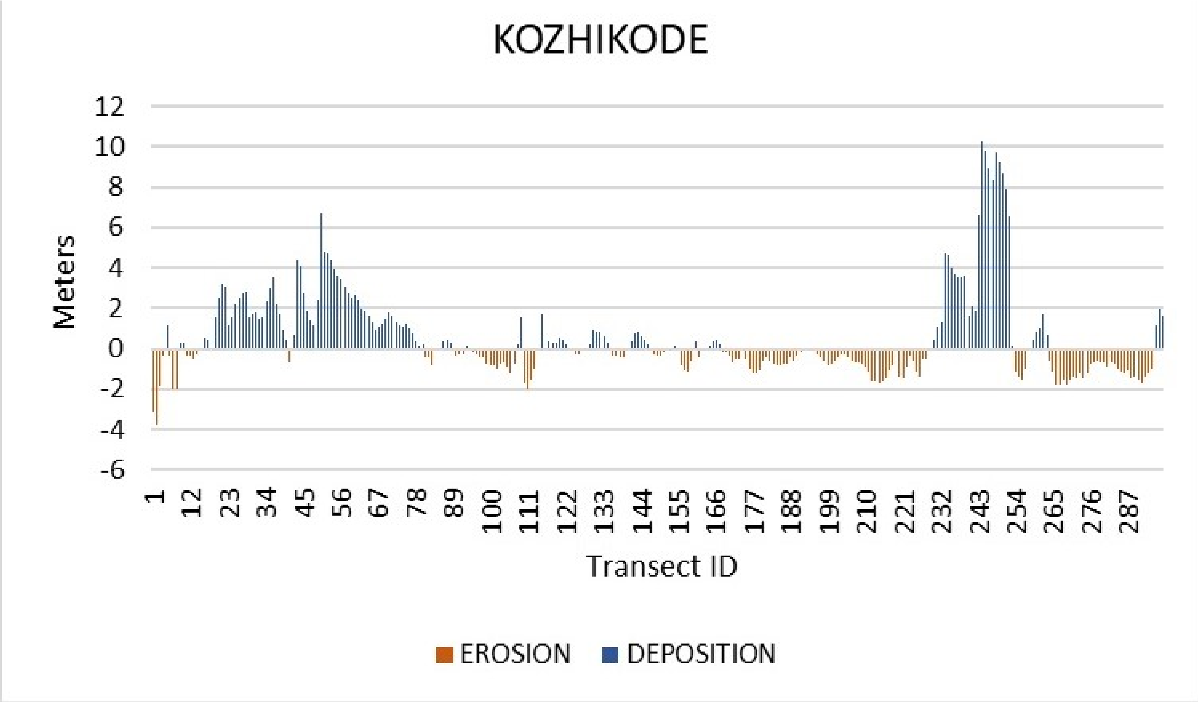

Fig. 5b. Graphical representation of shoreline change along the Zone III (Kozhikode taluk).

Table 2. Zone-wise shoreline analysis parameters.

Parameters	Zone I Vadakara	Zone II Quilandy	Zone III Kozhikode	Total
Transect ID range	1–161	162–471	472–768	1–768
Total number of transcets	161	310	297	768
Transects exhibiting erosion	132	163	160	455
Transects exhibiting accretion	29	147	136	312
Stable transects	0	0	1	1
Percentage of transects exhibiting erosion (%)	81.988	52.581	53.872	59.245
Percentage of transects exhibiting accretion (%)	18.012	47.419	45.791	40.625
Percentage of stable transects (%)	0	0	0.337	0.130
Mean shoreline change (m)	-0.595	-0.152	0.525	0.017
Maximum shoreline change (m)	10.28	6.35	10.27	10.28
Minimum shoreline change (m)	-7.26	-7.18	-3.8	-7.26
Mean erosion	-0.978	-0.766	-0.424	-0.678
Standard deviation for erosion rate (m)	1.119	1.247	0.588	1.033
Mean accretion rate (m)	0.383	0.614	0.949	0.695
Standard deviation for accretion rate (m)	1.539	1.065	1.859	1.528

1–2 km along Korapuzha–Quilandy sector. They also reported that the sector's coastal morphology and nearshore bottom features were redefined in the 1990s with the construction of the port of Beypur and two significant fishing harbours, namely Puthiyappa and Koyilandi. While the Quilandy Harbour has little effect on the development of a large beach, the shoreline south of Puthiyappa Harbor and Beypur breakwater is accreted. The expanded arm of the breakwater on the southern side has helped to prevent additional erosion in the southern sector by obstructing the movement of silt (Ramesh et al., 2023).

Sediment transport along the Kerala coast is generally a dynamic, multidirectional, and complex process (Noujas and Thomas, 2018). It is understood from this study that river mouths are prone to either erosion or accretion, depending on variations in the sediment budget due to the tidal effects. The reefs exposed and submerged rocks, parallel and transverse bars, and other nearshore bottom features along the river mouths gave the area a diverse appearance as the accretion effect. The geomorphological structure and the presence of hard rocks, such as charnockite, along the shoreline also influence the rates of erosion and accretion. Monsoon showers with strong storms and cyclones caused significant coastal erosion throughout the coast; nevertheless, the majority of the eroded beach and sediment materials return to the shore and begin to rebuild during the fair season (pre- and post-monsoon) (Dora et al., 2014).

The construction of harbors and the implementation of shoreline protective structures such as groins, ripraps, fences, green belts, and seawalls could help reduce shoreline encroachment. Among the 593 km coastaline of Kerala, more than 50% of the coast is protected with these artificial structures (Selvan et al., 2020). The study by Girija (2015) shows that nearly 22.7 km of breakwaters had been built by the end of 2015 as sea walls and breakwaters were seen to be a key defense against severe erosion along the Kerala coast. However, the study by Ramesh et al. (2023) along the Kozhikode coastline suggested that while the the breakwater is successfully safeguarding the beach to the south, it has disrupted longshore transport, which may lead to further erosion to the north. This view is supported by the study of Selvan et al. (2020), which found that the effectiveness of the coastal protective structures was rather limited. The outcome also showed that shoreline change on either side of breakwaters had a different accretion/erosion pattern depending on the location.

5. Conclusion

A long-term shoreline change analysis along the coast of Kozhikode district, Kerala from 1973 to 2020 was carried out using remote sensing data with the integration of GIS technology and USGS DSAS model. The composite band configurations or the ratios of the Landsat spectral bands yielded a substantial outcome for the investigation of shoreline delineation. This research results indicated that

- The DSAS analysis from 1973 to 2020 shows that 59.24% of the coastline (45.5 km) of the Kozhikode district experienced erosion, 0.13% (9.98 km) remained stable, and 40.63% (31.20 km) underwent accretion.
- Vadakara taluk in Kozhikode district facing the highest erosion rate of 82%, compared to 53% in Quilandy taluk.
- Erosion is mainly concentrated near river estuaries due to reduced fluvial inflow, with the lack of seawalls and protective structures, which further increased the erosion rate.
- The accretion is dominated along the harbor areas as well as river mouths such as Korappuzha River, Chaliyar River, Mahe River, etc.
- The river mouths are prone to either erosion or accretion, depending on variations in the sediment budget due to the tidal effects.
- The geomorphological structure and the presence of hard rocks, such as charnockite, along the shoreline also influence the rates of erosion and accretion.

Although the research is subject to certain limitations, such as the influence of tidal variations, satellite resolution constraints, and potential human error in the digitization of shorelines, which have not been adequately addressed in the current study, it is recommended that further investigations be conducted utilizing the proposed methodology to evaluate and monitor shoreline alterations through the application of high-resolution satellite data, thereby facilitating a comprehensive examination of recent coastal erosion and detailed monitoring efforts.

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CRediT statement

Arun: Conceptualization, Data curation, Supervision, Methodology, Validation, Software, Investigation, Resources, Writing – original draft. **Muhamed Bin Rahman**: Formal analysis, Methodology, Data curation, Software, Visualization. **Sreeja**: Conceptualization, Methodology, Software, Supervision, Writing – review & editing. **Thanooja**: Validation, Visualization, Writing – review & editing. **Megha**: Validation, Visualization, Writing – review & editing.

Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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