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# SPATIOTEMPORAL ASSESSMENT OF SHORELINE CHANGES IN ILAJE LOCAL GOVERNMENT AREA, ONDO STATE, NIGERIA

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## Abstract

The world we live in is dynamic, constantly changing and evolving, and changes, both natural and anthropological, have profound impacts on our environment and ecosystems. The goal of this study is to present a spatiotemporal assessment of shoreline changes in Ilaje Local Government Area (LGA), Ondo State, Nigeria, utilising remote sensing and Geographic Information System (GIS) techniques. The primary objectives were to quantify the extent of shoreline changes and to predict future shoreline dynamics. By analysing Landsat 7, 8 and 9 satellite imagery from 2003 to 2023, significant transformations were observed. QGIS 3.32.1 was utilised in pre-processing the imageries, ArcGIS 10.8.2 was utilised for creating composite images and spatial analysis. Digital Shoreline Analysis System (DSAS) software was used in calculating Linear Regression Rate (LRR), as well as predicting the shoreline changes. The results indicate a substantial shoreline retreat, with erosion impacting over 85% of the transects analysed, leading to an average shoreline retreat of over 160 meters. Predictive models suggest that vulnerable areas could experience up to 400 meters of additional erosion by 2033. These findings provide critical insights into the spatiotemporal dynamics of shoreline changes, supporting the development of adaptive management strategies. Recommendations include shoreline stabilisation efforts and integrated land-use planning to mitigate the adverse impacts of ongoing and future shoreline changes on the local ecosystems and communities.

**Keywords**: *Shoreline, Digital Shoreline Analysis System (DSAS), Erosion, Accretion, Remote Sensing (RS),*

## INTRODUCTION

Coastal areas are dynamic environments where land, sea, and atmospheric processes interact continuously, leading to significant geomorphological changes over time. These changes, often driven by natural forces such as waves, tides, and storms, as well as anthropogenic activities, pose substantial challenges to coastal management (Komolafe *et al,* 2022). In recent decades, the accelerated rate of shoreline erosion has become a critical issue, threatening infrastructure, ecosystems, and the livelihoods of coastal communities globally and this is the case for Ilaje Local Government Area (LGA), rich in biodiversity and home to a variety of flora and fauna, plays a crucial role in maintaining the ecological balance of the region. However, it has been observed that this area is undergoing significant changes in its shoreline. These changes, if left unchecked, could lead to severe ecological imbalance, loss of biodiversity, and adverse impacts on the local communities that rely on these ecosystems for their livelihood (Nandi et al. 2016). Shoreline changes are a result of the dynamic interaction between the ocean and the land, which can be influenced by both natural processes and human activities (Olusola, 2022). A shoreline that has retreated over the last 100 years may have experienced periods of shoreline advance. It is important, however, for coastal residents to understand that even though a particular beach may have been advancing or stable over the last several years, if it has been retreating for the previous decades, then retreat will eventually resume, an exception to this rule would be if something fundamental, such as a "permanent" increase or decrease in the sand supply, has changed in the system (Oyinloye *et al.,* 2016). The impact of these changes can lead to loss of property and infrastructure, impacting local economies (Prasad *et al.,* 2022). It can also affect recreational activities such as swimming and beach-going, impacting the quality of life for residents. In extreme cases, shoreline changes can lead to the displacement of coastal communities. According to (Oyinloye *et al.,* 2016) the position of the shoreline in the past, at present and where it is predicted to be in the future is useful for in the design of coastal protection, to calibrate and verify numerical models to assess sea level rise, map hazard zones and formulate policies to regulate coastal development. Therefore, predicting these changes is not just a matter of scientific interest but a necessity for effective planning and management. Understanding and managing these changes is essential for sustainable coastal development and disaster risk reduction.

There are significant challenges faced in shorelines of Ilaje Local Government Area (LGA), these challenges are particularly pronounced due to significant ecological changes impacting the shoreline ecosystems: (i) The region has experienced both accretion and erosion processes over the past three decades with approximately 40km of the coastline accreting at an average of +1.08m/year and about 35.4km eroding at an average of -1.40 m/year. (Komolafe *et al,* 2022). These changes have caused major damage to coastal structures and necessitated harbour dredging (Prasad and Raj, 2021). The economic, social, and environmental costs of these shoreline dynamics are substantial, necessitating effective prediction and management strategies. Integrating remote sensing and GIS is crucial for providing baseline information, informing conservation efforts, and mitigating the adverse impacts of these changes.

The primary goal of this research is to conduct a spatiotemporal assessment of shoreline changes in Ilaje Local Government Area (LGA) using GIS and remote sensing technologies. This study aims to address the following research questions: (i) what is the extent of shoreline changes in the study area over the past two decades? (ii) how can predictive models be developed to forecast future shoreline dynamics using remote sensing and GIS? By answering these questions, the research seeks to provide valuable insights into the extent and causes of shoreline changes, offering a foundation for developing strategies to mitigate adverse impacts and promote sustainable coastal management. The detection and extraction of the shoreline indicator are tedious tasks when using traditional techniques, such as in-situ surveys or manual digitisation, which are costly and time-consuming (Boussetta, 2022). Geographic Information Systems (GIS) and remote sensing offer powerful tools for Earth Observation mapping. GIS and remote sensing can effectively address the issue of shoreline erosion by providing accurate, timely, and detailed information on coastal dynamics. Remote sensing provides large-scale, high-resolution spatial data over time, while GIS offers robust analytical capabilities, making these

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technologies invaluable for assessing and managing coastal changes (Deepika *et al.,* 2014). These technologies enable the continuous monitoring of shoreline changes, allowing for the identification of erosion hotspots and the assessment of human impact (Kumar, 2011). Predictive models developed through GIS and remote sensing can inform proactive management strategies, such as shoreline stabilisation efforts and integrated land-use planning. By leveraging these tools, stakeholders can develop adaptive measures to mitigate the adverse impacts of shoreline erosion, enhance the resilience of coastal communities, and support sustainable coastal development.

## LITERATURE REVIEW

Many recent studies have been carried out on shoreline changes all around the world; Boussetta, *et al.,* (2022) utilized geographic information system (GIS) and the Digital Shoreline Analysis System (DSAS), geostatistical calculation tool to analyze erosion and accretion rates and the description of evolutionary trends across 32 years covering three periods (1989–1999, 1999–2009, and 2009–2021) in Jerba Island, North Africa. Murray *et al.* (2023) investigated shoreline changes along the southwestern coast of Africa from 1937 to 2020 using the Digital Shoreline Analysis System (DSAS); their result shows an extensive erosion occurring between 2015 and 2020. Spatiotemporal evolution of shoreline dynamics on the Oluvil coastline in the Ampara district in Sri Lanka was analysed by Zoysa *et al.* (2023) for a period of 2 decades using remote sensing and GIS, and they discovered that the area has undergone both accretion and erosion primarily due to harbour construction. While the study carried out by Shamsuzzoha and Ahamed (2023) uses GIS and remote sensing approaches to explore shoreline status with change assessment for a period of three years for an onshore Tasseled Cap Transformation (TCT) in Bangladesh Delta. Palanisamy *et al.* (2024) carried out a spatiotemporal analysis of shoreline changes along a 60km stretch of the southern coast of Rio de Janeiro, Brazil, from 1986 to 2018 and predicted the shoreline changes for 2 decades using Kalman filter model. While the study of Kundul and Mandal (2024) focused on shoreline change detection and future prediction of five islands in Sundarban Delta using a GIS and remote sensing approach. (Mbezi *et al.,* 2024) explore shoreline changes and their implications in the eastern coast of Unguja Island, Tanzania, using remote sensing approaches, and their result identified that a significant portion of shoreline erosion occurs in the northern part, with the main impact on the destruction of facilities along the coastal zone. Also, using multi-source data, and the CoastSat tool Yuan, *et al.* (2024) extracted and analysed shoreline data from 20 representative beaches of Hainan Island (China) and calculated the slopes of 119 beaches around the island for the period from 2013 to 2023. Song, *et al.* (2024) analysed changes in Yancheng coastline over 20 years based on remote sensing technology and revealed that the average siltation rate of various sections along the Yancheng coastline is 105.62 m/y, with the maximum siltation length measuring 12,048 m, located in the Tiaozini reclamation area.

In Nigeria researches have been carried on shoreline changes; Shoreline position trends in the Niger Delta was explored by (Dike, *et al.,* 2024), in their study they analysed spatial and temporal changes using sentinel-1 SAR data in assessing long-term shifts in shoreline positions; their result revealed prevailing erosion trends outweighing accretion. Ideki and Peace, (2024) analysed shoreline and erosion changes along the west African coast from 1980 to 2020 on a regional scale, and their findings revealed noticeable decadal changes and high erosion rates. Isiaka and Tata (2024) predicted Lagos lagoon coast shorelines using spaceborne SAR imagery and discovered a general erosion would occur in the area at a rate of 1.45 meters per year. Few recent studies have explored shoreline positional changes in the study area. Adagbasa *et al.* (2024) investigated the shoreline changes in Ilaje LGA using datasets from Landsat, Copernicus, Maxar Technologies and TerraMetrics for the years 1984, 2010, and 2023. Their findings indicated the dominance of erosion along the coast, with more than 70% of the coastline witnessing erosion. They also asserted that the cause is linked to the development on the adjacent coast of Lagos and Lekki. While Ogunrayi *et al.* (2023) undertook a spatiotemporal analysis of shoreline changes in Ilaje Coastal area. Their study revealed that approximately 86% of the coastline experienced erosion while 14% underwent accretion. Lastly, Komolafe *et al.* (2022) explored spatio-temporal analysis of shoreline positional change of Ondo State Coastline using four multi-temporal and spectral Landsat images from 1986 to 2017, and their findings revealed significant erosion.

Collectively, these studies provide a rich tapestry of methodologies, findings, and insights into shoreline changes and their impact on the environment. Specifically, our study provides additional support and gives credence to previous research on shoreline positional studies in Ilaje Local Government Area of Ondo State, particularly the recent study conducted by Adagbasa *et al.* (2024).

## METHODOLOGY

### Study Area

Ilaje is a local government area situated in the southern senatorial district of Ondo State, Nigeria (Wikipedia) (Figure 1). Spanning across a 281 km$^2$ region, Ilaje contains several islands within the Mangrove swamp forests adjoining the Atlantic Ocean coastline (Wikipedia). The prominent islands include Orere, Zion Pele, Ode Ugbo, Orioke Owodoyebo, Oba-Ile and Ode Mahin. The natural environment comprises interconnected river channels, freshwater swamps, lowland rainforests, sandy beaches, creeks, and coastal barrier islands. The regional climate is characterised by long wet seasons and short dry seasons influenced by the maritime southwestern monsoons and tropical rain belt (Akinluyi *et al,* 2022). Mean annual rainfall ranges from 2000 to 4000 mm, supporting lush mangrove ecosystems. The major economic activities comprise fishing, fish processing, salt making, lumbering, boat building, and palm oil processing (Olajide *et al,* 2020). Rich biodiversity supports marine fisheries critical for the indigenous Ilaje community's food security and livelihoods. However, shoreline erosion has occurred over the past decades. Quantitative ecological change assessments specific to Ilaje LGA are lacking. IPCC climate projections estimate continued sea level rise and increased storm intensity along West Africa coasts (IPCC). This underscores the need for spatio-temporal analyses and predictive modelling of shoreline changes in Ilaje LGA to support local climate adaptation policies.

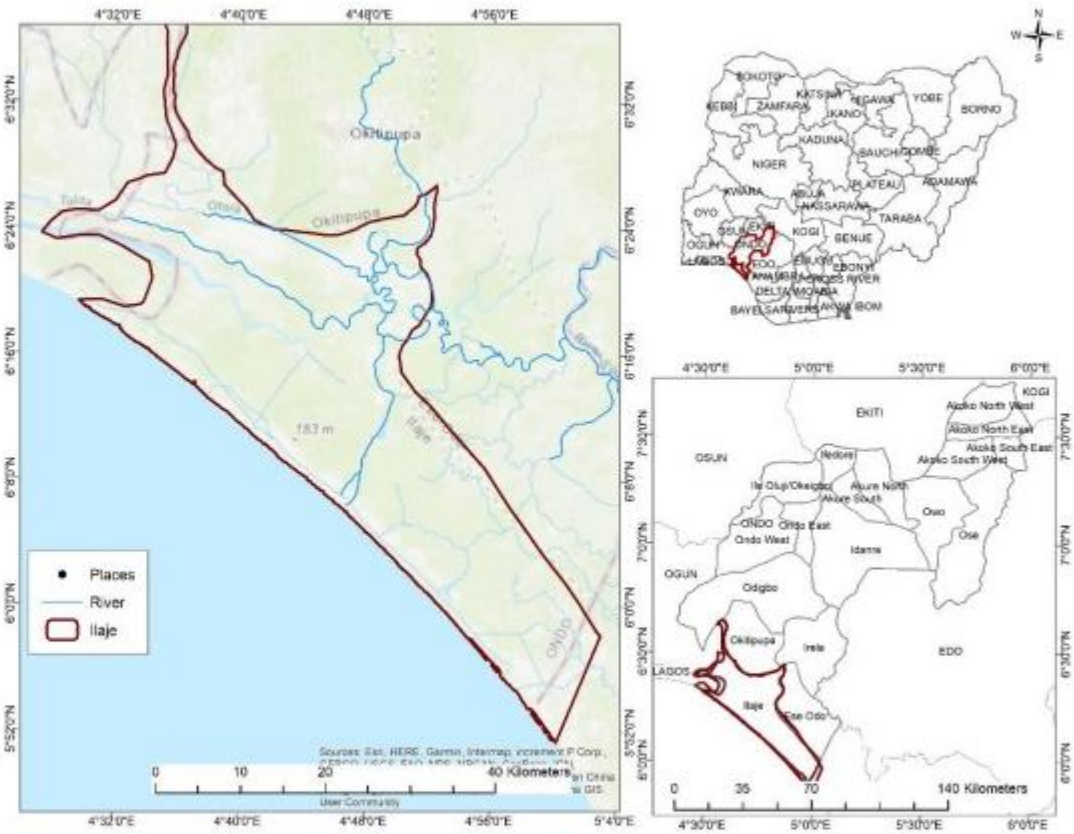


Figure 1: Study area map

**Data Collection and Processing**

The data used for this research consist of satellite images from various Landsat missions, including Landsat 7 with the Enhanced Thematic Mapper Plus (ETM+) sensor for the years 2003, 2008, and 2013; Landsat 8 with the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) for the year 2018; and Landsat 9 with the OLI-2 sensor for the year 2023. These satellites capture images across multiple spectral bands, with Landsat 7 providing 8 bands at a 30-meter resolution and Landsat 8/9 offering 11 bands at a resolution of 30 meters and 100 meters. The key visible, near-infrared, and shortwave infrared bands were particularly useful for differentiating between land, water, and vegetation. The satellite data were downloaded from the USGS Earth Explorer portal. A comprehensive approach was taken to process the data; to address the malfunction of the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) scan line corrector (SLC) mechanism, which often results in scanline errors in the imagery, the 'Fill Nodata' TOOL IN QGIS was utilised. This tool requires the input of various parameters, such as the gap mask and band number, to successfully correct these errors in the dataset. This preprocessing is essential to ensure the accuracy and usability of the Landsat 7 imagery for subsequent analysis. The composite band tool within the raster processing section of the Arc Toolbox was used for each study year (2003, 2008, 2013, 2018, and 2023). By inputting all the raster bands corresponding to each respective year into the tool, a composite band was generated, encapsulating the combined spectral information from the input bands.

Following this, the shorelines for each year were vectorised to capture detailed information about changes. A personal Geodatabase was established to organise and manage this spatial data effectively, with two primary inputs: Shoreline and Baseline. Both features were categorised as line features with distinct attributes to delineate their characteristics. For the Baseline feature, attributes such as ObjectId, Shape, Shape_Length, ID, Group, Offshore, and CastDir were defined, ensuring a structured and comprehensive dataset. The Digital Shoreline Analysis System (DSAS), an add-in for Esri ArcGIS, was then employed to generate transects and calculate rate-of-change statistics from multiple historical shoreline positions (Quang *et al., 2021*). The baseline served as a reference line from which measurements were taken, and transects were generated perpendicular to this reference baseline. Settings in DSAS, including parameters for transect generation and rate calculations, were user-specified to meet the specific requirements of the analysis. The system calculated rates of change by measuring the distance between the baseline and each shoreline intersection along a transect, incorporating date information and positional uncertainty to generate change metrics.

The shoreline change analysis proceeded with the calculation of shoreline rate statistics using various metrics. The Shoreline Change Envelope (SCE) was computed by measuring the total change in shoreline movement for all available shoreline positions (Kar *et al.,* 2017), highlighting the total variability over the time period of interest. The End Point Rate (EPR) was calculated to assess the rate of change based on multiple shoreline positions (Smith *et al.,* 2021), considering a transect spacing of 150 meters and a length of 5000 meters. The Net Shoreline Movement (NSM) provided the distance between the oldest and the youngest shorelines for each transect, offering insights into the absolute distance of shift (Ahammed and Pandey, 2022). Additionally, the Linear Regression Rate (LRR) method used a least-squares linear regression to consider all shoreline positions, providing a robust estimate of the rate of change (Himmelstoss *et al.,* 2018). These metrics were calculated for specific intervals (2003-2008, 2008-2013, 2013-2018, and 2018-2023) to analyse coastal dynamics over distinct periods. The result from the analysis can be classified into different classes, with negative values indicating erosion and positive values indicating accretion.

Finally, DSAS v5 software's forecasting feature was leveraged to predict future shoreline conditions over the next twenty (20) years. By incorporating the statistical rates calculated from historical data, DSAS projected the likely positions of the shoreline, providing valuable insights into potential coastal changes in the study area (Ogunrayi *et al*., 2024).

## RESULT AND DISCUSSION

The result's analysis is categorised into two sections: Shoreline changes mapping, and Prediction of future shoreline changes.

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**Shoreline Changes Mapping**

**Shoreline Changes for 2003 and 2008**

The statistical data for shoreline changes in Ilaje LGA (Table 1) from 2003 to 2008 provide insights into the dynamics of coastal transformation. The Shoreline Change Envelope (SCE) data, representing the overall averages, involves 509 transects. The average distance of shoreline change is 63.66meters, with a minimum distance of 0.08 meters and a maximum distance of 293.83 meters. Notably, the Net Shoreline Movement (NSM) data reveals an overall average of -2.34 meters, indicating a net retreat of the shoreline. About 58.55% of transects experienced negative distance, with a maximum negative distance of -202.45 meters, while 41.45% showed positive distances, with a maximum positive distance of 293.83 meters. The End Point Rate (EPR) data further emphasises erosional trends, with an average rate of -0.57 meters per year. Erosional transects account for 58.55% of all transects, while accretional transects constitute 41.45%, indicating the prevalence of shoreline retreat in Ilaje LGA during the specified period. This suggests significant land loss, which can displace communities, threaten infrastructure, and disrupt coastal ecosystems, leading to economic consequences and reduced land availability for development (Qiang & Brian, 2019). The erosion trends may be exacerbated by climate change and rising sea levels, necessitating coastal protection measures, continuous monitoring, and community engagement in planning to ensure sustainable development. These findings agree with Komolafe, *et al.* (2022) research, which stated that the coastline was found to be accreting with an average of +1.08 m/year followed by 35.4 km of coastal erosion. The shoreline change map is shown in Figure 2

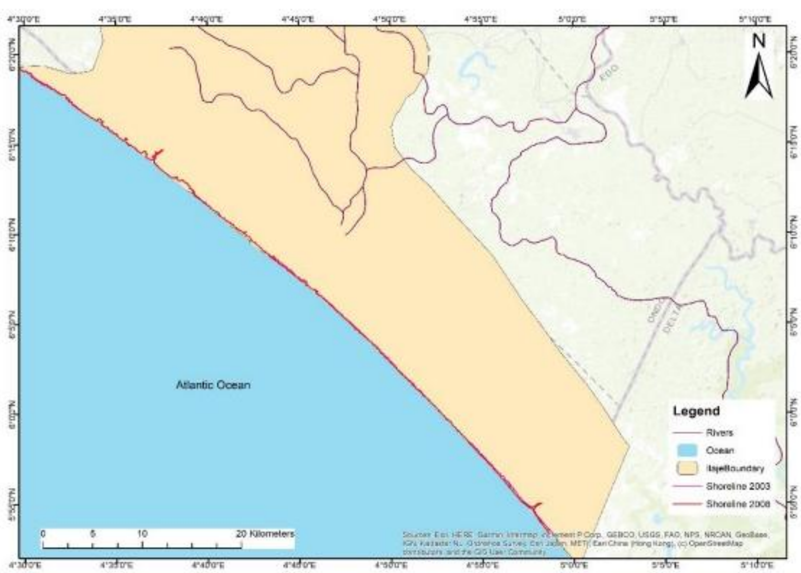


**Figure 2: Shoreline change map from 2003 -2008**

**Table 1:**
*Shoreline Change Statistics (2003-2008)*

| STATISTIC | VALUE | DETAILS |
|---|---|---|
| Number of Transects | 509 | |
| Average SCE | 63.66 m | Shoreline Change Envelope (SCE) uncertainty |
| Maximum SCE | 293.83 m | Transect ID: 509 |
| Minimum SCE | 0.08 m | Transect ID: 230 |
| Average NSM | -2.34 m | Negative indicates net erosion |
| % Transects with Erosional NSM | 58.55% | 298 transects eroding |
| % Transects with Accretional NSM | 41.45% | 211 transects accreting |
| Maximum Erosional NSM | -202.45 m | Transect ID: 100 |
| Maximum Accretional NSM | 293.83 m | Transect ID: 509 |
| Average Erosional EPR | -0.57 m/yr | Rate of erosion |
| Maximum Erosional EPR | -49.69 m/yr | Transect ID: 100 |
| Average Accretional EPR | 18.15 m/yr | Rate of accretion |
| Maximum Accretional EPR | 72.11 m/yr | Transect ID: 509 |

**Shoreline Changes for 2008 and 2013**

The statistical data for shoreline changes in Ilaje LGA from 2008 to 2013, as seen in Table 2, presents valuable insights into the coastal dynamics during this period. The Shoreline Change Envelope (SCE) data, involving 509 transects, indicates an average distance of 61.66 meters, with a maximum distance of 1161.37 meters. The Net Shoreline Movement (NSM) data reveals an overall average of -20.73 meters, signifying a net retreat of the shoreline. Notably, 64.64% of transects experienced negative distances, with a maximum negative distance of -1161.37 meters, while 35.36% showed positive distances, with a maximum positive distance of 224.72 meters. The End Point Rate (EPR) data further emphasises erosional trends, with an average rate of -3.51 meters per year. Erosional transects account for 64.64% of all transects, with a maximum erosion value of -196.45 meters/year, while accretional transects constitute 35.36%, with a maximum accretion value of 38.01

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meters/year. These statistics highlight the significant shoreline changes, with erosional processes dominating over accretion during the specified period. The shoreline change map for 2008 to 2013 is shown in Figure 3

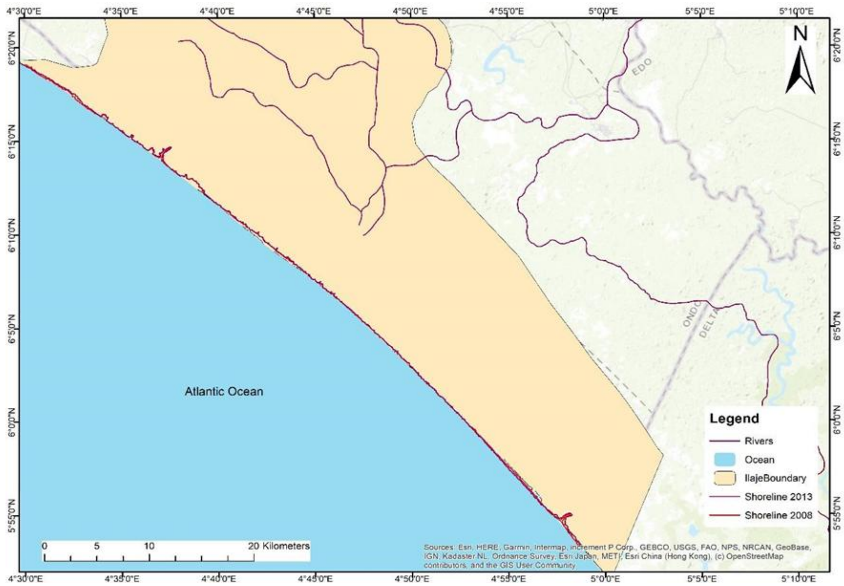


**Figure 3: Shoreline change map from 2008 to 2013**

**Table 2:**
*Shoreline Change Statistics (2008-2013)*

| STATISTIC | VALUE | DETAILS |
|---|---|---|
| Number of Transects | 509 | |
| Average SCE | 61.66 m | Shoreline Change Envelope (SCE) uncertainty |
| Maximum SCE | 1161.37 m | Transect ID: 142 |
| Minimum SCE | 0.22 m | Transect ID: 99 |
| Average NSM | -20.73 m | Negative indicates net erosion |
| % Transects with Erosional NSM | 64.64% | 329 transects eroding |
| % Transects with Accretional NSM | 35.36% | 180 transects accreting |
| Maximum Erosional NSM | -1161.37 m | Transect ID: 142 |
| Maximum Accretional NSM | 224.72 m | Transect ID: 445 |
| Average Erosional EPR | -3.51 m/yr | Rate of erosion |
| Maximum Erosional EPR | -196.45 m/yr | Transect ID: 142 |

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| | | |
|---|---|---|
| Average Accretional EPR | 9.79 m/yr | Rate of accretion |
| Maximum Accretional EPR | 38.01 m/yr | Transect ID: 445 |

**Shoreline Changes for 2013 and 2018**

The statistical data for shoreline changes in Ilaje LGA, as seen in Table 3 from 2013 to 2018, provides a detailed analysis of the coastal dynamics during this period. The Shoreline Change Envelope (SCE) data, encompassing 508 transects, reveals an average distance of 49.46 meters, with a minimum distance of 0.09 meters and a maximum distance of 625.71 meters. The Net Shoreline Movement (NSM) data indicates an overall average of -33.91 meters, signifying a net retreat of the shoreline. Notably, 75.59% of transects experienced negative distances, with a maximum negative distance of -625.71 meters, while 24.41% showed positive distances, with a maximum positive distance of 298.5 meters. The End Point Rate (EPR) data underscores erosional trends, with an average rate of -8.38 meters per year. Erosional transects account for 75.59% of all transects, with a maximum erosion value of -154.71 meters/year, while accretional transects constitute 24.41%, with a maximum accretion value of 73.8 meters/year. This resonates with the research carried out by Adedeji & Ezenwa, (2017) that the shoreline had undergone significant changes caused by shifts in the shoreline positions. The shoreline change map for 2013 to 2018 is shown in Figure 4

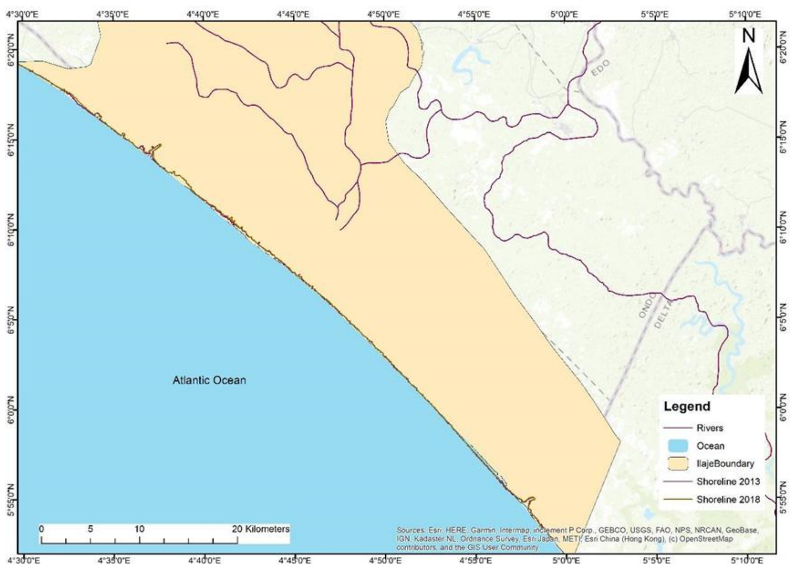


**Figure 4: Shoreline Change map from 2013 to 2018**

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**Table 3:**
*Shoreline Change Statistics (2013-2018)*

| STATISTIC | VALUE | DETAILS |
|---|---|---|
| Number of Transects | 508 | |
| Average SCE | 49.46 m | Shoreline Change Envelope (SCE) uncertainty |
| Maximum SCE | 625.71 m | Transect ID: 141 |
| Minimum SCE | 0.09 m | Transect ID: 236 |
| Average NSM | -33.91 m | Negative indicates net erosion |
| % Transects with Erosional NSM | 75.59% | 384 transects eroding |
| % Transects with Accretional NSM | 24.41% | 124 transects accreting |
| Maximum Erosional NSM | -625.71 m | Transect ID: 141 |
| Maximum Accretional NSM | 298.5 m | Transect ID: 134 |
| Average Erosional EPR | -8.38 m/yr | Rate of erosion |
| Maximum Erosional EPR | -154.71 m/yr | Transect ID: 141 |
| Average Accretional EPR | 7.87 m/yr | Rate of accretion |
| Maximum Accretional EPR | 73.8 m/yr | Transect ID: 134 |

**Shoreline Changes for 2018 and 2023**

The statistical data for shoreline changes in Ilaje LGA from 2018 to 2023, as seen in Table 4, reveal substantial coastal dynamics during this period. The Shoreline Change Envelope (SCE) data, encompassing 508 transects, shows an average distance of 116.11 meters, with a minimum distance of 0.15 meters and a maximum distance of 1424.97 meters. The Net Shoreline Movement (NSM) data indicates an overall average of -106.56 meters, indicating a significant net retreat of the shoreline. Impressively, 84.84% of transects experienced negative distances, with a maximum negative distance of -1424.97 meters, while 15.16% showed positive distances, with a maximum positive distance of 229.11 meters. The End Point Rate (EPR) data underscores erosional dominance, with an average rate of -17.93 meters per year. Erosional transects account for 84.84% of all transects, with a maximum erosion value of -239.71 meters/year, while accretional transects constitute 15.16%, with a maximum accretion value of 38.54 meters/year. These statistics highlight the pronounced shoreline retreat during the specified years, with erosion significantly outweighing accretion (Adagbasa *et al.*, 2024). The shoreline change map for 2018 to 2023 is shown in Figure 5.

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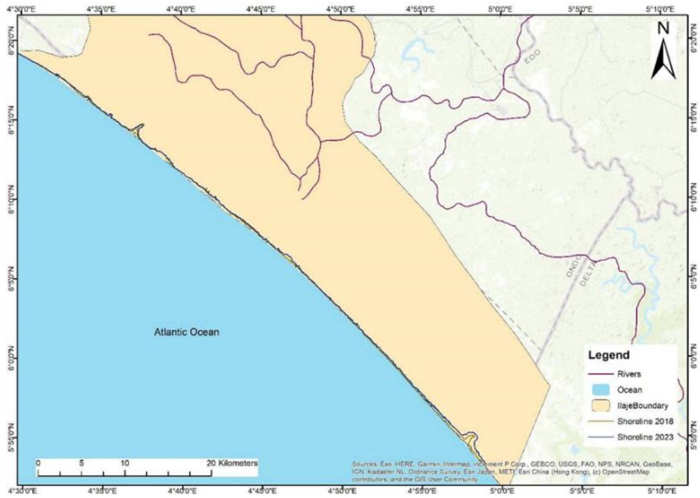


**Figure 5: Shoreline Change map from 2018 to 2023**

**Table 4:**
*Shoreline Change Statistics (2018-2023)*

| `STATISTIC | VALUE | DETAILS |
|---|---|---|
| Number of Transects | 508 | |
| Average SCE | 116.11 m | Shoreline Change Envelope (SCE) uncertainty |
| Maximum SCE | 1424.97 m | Transect ID: 495 |
| Minimum SCE | 0.15 m | Transect ID: 15 |
| Average NSM | -106.56 m | Negative indicates net erosion |
| % Transects with Erosional NSM | 84.84% | 431 transects eroding |
| % Transects with Accretional NSM | 15.16% | 77 transects accreting |
| Maximum Erosional NSM | -1424.97 m | Transect ID: 495 |
| Maximum Accretional NSM | 229.11 m | Transect ID: 98 |
| Average Erosional EPR | -17.93 m/yr | Rate of erosion |
| Maximum Erosional EPR | -239.71 m/yr | Transect ID: 495 |
| Average Accretional EPR | 5.3 m/yr | Rate of accretion |
| Maximum Accretional EPR | 38.54 m/yr | Transect ID: 98 |

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**Shoreline Changes for 2003 and 2023**

The overall statistical data for shoreline changes in Ilaje LGA from 2003 to 2023, as seen in Table 5, provides a comprehensive understanding of the coastal dynamics over the two decades. The Shoreline Change Envelope (SCE) data, involving 511 transects, shows an average distance of 231.38 meters, with a minimum distance of 12.39 meters and a maximum distance of 1579.41 meters. The Net Shoreline Movement (NSM) data indicates an overall average of -163.95 meters, reflecting a significant net retreat of the shoreline. Remarkably, 85.13% of transects experienced negative distances, with a maximum negative distance of -1468.73 meters, while 14.87% showed positive distances, with a maximum positive distance of 211.89 meters. The End Point Rate (EPR) data underscores erosional dominance, with an average rate of -8.24 meters per year. Erosional transects account for 85.13% of all transects, with a maximum erosion value of -73.53 meters/year, while accretional transects constitute 14.87%, with a maximum accretion value of 10.61 meters/year. Additionally, the Linear Regression Rate (LRR) data reiterates erosional trends, with an average rate of -7.79 meters per year and 84.28% of transects exhibiting erosional processes. This gives credence to Mahamoud *et al.,* (2023) research on monitoring shoreline changes in Ngazidja Island Coast Comoros. The overall shoreline change map for 2003 to 2023 is shown in Figure 6.

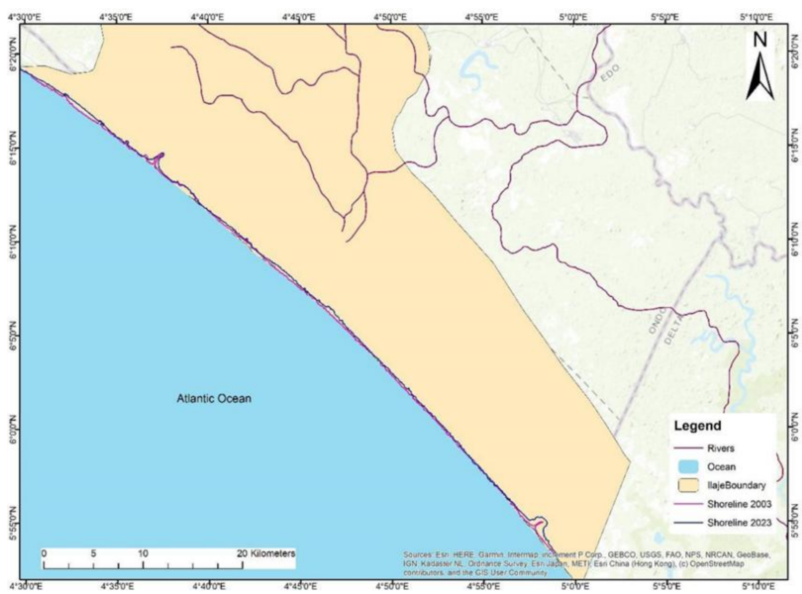


**Figure 6: Overall Shoreline change from 2003 to 2023**

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**Table 5:**
*Overall Shoreline Change Statistics (2003-2023)*

| STATISTIC | VALUE | DETAILS |
|---|---|---|
| Number of Transects | 511 | |
| Average SCE | 231.38 m | Shoreline Change Envelope (SCE) uncertainty |
| Maximum SCE | 1579.41 m | Transect ID: 495 |
| Minimum SCE | 12.39 m | Transect ID: 34 |
| Average NSM | -163.95 m | Negative indicates net erosion |
| % Transects with Erosional NSM | 85.13% | 435 transects eroding |
| % Transects with Accretional NSM | 14.87% | 76 transects accreting |
| Maximum Erosional NSM | -1468.73 m | Transect ID: 495 |
| Maximum Accretional NSM | 211.89 m | Transect ID: 135 |
| Average Erosional EPR | -8.24 m/yr | Rate of erosion |
| Maximum Erosional EPR | -73.53 m/yr | Transect ID: 495 |
| Average Accretional EPR | 3.48 m/yr | Rate of accretion |
| Maximum Accretional EPR | 10.61 m/yr | Transect ID: 135 |
| Average Erosional LRR | -7.79 m/yr | Rate of erosion |
| Maximum Erosional LRR | -79.08 m/yr | Transect ID: 142 |
| Average Accretional LRR | 3.82 m/yr | Rate of accretion |
| Maximum Accretional LRR | 12.71 m/yr | Transect ID: 135 |

**Prediction of Future Shoreline Changes.**

**Shoreline Positions**

Figure 7 predicts significant shoreline changes along the coast of Ilaje LGA between 2023-2033. The most striking change is severe erosion in the westernmost transects, near transect 140, where over 400 meters of shoreline retreat is expected by 2033. This region is clearly a hotspot experiencing rapid erosion, likely threatening coastal assets. More moderate erosion between 100200 meters is also predicted at the eastern end of the study area from transects 470-490. However, the forecast also shows shoreline advancement from accretion in some central transects, especially 300-350, where accretion above 50 meters is expected. Overall, there is a predominant eastward trend of net erosion, meaning long-term land loss. But areas of predicted accretion suggest some variability and complexity in shoreline changes. Uncertainty levels in the forecasts

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highlight this uncertainty, with error bounds of +/- 260 meters at some locations. This means actual shoreline positions could vary significantly from predictions as coastal processes evolve.

Monitoring shoreline changes with regular surveys will be crucial for coastal communities and infrastructure in Ilaje LGA to track erosion and manage evolving coastal flood/erosion hazards.

The forecast provides an important high-level overview of areas to monitor for erosion or accretion over the next decade. Adaptive planning for shoreline management will provide resiliency for assets and populations likely to be impacted by the clearly dynamic shorelines.

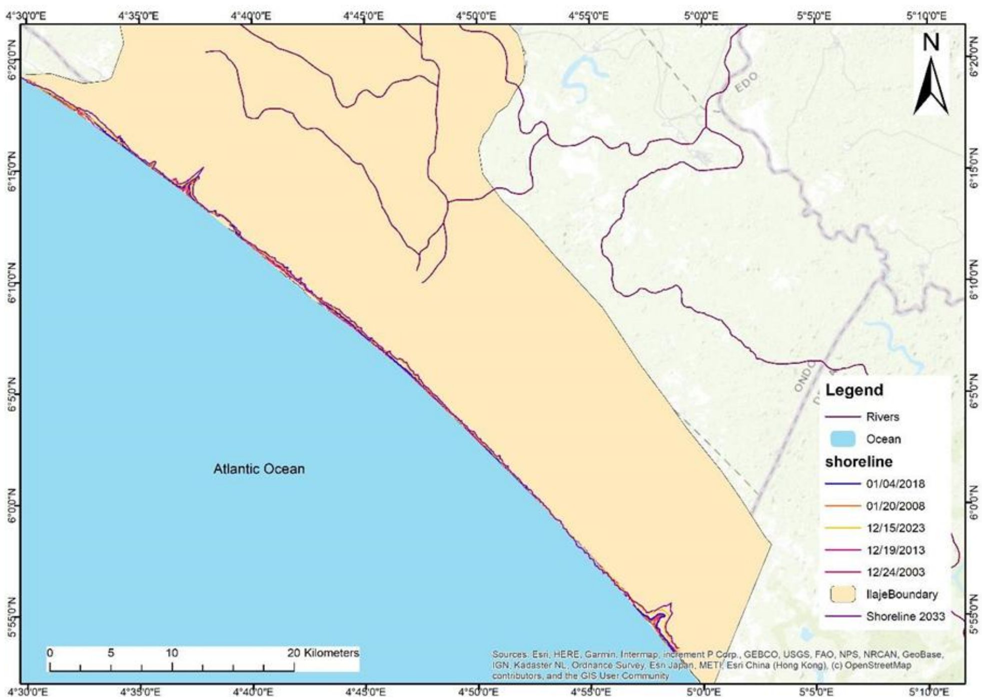


**Figure 7: Shoreline Change Prediction from 2023 to 2033**

## CONCLUSION

Our study on the shoreline changes in Ilaje LGA underscores the critical importance of understanding and addressing coastal dynamics in this region, utilising advanced remote sensing and GIS techniques. This study reinforces and gives credence to research conducted by Adagbasa *et al.* (2024), Ogunrayi *et al.* (2023), and Komolafe *et al. (*2022). We were able to quantify the historical shoreline changes and predict future trends, providing key insights into the patterns and drivers of coastal erosion and accretion. Over the past few decades, Ilaje LGA has experienced notable shoreline changes, with certain areas showing significant erosion while others exhibiting accretion, highlighting the complex interplay of natural processes and human activities affecting the coast (Komolafe *et al.,* 2022). Key factors driving these changes include natural processes such as wave action, sea-level rise, and sediment transport, alongside human activities like sand mining, construction, and land reclamation. Understanding these drivers is crucial for developing effective management strategies. Accurate predictions of future shoreline positions, achieved through predictive modelling, indicate potential areas at high risk of erosion. This information is vital for planning and mitigation efforts, enabling better risk assessment and prioritisation of vulnerable areas for protective measures. Moreover, understanding shoreline dynamics guides sustainable development practices, ensuring that construction projects are planned in less vulnerable areas and buffers like mangroves are protected or restored. Engaging local communities in shoreline management is essential, as raising awareness of the risks and involving residents in conservation efforts fosters a collective approach to protecting the coastline. The data and insights from this study provide a solid foundation for formulating policies aimed at mitigating coastal erosion and managing shoreline changes effectively.

## RECOMMEDATION

While this research has provided an up-to-date comprehensive understanding of shoreline changes in Ilaje LGA, continuous monitoring and further research are essential. Future work could focus on employing high-resolution satellite imagery and more frequent data collection to improve the accuracy of change detection, tracking of rehabilitation efforts as adaptive management responds to the inevitability of continued change, and zoning restrictions on further coastal development. Ultimately, conservation solutions must balance environmental protection, economic needs and social welfare to sustain Ilaje LGA's vital ecosystems.

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The Author declared that there is no potential conflict of interest

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