Received: 10.03.2026| **Accepted:** 27.03.2026 | **Published:** 03.04.2026 Citations: Akan, A.T & Eighemhenrio, D. E. (2026) . Geospatial Investigation Of Shoreline And Land Cover Changes In Ilaje Lga Coastal Stretch, Nigeria (1987–2024) Vol.1.1.2026 pp.1-12 **http://globreshub.org/index.php/gaijm**
https://doi.org/10.65186/gaijm.v1.i1

GEOSPATIAL INVESTIGATION OF SHORELINE AND LAND COVER CHANGES IN ILAJE LGA COASTAL STRETCH, NIGERIA (1987–2024)

[1]*Akan A. Tom & [2]David E. Eighemhenrio
*akan.tom@iuokada.edu.ng; david.eighemhenrio@iuokada.edu.ng
[1,2]Department of Geography and Regional Planning, Igbenidion University Okada
+2348069797058; +2348037742705

Abstract

This study examines the spatio-temporal changes of the Ilaje Local Government Area (LGA) coastline and its surrounding land use between 1987 and 2024. The Ilaje coastline, a critical segment of Nigeria's Niger Delta, is subject to intense natural forces and anthropogenic pressures. Using multi-temporal satellite imagery from Landsat and GIS techniques, we extracted shorelines for 1987, 2005, and 2024. We used the Digital Shoreline Analysis System (DSAS) to calculate the Net Shoreline Movement (NSM) and End Point Rate (EPR) to quantify the rate and magnitude of erosion and accretion. Furthermore, a land use/land cover change (LULC) analysis was conducted to assess the impact of urban expansion and economic activities on the coastal environment. Findings of the work reveal a significant net erosion trend in key areas, threatening local communities, infrastructure, and livelihoods. The study also identifies a clear correlation between the aggressive shoreline retreat and the expansion of residential and commercial areas. These results provide vital data for coastal managers, policymakers, and communities to develop informed strategies for hazard zoning, coastal protection, and sustainable development.

Keywords: Shoreline change, erosion, accretion, GIS/Remote sensing, land use/land cover.

INTRODUCTION

Coastal zones serve as transitional regions between terrestrial and marine environments and are key areas for the exchange and concentration of materials and energy. The coastline is a dynamic and essential boundary between land and sea, constantly changing due to natural forces like waves and wind, as well as human activities (Chen et al., 2019a; Wu et al., 2020). Understanding these changes is critical because coastal erosion can cause significant damage and economic loss (Srivastava, 2005). Historically, monitoring changes in Nigerian shoreline was difficult and inaccurate, relying on outdated methods like theodolites and chain measurements. While modern tools like Remote Sensing (RS) and Geographical Information Systems (GIS) are used globally for this purpose, they are rarely applied to Nigerian coastlines.
This lack of monitoring hinders the ability to predict shoreline changes and understand the true

*Corresponding author. Akan, A.T Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

extent of coastal erosion in Nigeria. Recent coastal disasters, such as flooding in Lagos and Akwa Ibom, and others, highlight the urgent need for this information. The Ilaje coastline, a part of the Niger Delta's fragile wetland ecosystem, is crucial for both local livelihoods and the national economy, particularly due to its oil resources and vibrant fishing industry, attracting more residents and development leading to changes in Land Use/Cover (LUCC). However, this dynamic environment is constantly reshaped by natural processes such as waves and tides, and exacerbated by human activities (Aedla, Dwarakish and Reddy, 2015).

This paper addresses a critical gap in the regular monitoring of Nigerian shorelines, which have historically been neglected, leaving communities vulnerable to coastal hazards. Previous studies have highlighted the erratic nature of the shoreline and the increasing intensity of coastal disasters, but a comprehensive, long-term analysis of the Ilaje area is lacking (Adeyinka, 2006). This paper specially aims to evaluate the erosion and accretion rates of the Ilaje LGA coastline between 1986 and 2024 to better understand these processes and their impacts, leveraging on modern GIS and Remote Sensing techniques to fill this gap, providing accurate and quantitative data on shoreline and land-use changes over a 38-year period.

THEORETICAL REVIEW

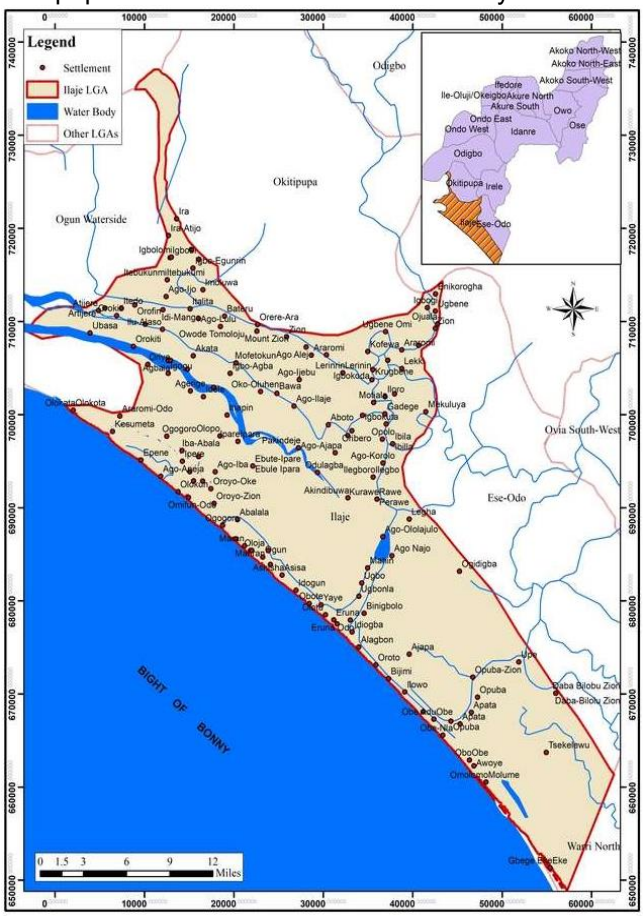
Previous studies highlight the various historical methods for shoreline extraction, from the older, manual on-screen digitizing to more automated approaches using aerial and satellite imagery. Liu, (1998); Galgano and Douglas, (2000) assert that accurate estimation of historical shoreline change rates is complex due to spatio-temporal variability. The DSAS software provides a comprehensive toolkit to analyze these changes using methods like the End Point Rate (EPR), Linear Regression Rate (LRR), and Net Shoreline Movement (NSM). The EPR is a simple method that uses only the oldest and most recent data points, making it susceptible to inaccuracies from erroneous endpoints. In contrast, the LRR is highlighted as a more robust technique that accounts for all data points. Other statistical methods, such as Reweighted Least Squares (RLS) and the Jackknife (JKF), have been developed to further improve accuracy by accounting for outliers and data variability (Rousseeuw and Leroy, 1987; Dolan, Fenster, and Holme, 1991). Eikoushy, (2002); Scott, Moore, Harris, and Reed, (2003) emphasises that the accuracy of these methods depends on high-quality image orthorectification and classification. Various techniques have been developed, including on-screen digitizing (Efe and Tagil, 2001), automated extraction using Tasseled Cap transformation (Scott, Moore, Harris and Reed, 2003) or edge detection (Liu and Jezek, 2004), and more advanced methods using machine-learning algorithms on high-resolution data like Ikonos imagery (Michalis, Nektarios and Yiannis, 2008). A recent study on Saint Martin Island, Bangladesh, used tools like the Normalized Difference Water Index (NDWI) and the Digital Shoreline Analysis System (DSAS) to extract shoreline and measure shoreline changes, revealing that erosion and accretion are happening at different rates across the island. Indicating that roughly 55% of the island's coastline is eroding, with specific high-risk areas identified. It also used a Kalman Filter Model (KFM) for future predictions. Furthermore, Hossen and Sultana, (2023) analysed shoreline change using the automatic shoreline extraction method and determine the rate of change in terms of erosion and accretion rate before and after the construction of coastal structures during the period from 2014 to 2023. The SWAT model was applied to analyse the influence of surface runoff on shoreline changes near Maravanthe Beach for the periods 2004–2014 and 2012–2023. Also, runoff was chosen as one of the parameters for validation of the analysis. It was noticed that the shoreline stretch had experienced significant erosion prior to the construction of shore protection infrastructure. Soon after the deployment of certain shore structures, the shoreline progressed from a high erosion stretch to a low erosion stretch. This study reveals that Maravanthe Beach witnessed greater erosion during the period 2014–2018 than it did from 2019–2023 and also observed a decrease in erosion from 11% to 3% and an increase in the accretion zones from 2 to 9%. Accurate, multi-year mapping of these changes is essential for coastal hazard assessment and management. The combination of remote sensing and GIS is also fundamental for monitoring Land Use and Land Cover Change (LUCC). This technology provides cost-effective, multi-temporal data that is essential for understanding land development patterns and changes in the coastal environment (Weng, 2002). This present study moves beyond outdated, manual surveying techniques to apply modern geospatial and statistical methods in analysing shoreline and land use changes.

MATERIALS AND METHODS

The Study Area

Ilaje Local Government Area (LGA) in Nigeria's Ondo State is a significant coastal region with a rich history and a diverse economy. Established in

1996, the LGA is home to the Ilaje people, a Yoruba sub-group who migrated to the area in the 10th century. It is traditionally divided into four kingdoms: Ugbo, Mahin, Etikan, and Aheri. Ilaje is a part of the Niger Delta's wetland ecosystem, covering approximately 3,000 square kilometres with a coastline of about 82 kilometres along the Bight of Bonny. The terrain is low-lying and riverine, characterized by a complex network of waterways and a sandy shoreline. The region's tropical climate brings high annual rainfall, contributing to frequent flooding. Due to extensive coastal erosion, the native brackish mangroves are being replaced by more salt-tolerant grasses. According to the 2006 census, Ilaje had a population of 289,838. The riverine nature of the area and limited accessibility may have led to an underestimation of the true population in the census. The economy of Ilaje is multifaceted, with fishing as the primary occupation. The area is also rich in natural resources, including crude oil, bitumen, and glass sand. Agriculture is significant, with crops like maize, oil palm, and cassava being cultivated. Key industries include boat building, mat weaving, and lumbering. Igbokoda, the LGA headquarters, is a major trade hub, attracting merchants from across Nigeria and other West African countries. Due to the difficult terrain, transportation is predominantly by waterways, with boats and canoes serving as the main mode of travel between communities. While motorcycles, tricycles, and buses are used on available roads, efforts by the Ondo State Oil Producing Areas Development Commission (OSOPADEC) are underway to improve road connectivity to link the riverine communities.



Ilaje Local government Area (The Study Area)

Data Collection

The political map of Ondo state, map of Ilaje LGA and Satellite imagery for 1987 (Landsat 5), 2005 (Landsat 7), and 2024 (Landsat 8) from the United States Geological Survey (USGS) Earth Explorer, map of Ilaje map were obtained. These images were selected based on their low cloud cover and minimal tidal influence to ensure consistency.

i. Shoreline Extraction and Change Analysis

To extract shorelines from satellite images, shapefiles were used. The high-water line (HWL) was chosen as the reference feature for digitization because it's easily visible as a wet/dry line, especially in high-resolution imagery like Ikonos as shown in Plates 1-3. The HWL is also a

standard reference feature used in NOAA nautical charts (Parker, 2003). The extraction process involved on-screen digitization using ArcMap. A user traced the HWL on each image with a digitizer puck, creating a series of vertices to capture the shoreline. This manual process was necessary because automated methods, such as supervised classification or assigning unique spectral values, failed to consistently track the HWL. This was particularly difficult with Landsat imagery, where the wet/dry area had similar spectral values to the river, making delineation challenging. Geo-Eye imagery provided a clearer distinction between the river and the wet/dry areas, making the process more accurate. The accuracy of the extraction was largely dependent on the imagery resolution, with higher-resolution images providing a clearer and more consistent HWL for digitization.

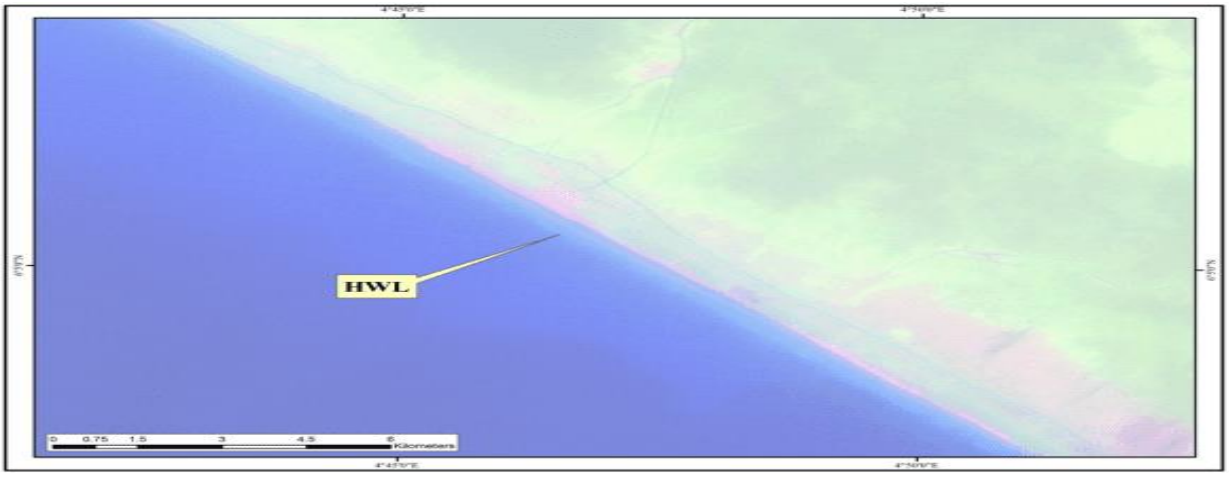


Plate 1: High water line/wet land from 1986 Landsat imagery



Plate 2: High water line/wet land from 2005 Landsat imagery

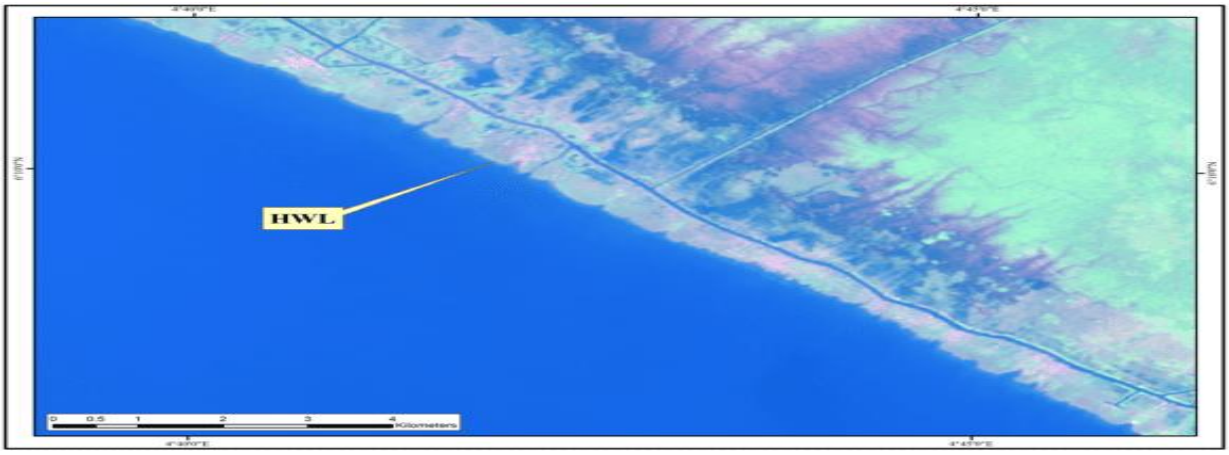


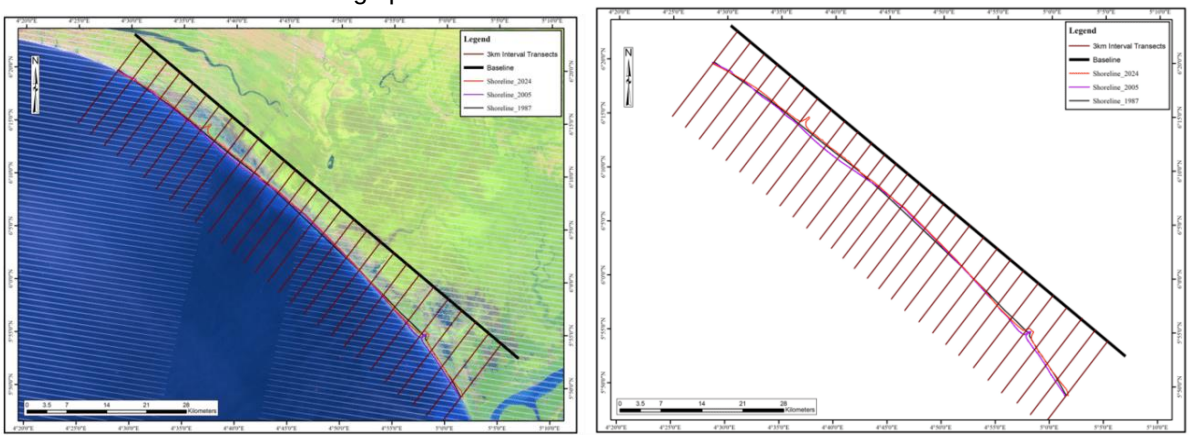
Plate 3: High water line/wet land from 2024 Landsat imagery



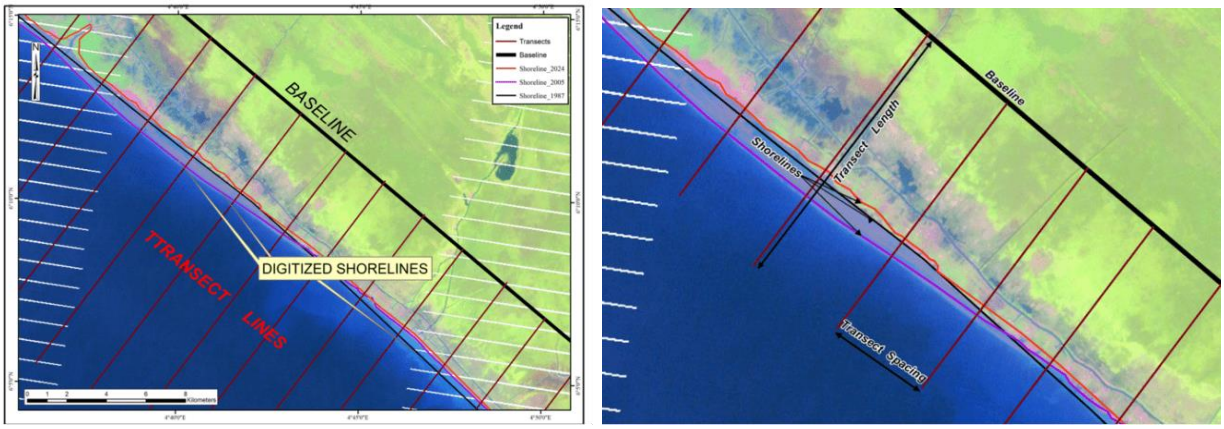
Plate 4: High water line/wet land from Picture taken at the Field

ii. Rate of Shoreline Change Analysis

To calculate the rate of shoreline change, Geographic Information System (GIS) was used to analyse a series of shoreline shapefiles. A single imaginary baseline was created parallel to the extracted shorelines. This was done by buffering the shoreline shapefiles 600 meters landward. The buffer was then edited and smoothed into a single, continuous line. This baseline served as the starting point for all subsequent measurements. The Digital Shoreline Analysis System (DSAS) extension in ArcGIS was then used to measure changes over time. DSAS automatically generated a series of transects (perpendicular lines) from the baseline. These transects were cast at 3-kilometer intervals and were drawn to intersect all the shoreline data (as shown in figure 1-4) given that the measurements needed to determine the rate of change See



Figures 1&2: Transect Lines, Base Lines and Extracted shorelines



Figures 3&4: A section of the Transect lines/Length, Base lines and Extracted shoreline

In the shoreline analysis, the spacing of measurement points called transects, is crucial for accuracy. Closely spaced transects provide a more detailed analysis, while wider spacing may miss important information. The nature of the shoreline, be it smooth or irregular guided the choice of transect spacing. Although DSAS offers four methods, the Endpoint Rate (EPR) method was chosen because it is simple and requires only two shorelines for analysis. The EPR method calculates change by subtracting the earliest shoreline measurement from the latest one. Its main limitation is that it ignores information from any intermediate shorelines, which can cause subtle changes in the shoreline's behaviour to be missed.

iii Image Processing and Analysis

To make features more visible, the raw satellite images were enhanced using Principal Component Analysis (PCA). PCA is a technique that reduces image data redundancy and highlights subtle spectral differences, making it easier to identify features like the shoreline. The study also performed a supervised classification to group pixels with similar characteristics into distinct land use and land cover (LULC) classes: water, vegetation, settlements (built-up areas), and bare land. This involved using specific band combinations (e.g., bands 5-4-3 for the 1987 image) to create a map of different land types. The accuracy of this classification was verified using aerial photographs from the same period. A change detection analysis was then conducted to quantify the spatial and temporal shifts in these LULC categories and correlate them with the observed shoreline movements. This process was performed using Erdas Imagine.

RESULTS AND DISCUSSIONS

i. Shoreline extraction and changes

The study revealed a striking reversal in coastal processes between the two periods studied: between 1987–2005, the shoreline experienced a net gain of land. Twenty of the 29 transects measured showed accretion (land building), resulting in a total net gain of 4,681.97 meters. The highest accretion at a single point was 720.43 meters, indicating that the shoreline was largely stable or expanding during these years. 2005–2024 witness Severe Erosion This period saw a dramatic reversal, with the coastline experiencing severe erosion. A total of 27 transects showed erosion (land loss), leading to a staggering net loss of 9,759.28 meters. The most intense erosion at a single point was 996.32 meters. This finding suggests a significant change in the factors influencing the shoreline, leading to rapid and widespread land loss. Overall Trend: Net Accretion Despite the intense erosion in the later period, the overall trend from 1987 to 2024 was a net accretion of 5,422.05 meters. This indicates that the land gained in the first period was greater than the land lost in the second, but the rate of change has become much more destructive in recent years. The Endpoint Rate (EPR) method was used to calculate these changes, as it is a simple and effective method for comparing two shorelines.

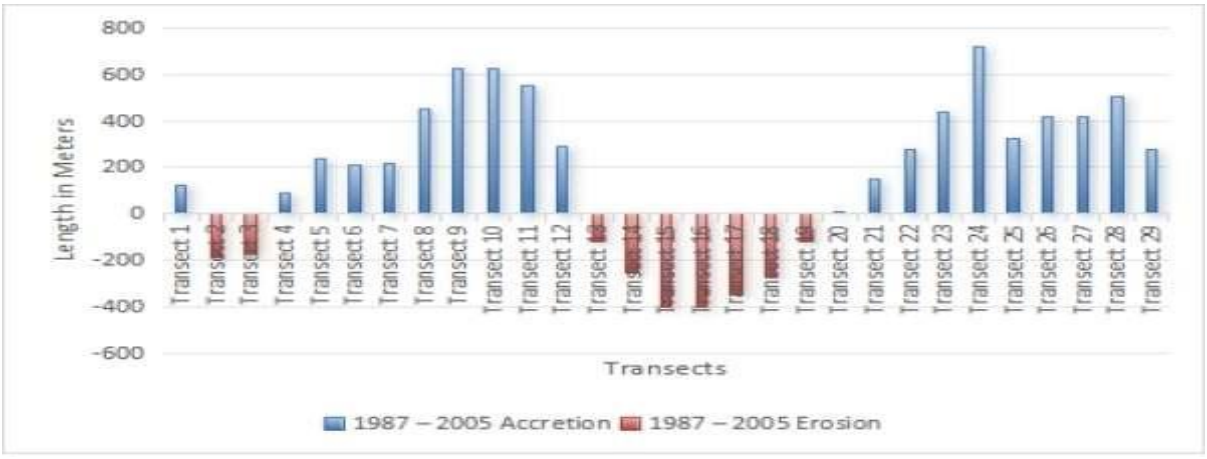


Figure 5: Graph showing Accretion and Erosion between 1987 - 2005

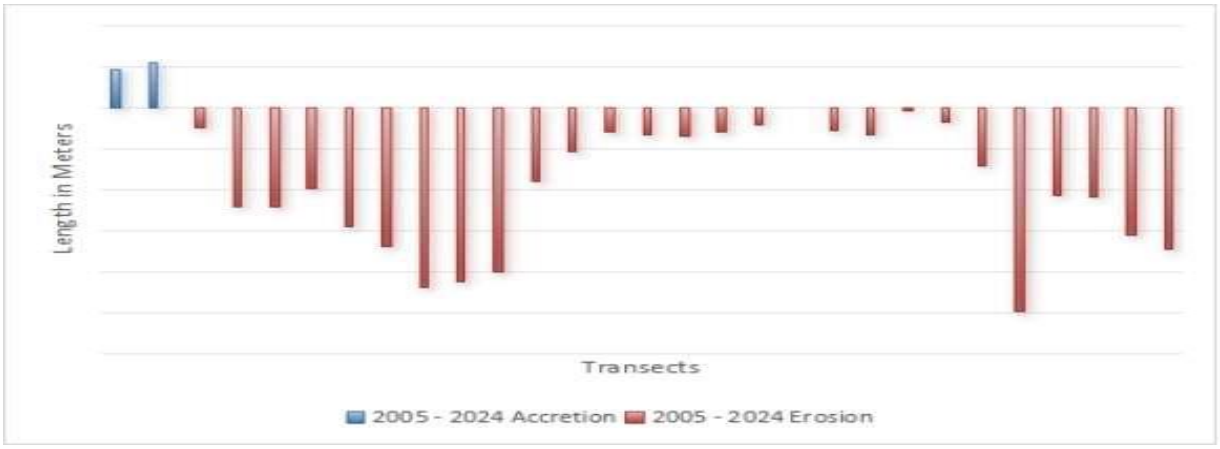


Figure 6: Graph showing Accretion and Erosion between 2005 - 2024

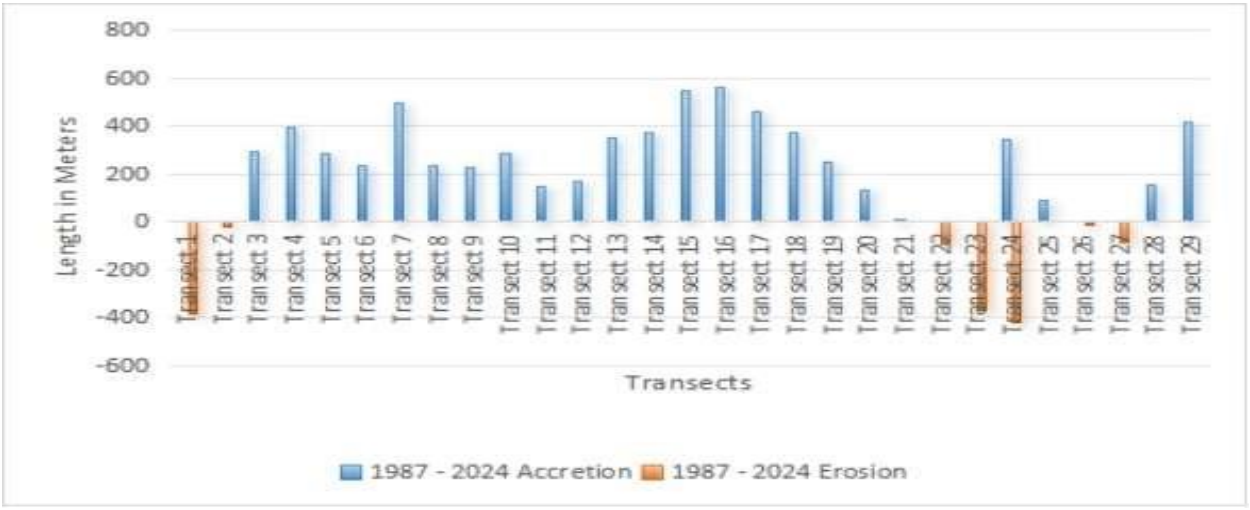


Figure 7: Graph showing Accretion and Erosion between 1987 - 2024

Table 1: Shoreline Erosion, Accretion and Net change in Metres

Periods	Accretion (m)	Erosion (m)	Net Change (m)
1987 – 2005	6963.41	-2281.44	4,681.97
2005 - 2024	407.99	-10167.27	-9,759.28
1987 - 2024	6806.48	-1384.43	5,422.05

Source: Researcher's compilation, 2025

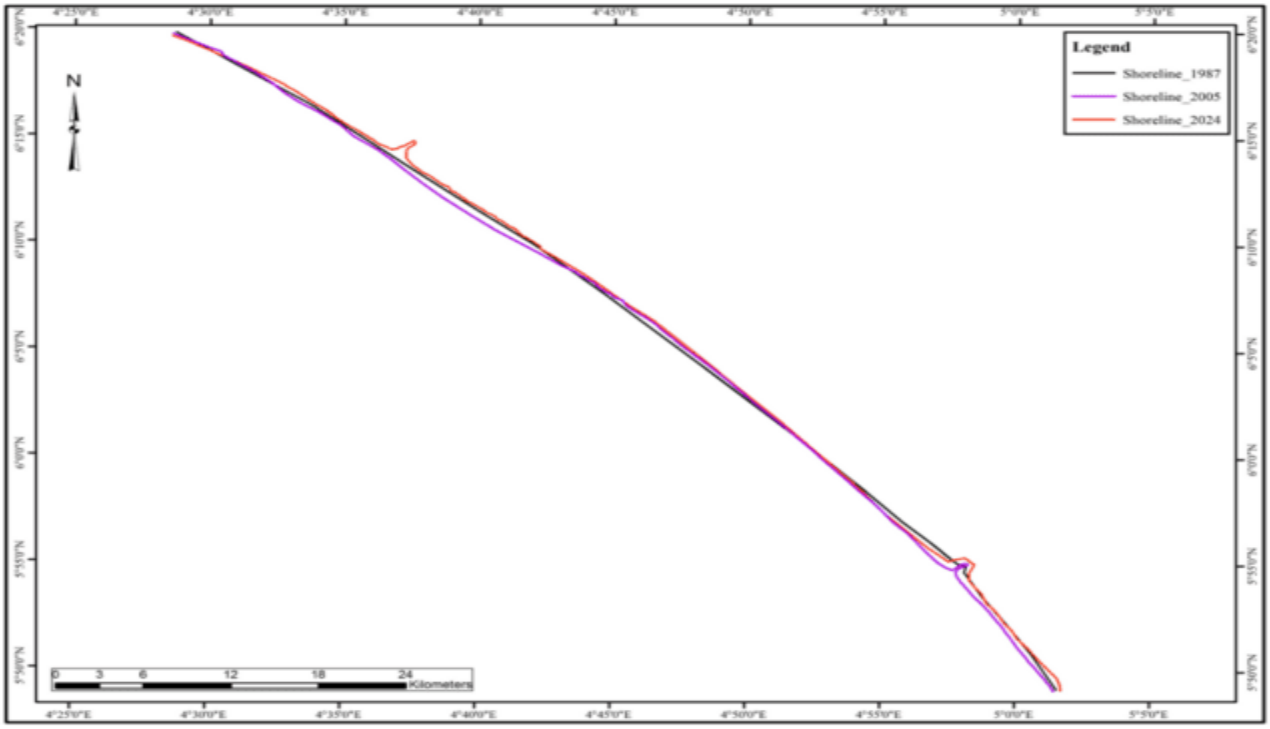


Figure 8: 1987, 2005 and 2024 Shorelines of Ilaje LGA, Ondo State

The result the shoreline change reveals a significant trend of erosion along the Ilaje coastline. The EPR analysis indicates that certain sections of the shoreline have a net retreat rate of over 5 meters per year, a rate that far exceeds natural processes and suggests strong anthropogenic influence.



Plate 5: Shoreline erosion encroachment in Ayetoro community



Plate 6: Shoreline erosion encroachment/destruction



Plate 7: Coastal Erosion in Araromi Sea side



Plate 8: Settlement destruction in the study area due to coastal accretion



Plate 9: Coastal Erosion in the study area

The land use land cover change (LULCC) analysis which revealed major changes in the forest and urban/bareland increasing at 1.18% and 1.04% per annum respectively, and marginal changes in the disturbed forest and cultivated land signified severe conversion/alteration of the natural coastal ecosystem leading loss and destruction of funa and floral in the study area. As shown on Plates 10 - 13.



Plate 10: Destruction of coastal environment due shoreline movements



Plate 11: Destruction of coastal environment due shoreline movements



Plate 12: Destruction of coastal environment due shoreline movements



Plate 13: Wastes deposited at the shoreline due to coastline movements

The implication of this finding is that area's affected by accretion will hinder free movement of passer-by,

support capsizing of fishing boats and the soften nature of the shifting sand bars will pose a threat when jetties are sited close to them. Furthermore, the areas affected by erosion will experience flooding and disaster, Therefore, infrastructure will be threatened when sited near eroding region of the shoreline. Also, the coastal areas of Ilaje have increased in population over the years around the shoreline and this development has increased the vulnerability of the population to Erosion.

ii. Land use land cover Analysis

The land use land cover change detection analysis shown in Table 2 and Figures 9 & 10 revealed that in 1987, forest occupied 46942.74 hectares (31.9%), disturbed forest 43325.91 hectares (29.45%), cultivated land 38218.68 hectares (12.68%) and urban/bareland 18664.83 hectares (12.68%). Also, in 2024 forest covered 23584.65 hectares representing 16.03% of the entire study area, disturbed forest 49444.21 hectares (33.6%), while cultivated land and urban/bare land covered 34906 hectares (23.72%) and 39217.3 hectares (26.65%) respectively. The analysis revealed that for the 37year period under investigation (1987 - 2024), forest cover decreased by -23,358.09h representing 43.79%, disturbed forest changes positively by gaining 6,118.3 hectares (11.47%). Moreover, cultivated land was lost by -3,312.68 hectares (6.21%) while the urban/bare land gain 20,552.47 hectares representing 38.53%.

Table 2: Land Use / Land Cover Status for 1987 and 2024 Imagery

LULC Classes	1987 Area Coverage in Hectares	%	2024 Area Coverage in Hectares	%	Change between 1987 to 2024	Percentage Change (%)
Forest	46942.74	31.9	23584.65	16.03	-23,358.09	43.79
Disturbed Forest	43325.91	29.45	49444.21	33.6	6,118.3	11.47
Cultivated Land	38218.68	25.97	34906	23.72	-3,312.68	6.21
Urban Land	18664.83	12.68	39217.3	26.65	20,552.47	38.53
Total	**147152.16**	**100**	**147152.16**	**100**	**53341.54**	**100**

Source: Researcher's compilation, 2025

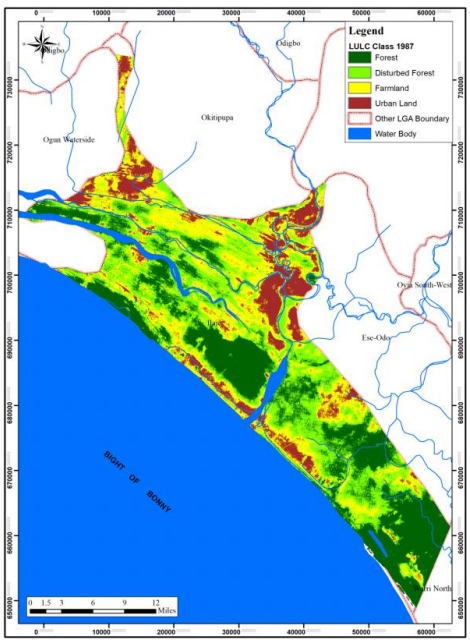


Figure 9: Land Use Land Cover 1987

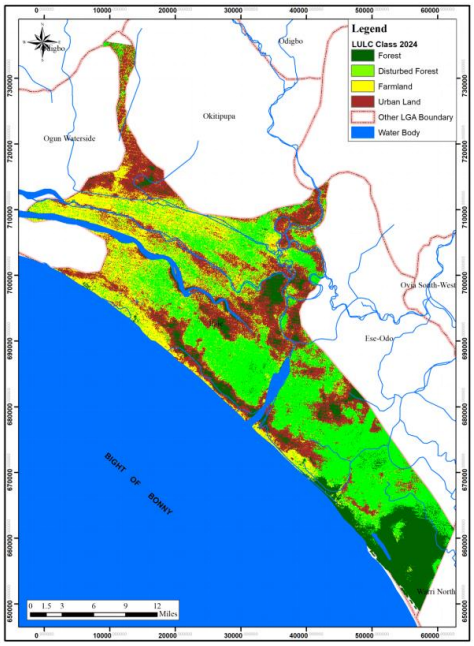


Figure 10: Land Use Land Cover 2024

The LULC change detection shown in Table 2 and Figures 8 & 9 confirms a substantial increase in built-up areas at the expense of vegetation and agricultural land, particularly between 2005 and 2024. This rapid expansion of settlements and infrastructure is putting increasing pressure on the

fragile coastal ecosystem, exacerbating erosion and increasing the vulnerability of the local population to coastal hazards. The study highlights the dynamic nature of the Ilaje coastline and provide critical data for predicting future changes.

CONCLUSION

This study provides compelling evidence of the rapid and detrimental changes occurring along the Ilaje coastline. The findings underscore the urgent need for a robust coastal management plan that integrates urban development with environmental protection. Without a comprehensive understanding of these trends, the economic and social viability of Ilaje LGA will be seriously threatened. The data presented here can serve as a foundational resource for policymakers to implement informed strategies, such as development setbacks and shoreline protection measures, to safeguard this critical coastal community.

REFERENCES

Aedla, R., Dwarakish, G. S., & Reddy, D. R. (2015). Coastal vulnerability assessment of the Ennore coast, Tamil Nadu, India, using GIS and remote sensing. *International Journal of Geomatics and Geosciences*, 6(1), 1-15.

Adeyinka, A. (2006). Coastal erosion in Nigeria: A case study of the Lagos coastline. *Journal of Coastal Research*, 22(3), 643-652.

Ayo-Odifiri, S. O., et al. (2021). Assessment of urban sprawl in Benin metropolis, Nigeria. *International Journal of Research and Innovation in Applied Science*, 6(7), 110-117.



Funding: This research is not funded.

Acknowledgments

Not applicable.

Chen, Y., et al. (2019a). A unified georeferencing model for coastal zone mapping. *ISPRS Journal of Photogrammetry and Remote Sensing*, 148, 10-21.

de Bruin, S., & Holleman, C. (2023). *Urbanization is transforming agrifood systems across the rural–urban continuum creating challenges and opportunities to access affordable healthy diet*. Food and Agriculture Organization of the United Nations (FAO).

Galgano, F. A., & Gouglas, B. C. (2000). A method for calculating shoreline erosion rates. *Journal of Coastal Research*, 16(4), 1146-1153.

Hou, J., et al. (2020). Assessment of coastal vulnerability to sea-level rise in China's Pearl River Delta. *Science of the Total Environment*, 709, 135899.

Liu, X., & Jezek, K. C. (2004). Automatic coastline extraction from satellite imagery using edge detection. *International Journal of Remote Sensing*, 25(10), 1843-1856.

Liu, X. (1998). Developing GIS applications in analysis of responses to Lake Erie Shoreline Changes in Ohio USA. *GIS for the 21st Century*, 12(4), 587-598.

Odeleye, J. O. (2023). Reflections on the Impact of Urban Sprawl on the Architecture of the City: Lessons from Benin City, Nigeria. *Forum Geografi*, 37(1), 1-13.

Saint Martin, A., et al. (2021). Spatiotemporal analysis of shoreline changes and prediction of future changes on Saint Martin Island, Bangladesh. *Geoscience and Remote Sensing Letters*, 18(11), 1957-1961.

Uko, A., Binns, J., & Nel, A. (2022). 'I lost my job suddenly, but I was prepared': the significance of urban and peri-urban agriculture in Benin City, Nigeria. *Cities & Health*, 1-10.

Conflicts of Interest

The authors declare no conflict of interest.

Authenticity

This manuscript is an original work