

# Spatial analysis of wetland dynamics and Sea level rise effects on Nigerian coastal area: Case study of Ilaje local government area, Ondo state

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## Abstract

Coastal wetlands are among the most productive ecosystems globally, providing essential ecological, economic, and social services. The effects of coastline changes mostly becoming noticeable on the coastal wetlands. The study of the hydrodynamics of the coastal wetlands can serve as pointer to the evaluation of the sea level rise. The study assessed the dynamics of wetland resources in Ilaje Local Government Area (LGA), Ondo State, Nigeria, over a 30-year period (1995 - 2025) to extract information on the changes taking place in the shoreline and the effects on wetland resources. The study utilized geospatial analyses on satellite remote sensing data.

Findings reveal that marshy land and marine vegetation, which constituted the dominant wetland class in 1995, experienced significant reduction over the study period. A net loss of approximately 20, 153ha of wetland was recorded between 1995 & 2025, representing an annual decline of -671.78ha. Normalized Difference Vegetation Index (NDVI) results indicated shifts in vegetation health, reflecting the dual influence of settlement expansion, shoreline erosion, and recurrent flooding. Water bodies expanded considerably within the period under consideration indicating large volume of water incursion into the previous vegetation area. The landuse projection to year 2035 shows that water body will significantly increase to 11,281ha , the highest change projected. The study confirm sea level rise and coastal subsidence in Ilaje Local government area and the urgent need to reduce incursion of sea water into the marine ecosystem.

The study recommends community-based coastal landscape management in order to reduce the negative effects of sea level rise and wetland loses in the project area.

Keywords: Wetlands, NDVI, GIS, Ilaje, landuse change, satellite images

## 1. Introduction

Coastal wetlands are ecosystems around the shoreline that remain saturated with water either permanently or seasonally, creating unique ecological condi-

tions that support hydrophytic vegetation and hydric soil development (CTCN, 2020; Ogunlade, 2024). They perform essential ecological and socio-economic functions, acting as natural buffers against flooding, supporting biodiversity, regulating water quality, and contributing to climate change mitigation through carbon sequestration (Ramsar Convention Secretariat, 2023). Wetlands also supply critical resources such as fisheries, fuelwood, medicinal plants, and fertile agricultural land, thereby sustaining local livelihoods (Oscar *et al.*, 2022; Olajide & Popoola, 2021). In Nigeria, wetlands are indispensable to coastal communities like those in Ilaje Local Government Area (LGA) of Ondo State, where fishing, farming, and other livelihood activities depend directly on wetland productivity (Ogunlade, 2023).

Ilaje LGA, located along Nigeria's southwestern coastline, is endowed with extensive wetland systems that support biodiversity and serve as the foundation for aquaculture, logging, and crop cultivation (James *et al.*, 2024; Ogunlade, 2023). However, the region's wetlands are increasingly under threat from a combination of climatic and anthropogenic pressures. Shoreline erosion, pollution, and rising sea levels exacerbated by climate change have altered hydrological cycles and increased salinity intrusion, degrading wetland habitats and diminishing their ecological services (Aderele, 2023; Oscar *et al.*, 2022). These environmental disruptions reduce wetland productivity, undermine fisheries and agriculture, and heighten community vulnerability to food insecurity and displacement (Komolafe *et al.*, 2024). Such conditions necessitate an integrated assessment of wetland changes to support adaptation and sustainable management strategies.

Beyond climate induced impacts, unsustainable land use practices have accelerated wetland degradation in Ilaje LGA. Activities such as mangrove deforestation, sand mining, and unplanned urban expansion disrupt hydrological balance, cause soil erosion, and degrade water

quality (Olajide & Popoola, 2021; Ogunlade, 2023). The combined effects of these factors threaten biodiversity, reduce natural flood control capacity, and release previously sequestered carbon, further intensifying global warming (James *et al.*, 2024; Komolafe *et al.*, 2024). According to Uluocha and Okeke (2004), similar threats across Nigeria including population pressure, coastal reclamation, oil pollution, and over-exploitation underscore the urgent need for wetland conservation policies supported by spatial data and evidence-based decision making.

Geospatial analysis offers an effective and data driven approach for assessing wetland dynamics. The integration of Geographic Information System (GIS) and remote sensing techniques enables researchers to detect spatial and temporal patterns in wetland resource distribution, quantify land cover changes, and model their ecological implications (Emmanuel *et al.*, 2023; Aderele, 2023). Previous studies (Rebelo *et al.*, 2009; Ghobadi *et al.*, 2012; Wu, 2017) have demonstrated the utility of GIS in wetland inventory, monitoring, and change detection, while integrating climate and land use models enhance predictive understanding of ecosystem transformation. Despite these advances, limited empirical data exist on the long-term spatial dynamics of wetlands in Ilaje LGA, creating a gap that this study seeks to fill.

Wetlands in Ilaje LGA play multiple roles in supporting ecological balance and human welfare. They provide timber and non-timber forest products (NTFPs), including fuelwood, medicinal plants, and materials essential for local livelihoods (Olukemi, 2023). Their capacity for carbon sequestration contributes to climate regulation, while their hydrological functions mitigate floods and stabilize microclimates (Aderele, 2023; Emmanuel *et al.*, 2023). Yet, the degradation of these ecosystems undermines their ecological integrity and economic value, making conservation a matter of both environmental and developmental urgency. Scholars such as Xu *et al.* (2019) and Bhowmik (2022) emphasize that wetlands are among the most productive ecosystems globally, accounting for nearly half of the total value of ecosystem services, yet nearly 87% of global wetlands have been lost since 1700 (Adhya & Banerjee, 2022).

In this context, assessing the spatial and temporal dynamics of wetland resources in Ilaje LGA is

both timely and essential. Through geospatial analysis, this study examines wetland distribution and transformation over a 30-year period (1995–2025), identifies key drivers of change, and evaluates their ecological and socio-economic implications. The findings provide empirical evidence to guide sustainable land use policies, conservation planning, and climate adaptation strategies in coastal Nigeria.

The main aim of the study was to assess the spatial and temporal dynamics of wetland resources around the coastal area in Ilaje Local Government Area, Ondo State, and identify if any, the nature of sea level rise in the coastal area.

The specific objectives are to:

- conduct a 30-year change analysis (1995–2025) of wetland resources to evaluate spatial and temporal variations;
- examine the key factors driving wetland changes, particularly those linked to climate and human activities; and
- evaluate the implications of sea level rise on the coastal wetland resources

## 2. The Study Area

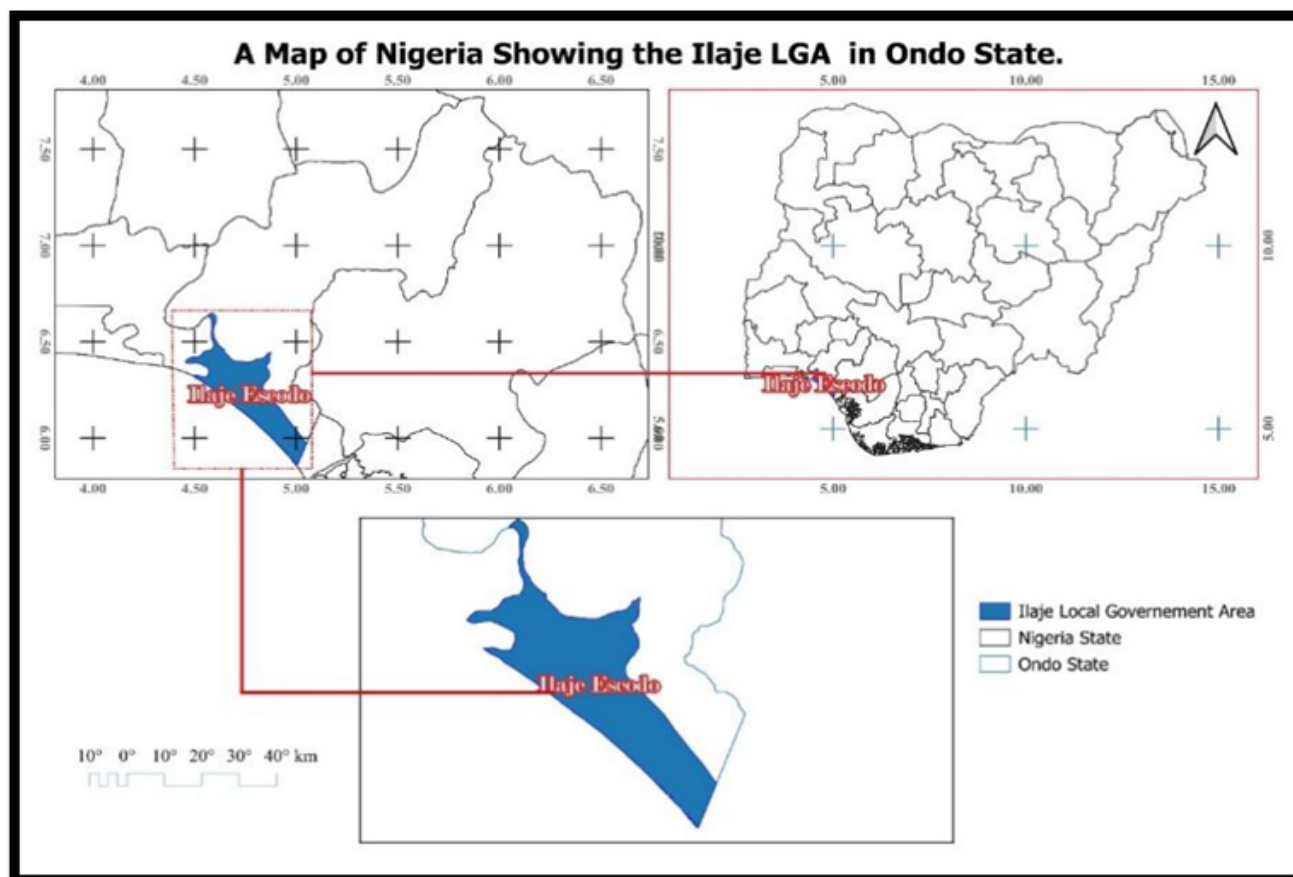
This area of study falls within the wetland of the Niger-Delta of Nigeria (see figure 1), covering an area of 3,000 sq.km and a population of 289,838 (2006 population census) (Olagunju, 2022) and with a projected population of approximately 448, 685 in 2025, based on a 2.3% annual growth rate from the 2006 population census. The Ilaje LGA shares boundaries with Okitipupa LGA in the North; the Atlantic Ocean in the south; Ijebu Waterside Local Government Area (Ogun State) in the west, and Delta state in the east (Ayadi & Lawson, 2021). The study area lies within the latitudes 5° 45' and 6° 30' north of the equator and longitudes 4° 30' and 5° 07' east of Greenwich Meridian (Ogunrayi, 2024). It has a total land area of 1,318 km<sup>2</sup>. Ilaje has towards the western reaches, the Aheri and Etikan share a border with the Ijebus, the Ikales to the northbound, the Mahins, the Itsekiri people whom the Ilajes consider their cousins, share the eastern border with the Ugbo, the Yoruba-speaking Apoi and Arogbo Ijaws are located to the northeast in Ese-Odo LGA, and the Atlantic Ocean is on the southern boundary (Ogunlade, 2023). The minerals found in this area include petroleum, glass sand, salt, tar sand/bitumen, quartz, and clay. Through-

out the year, temperature typically ranges from 22°C to 32°C, rarely dipping below 18°C or exceeding 34°C. The region experiences a rainy season that lasts for ten

months, with an average annual rainfall of 2,210 mm.

This research utilizes secondary data sourced from the United States Geological Survey (USGS) Earth Explor-

Fig. 1 Map of the Study area



Source: Authors' 2025

Table 1: Characteristics of input data

S/N	DATA	SOURCE	YEAR	RESOLUTION
1.	Landsat 7 (LE07), Enhanced Thematic Mapper (ETM+)	USGS	1995	30m (Multispectral), 15m (Panchromatic)
2.	Landsat 8 (LC08), Operational Land Imager (OLI)	USGS	2015	30m (Multispectral), 15m (Panchromatic), 100m (Thermal Bands)
3.	Landsat 9 (LC09), Operational Land Imager (OLI)	USGS	2025	30m (Multispectral), 15m (Panchromatic), 100m (Thermal Bands)

Source: Authors' 2025

er platform to obtain satellite imagery (raster data) to analyze land cover changes. (see Table 1).

### 3. Land Use Dynamics in the Study Area (1995-2025)

For the purpose of this research, wetlands are denoted by marine vegetation and marshy using the machine learning feature on ArcMap (Maximum Likelihood Classification), training samples were selected with the google earth pro as a reference for the study site for a better resolution that aids better understanding of the land feature to select the appropriate pixels denoting the classification schemes as also identified from the supervised classification outputs. These categories represent both vegetated and non-vegetated wetland features within the Ilaje LGA

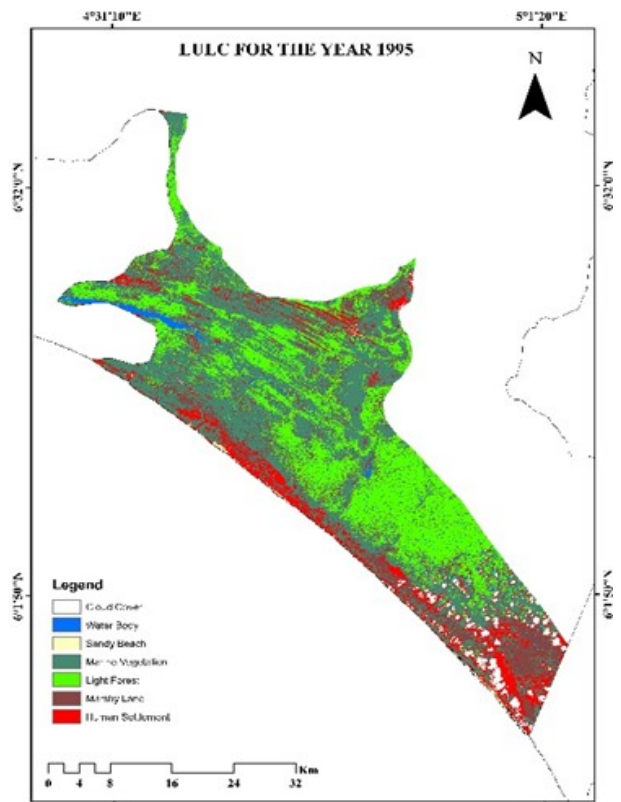


Fig.2: LULC map for the year 1995

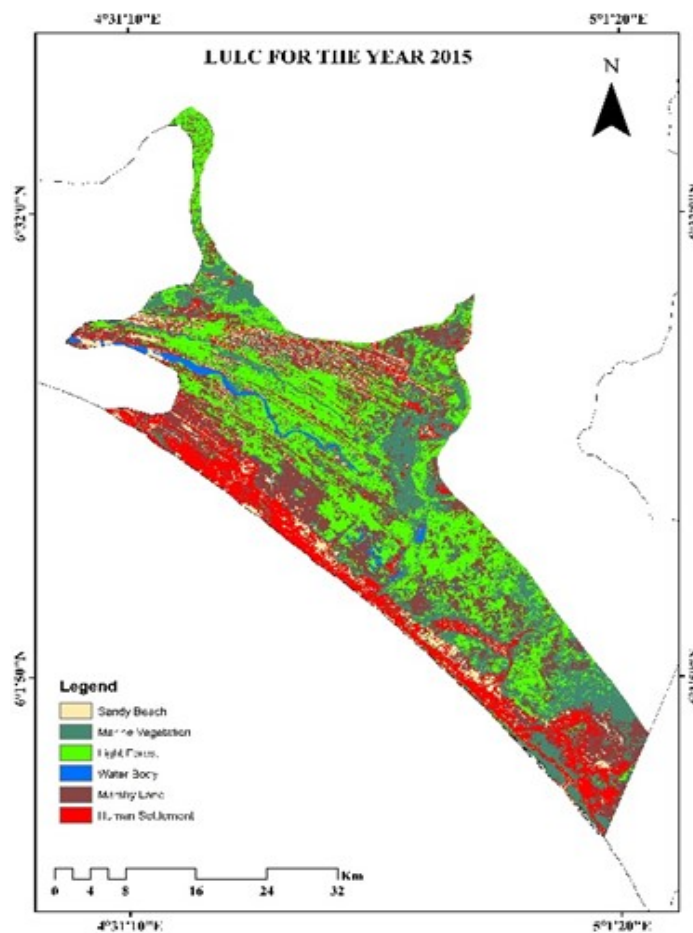


Fig.3: LULC Map for 2015  
CIPES September 2025

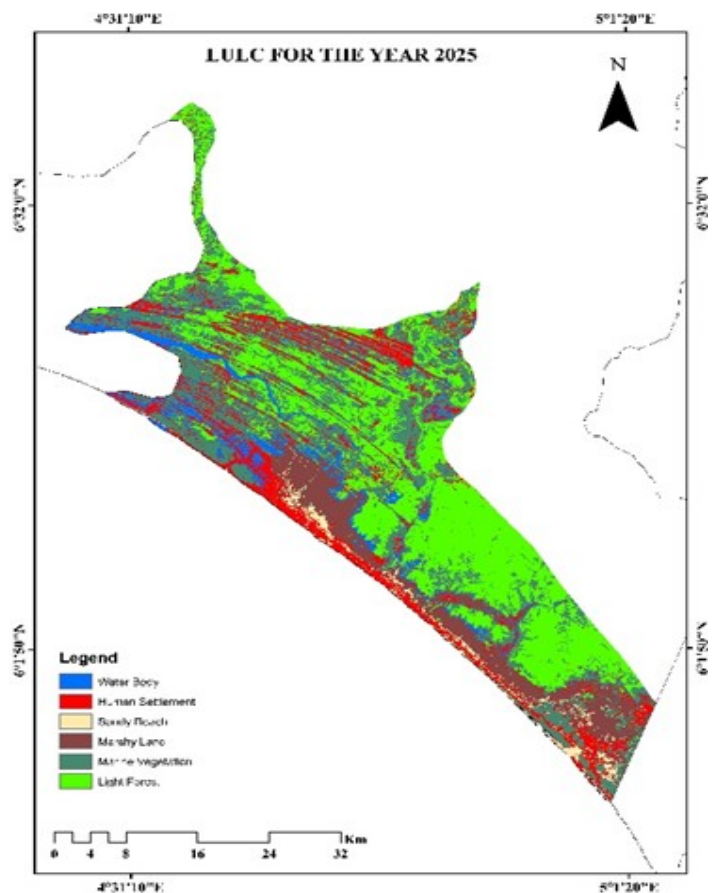
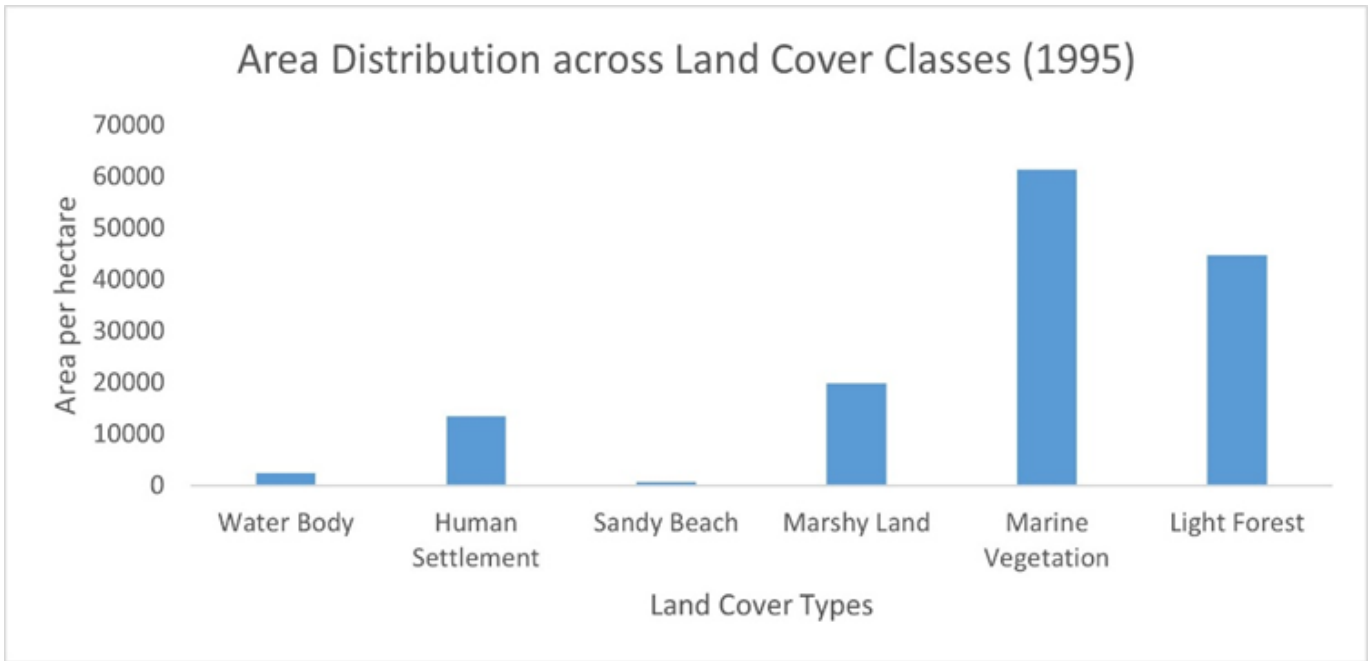
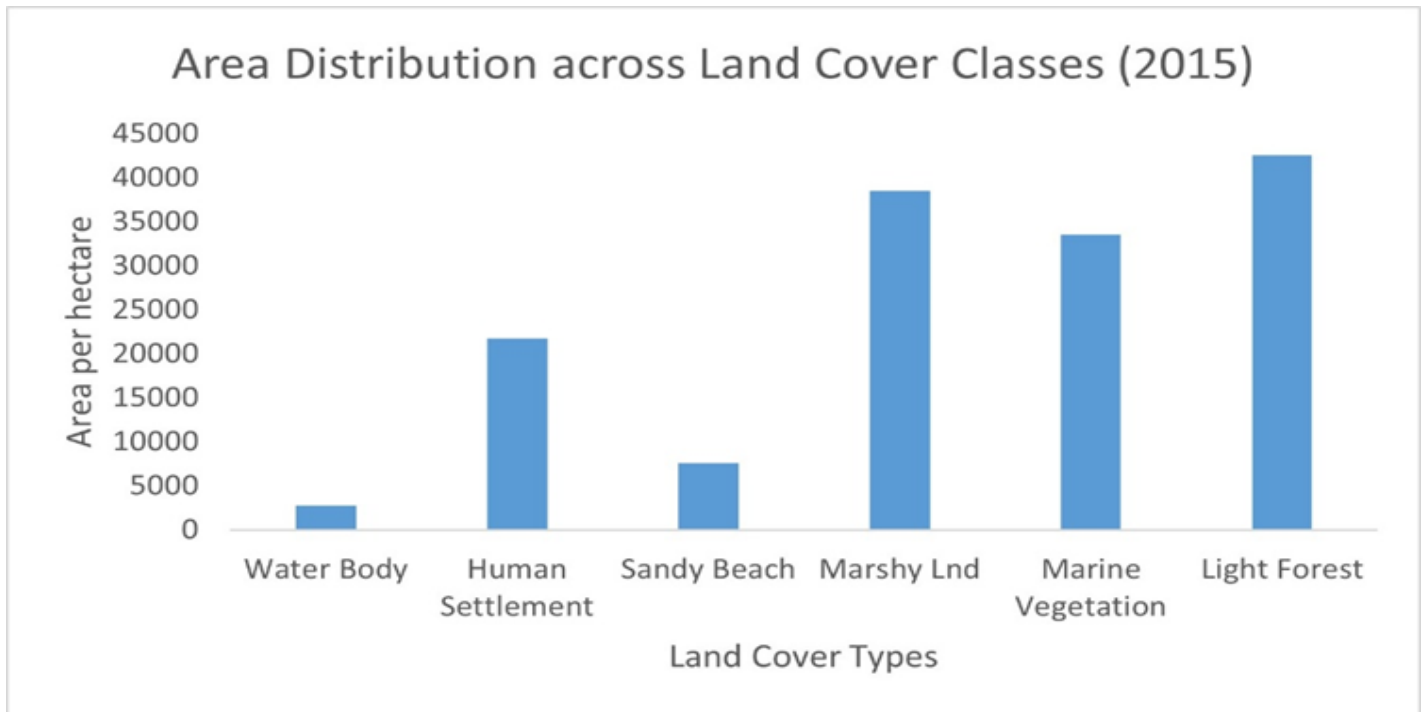


Fig.4: LULC for the year 2025  
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**Fig.5. Areal distribution of Land cover classes 1995**

Source: Authors' 2025



**Fig.6. Areal distribution of Land cover classes 2015**

*Table 2: LULC Class Distribution*

S/N	Water Body (ha)	Human Settlement (ha)	Sandy Beach (ha)	Marshy Land (ha)	Marine Vegetation (ha)	Light Forest (ha)
1995	<b>2517.81</b>	13442.08	660.85	19899.91	61357.88	44803.44
2015	<b>2743.93</b>	21757.21	7585.51	38538.13	33522.05	42511.17
2025	<b>9090.70</b>	19887.00	3134.81	16108.60	44995.90	53447.85

Source: Authors, 2025

In 1995, marshy land in Ilaje LGA occupied approximately **19,899.91 hectares**, largely distributed along the coastal fringes, river mouths, and estuarine zones in the southern, western, and eastern parts of the LGA. Marine vegetation (dominated by *Rhizophora mangle*) covered a significantly larger area of **61,357.88 hectares**, forming dense stands along tidal creeks, sheltered bays, and lagoon edges.

By **2015**, marshy land expanded to **38,538.13 hectares**, almost doubling its 1995 coverage. This increase may be linked to prolonged inundation from coastal flooding and reduced conversion pressure in some zones. In contrast, marine vegetation declined sharply to **33,522.05 hectares**, likely due to overharvesting, coastal reclamation, and infrastructure development along water corridors.

In **2025**, marshy land declined drastically to **16,108.60 hectares**, representing a net loss of **3,791.30 hectares** from its **1995** extent and a sharp drop from its 2015 peak. Marine vegetation, however, showed signs of recovery, increasing to **44,995.90 hectares**, and a gain of **11,473.85 hectares** from **2015**. This resurgence could be attributed to natural regeneration of mangrove stands and possible community-led restoration activities.

When combined, the total area occupied by wetland (marshy land + marine vegetation) declined from **81,257.78 hectares** in **1995** to **61,104.50 hectares** in **2025**, a net loss of **20,153.28 hectares** over 30 years, equivalent to an annual loss rate of **-671.78 hectares/year**.

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#### 4.1. Normalized Difference Vegetation Index (NDVI) Analysis

The NDVI analysis was carried out for the years 1995, 2015, and 2025 to evaluate the spatial and temporal variations in vegetation density and health within the Ilaje wetlands. The NDVI values were also reclassified using the established six classification scheme; waterbody, human settlement, sandy beach, marshy land, marine vegetation, and light forest

In **1995**, NDVI values ranged between -0.45 to 0.44 across the six categories. This spatial distribution reveals that the southern coastal belt was dominated by human settlement and waterbody (negative to low NDVI values), while large areas in the central and northern parts exhibited light forest and marine vegetation cover (positive NDVI values). This suggests that much of the wetland vegetation was still relatively intact, though increasing human settlement and shoreline modification were already evident (Ogunrayi *et al.*, 2024).

By **2015**, NDVI values improved slightly, ranging from -0.07 to 0.46. The figures indicate a gradual expansion of human settlement and waterbody along the coast. These values can also be attributed to coastal flooding which is the major driver of the landscape modification during this period. The flooding process increased the extent of marshy lands, particularly in the southern and estuarine zones, which explains the marked rise in this as shown in the area statistics (*see*

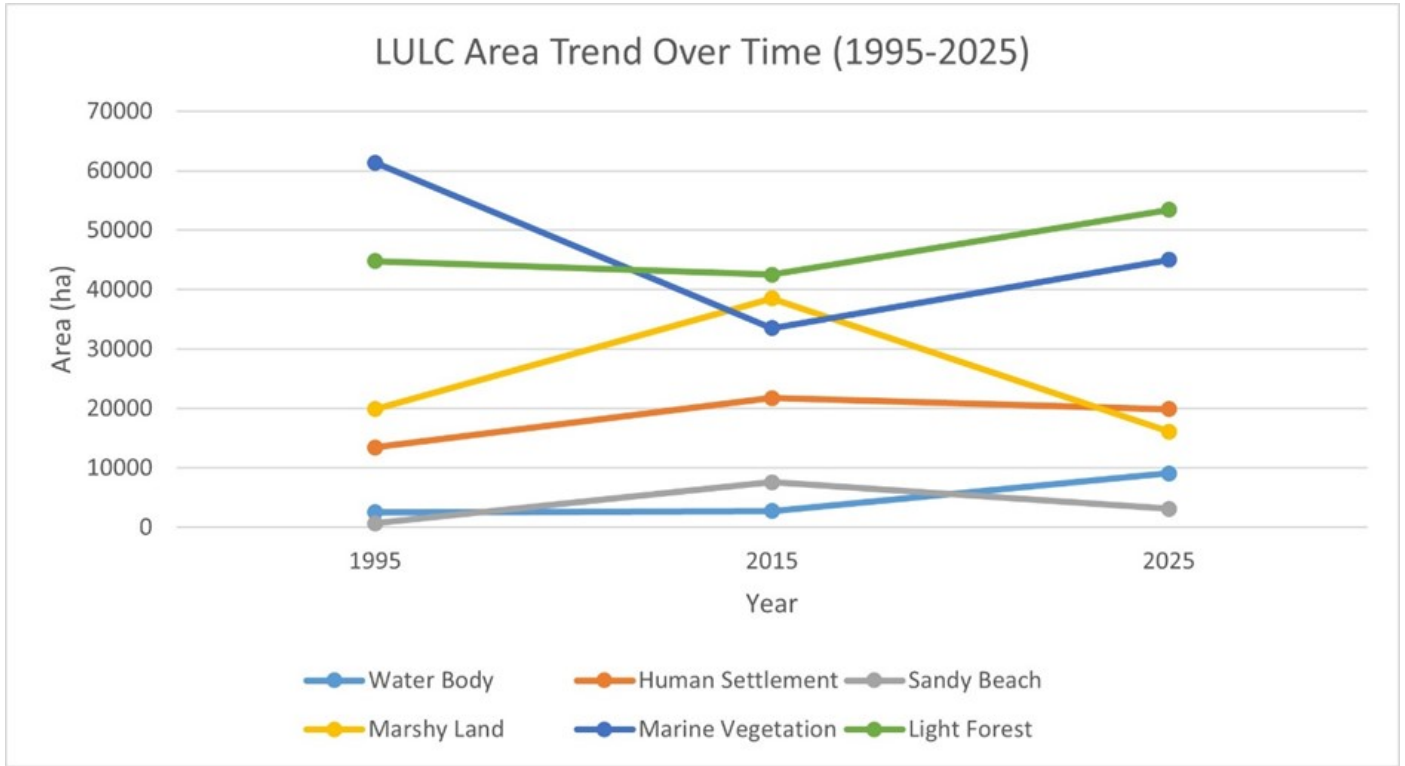
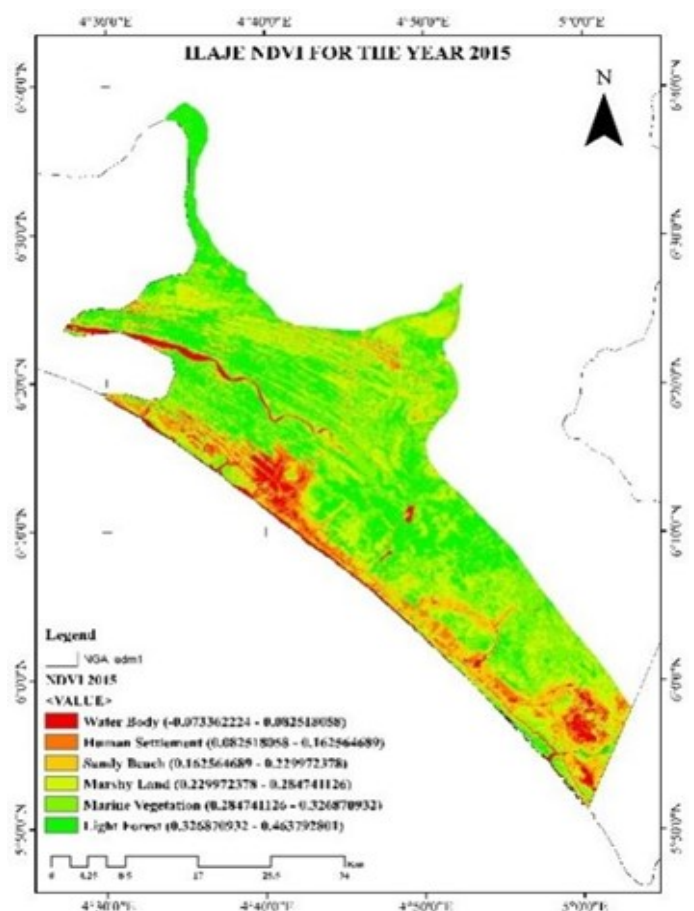
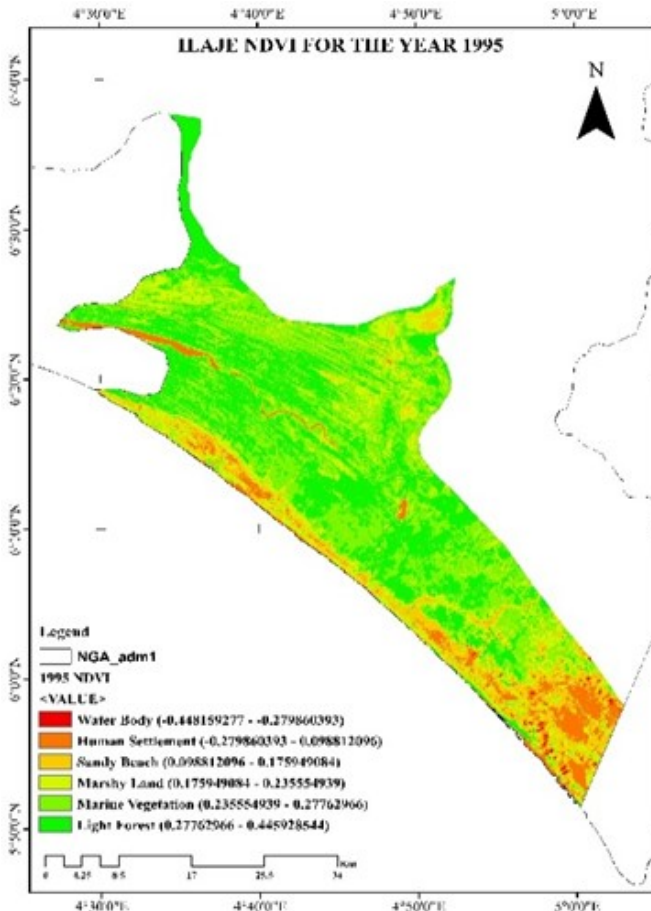


Fig.8: NDVI for 1995

Fig.9: NDVI for 2015



Source: Authors' 2025

figure 3). Despite these pressures, light forest and inland vegetation patches persisted in the central and northern sections of the study area, maintaining relatively high NDVI values. This improvement in maximum NDVI compared to 1995 can be partly attributed to a regrowth in less-disturbed areas, but the overall pattern underscores how both human activity and climate-related actions reshaped the wetland composition during this period.

NDVI for year 2025 using available data ranges between -0.09 and 0.49, shows a further increase in vegetation greenness in some patches, but also a more extensive spread of low NDVI zones (human settlement and waterbody) along the coast. This reflects ongoing urban expansion and land use pressure on wetland ecosystems. The persistence of high NDVI values in the inland wetlands reveals that mangrove and marshland ecosystems are still func-

tioning, but under increasing stress.

### 5 Discussion and recommendations

The 30- year (1995-2025) change map (fig. 11) along with the annual rate of change results (see table 2) provides important insights into the dynamics of wetland resources in Ilaje Local Government Area.

The change detection map (see. Fig 12) reveals distinct patterns of transformation across landscapes. Significant conversions are observed along the southern coastal belt, where marine vegetation and marshy land have been lost and replaced by human settlements, sandy beaches, and water bodies. These transitions reflects both natural and anthropogenic drivers which includes; coastal flooding, shoreline erosion, and the expansion of settlements

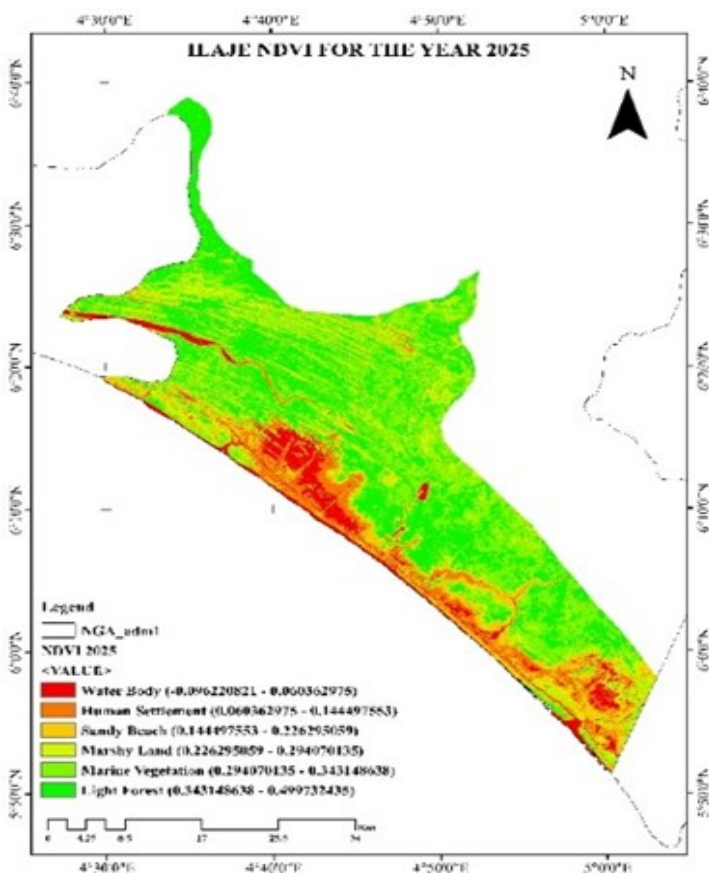


Fig.10: NDVI for 2025

Source: Authors' field work , 2025

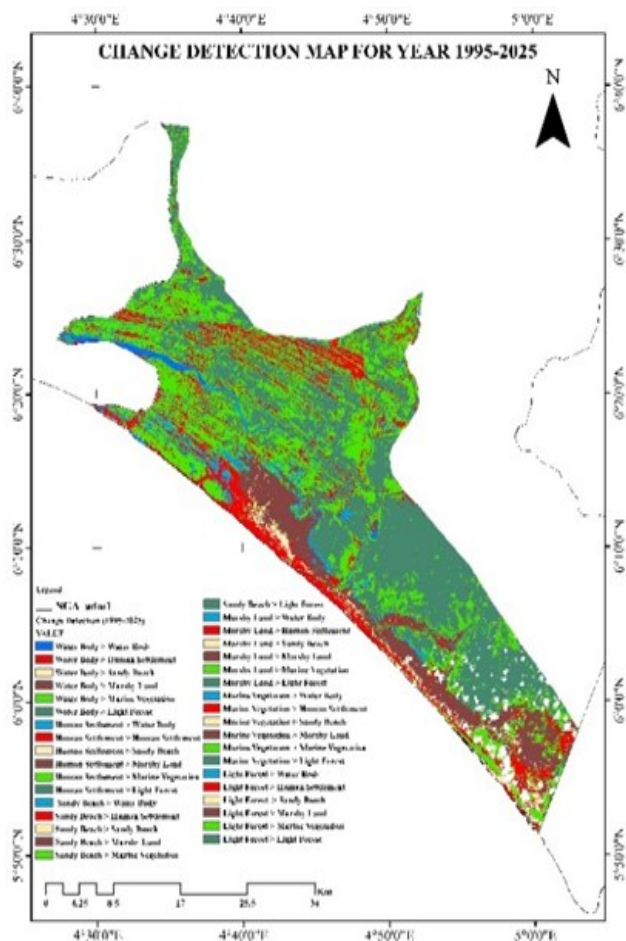
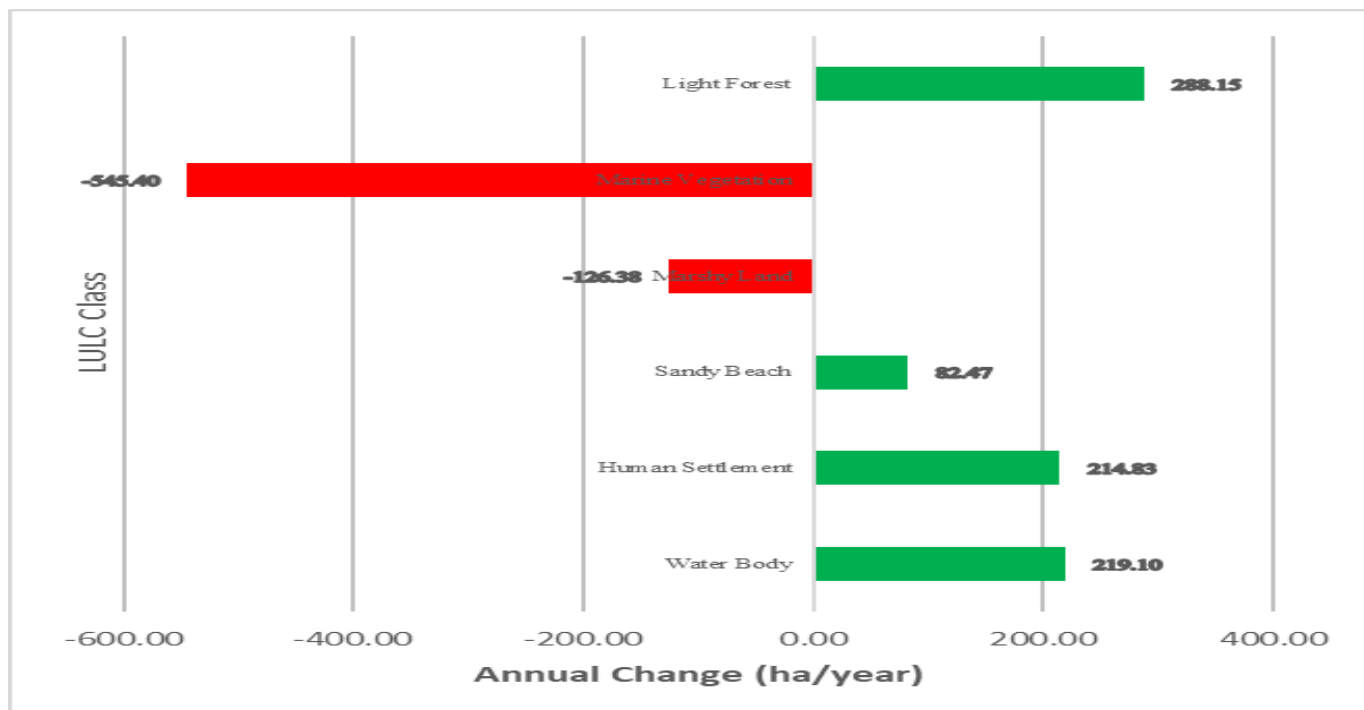


Fig 11: Change Detection Map



**Fig. 12: Annual rate of change between 1995 to 2025**

Marine vegetation experienced the highest rate of decline (**-1636.20 ha/year, -26.67%**), suggesting widespread degradation of mangrove ecosystems. This decline can be linked to a combination of factors: over-exploitation of mangroves for economic activities, rising sea levels originating from global glacial melt, and the expansion of human settlements. In many cases, mangrove trees are harvested and used as construction material for housing in water-logged and marshy areas, thereby accelerating the loss of these critical wetland ecosystems.

Marshy lands also declined (**-337913ha/year, -19.05%**), indicating that wetlands are progressively being encroached upon or transformed into other land cover types.

In contrast, light forest cover expanded substantially (**+864.44 ha/year, +19.29%**). The increase could be due to regeneration in less-disturbed inland areas or mis-classification of secondary vegetation regenerating on abandoned lands.

Water bodies (**+657.29 ha/year, +261.06%**) and human settlements (**+644.49 ha/year, +47.95%**) also showed considerable expansion, highlighting the dual influence of flooding and anthropogenic growth.

Sandy beaches grew moderately (**+247.40 ha/year, +374.36%**), reflecting shoreline modification and

coastal sediment deposition.

#### 5.1. Thirty-Year Change Analysis of Wetland Resources in Ilaje LGA

These results align with the first objective of assessing the 30-year dynamics of wetlands in the study area. The expansion of settlements and water bodies, coupled with the loss of marine vegetation and marshy lands underscore the pressures on wetland ecosystem. The change detection maps and annual rate of change statistics (table 4) both illustrate this transition, highlighting the vulnerability of wetland resources to anthropogenic and climatic influences.

This trend corroborates Ogunlade (2023), who reported significant transformations in Ilaje wetland across different epochs (1986-2015 and 2015-2019). The study reveals shifts in hydrology, hydric soils, and hydrophytic vegetation, projecting further alterations by 2030 if current pressures persist. The similarity between these findings and his (Ogunlade 2023), underscores the ongoing dynamics of wetland reduction driven by land reclamation, settlement encroachment, and environmental stressors.

### 5.2. Spatial Distribution of Wetlands (1995–2025)

In 1995, wetlands such as marshy lands and marine vegetation dominated the landscape, particularly in coastal and estuarine zones. By 2015, human settlements and sandy beaches began expanding, fragmenting wetland continuity. With greater transformations also revealed in 2025, with concentrated wetland loss in coastal fringes and replacement by human-dominated land uses. Despite some persistence of mangroves and light forest inland, the wetlands have been increasingly reduced in spatial extent and ecological function.

This pattern is consistent with findings from Fabricante *et al.* (2022), who reported that global datasets often underestimate wetland extent compared to locally derived analysis, that is, wetlands are missed in global datasets and studies as this with local datasets and information of wetlands helps in contributing globally from acting locally.

### 5.3. Drivers of Wetland Change with Emphasis on Climate-Related Factors

In identifying the drivers of change, the evidence points strongly to a combination of climate-related impacts (coastal flooding, sea-level rise, shoreline erosion) and human activities (settlement expansion, resource extraction, and land reclamation). These forces have accelerated wetland transformation, especially in vulnerable coastal zones.

These findings align with global trends where

climate-related drivers, including sea-level rise and increased flooding, which are primarily the forces behind wetland alteration. This mirrors Arctic studies (Seifollahi-Aghmiuni *et al.*, 2019), which show that climate change dominates wetland transformation through impacts on vegetation, carbon cycles, and biodiversity. In Ilaje, we also observe that while human settlement expansion is contributing to LULC shifts, the overall influence of climate stressors exemplifies the dual natural-anthropogenic pressures shaping wetland sustainability.

### 5.4. Human Settlement Expansion and Land Use Pressure on Wetlands

Population growth and rapid settlement expansion have been the primary direct drivers of wetland modification. Settlements encroach into marshy lands and mangrove zones, often involving land reclamation, sand filling, and clearing of vegetation. This urban sprawl has not only reduced wetland coverage but also introduced pollution and altered natural hydrology.

Studies have shown that the conversion of wetlands for urban, agricultural, and infrastructural uses is one of the most widespread pressures globally, leading to the loss of ecological integrity. Newton *et al.* (2020) reported that settlement expansion significantly increas-

*Table 3: Spatial Distribution 1995-2025*

SN	LULC Classes	1995 Area(ha)	2025 Area	Annual Rate of	% Contribu-
1	Water Body	2517.81	9090.70	219.10	14.84
2	Human Settlement	13442.08	19887.00	214.83	14.55
3	Sandy Beach	660.85	3134.87	82.47	5.59
4	Marshy Land	19899.91	16108.60	-126.38	-8.56
5	Marine Vegetation	61357.88	44995.90	-545.40	-36.94
6	Light Forest	44803.44	53447.85	288.15	19.52
				1,476.33	100%

Source: Analysis by Authors

es water abstraction, pollution loads, and habitat degradation, thereby weakening the resilience of wetlands to climatic shock.

### 5.5. Impact of Sea level rise on wetlands

Climatic factors, particularly sea-level rise and recurrent tidal surges, have intensified wetland changes. Low-lying areas of Ilaje are highly vulnerable to inundation, leading to the conversion of vegetated marshes into open water bodies. Shoreline erosion further accelerates this process, reshaping the wetland boundaries and displacing local communities.

The observed expansion of water bodies and reduction in marshy lands in Ilaje resonates with the long-standing global projections of wetland vulnerability to sea-level rise. Nichols *et al.* (1999) highlighted that rising seas would significantly increase the exposure of coastal populations while simultaneously driving extensive wetland loss. More than a decade later, Blankespoor *et al.* (2014) provided empirical evidence that reinforced these concerns, demonstrating that a 1m rise in sea level could expose over two-thirds of coastal wetlands in developing regions to inundation, with severe ecological and economic con-

sequences. Together, the findings of Nicholls *et al.* (1999) and Blankespoor *et al.* (2014) provide converging evidence that sea-level rise and associated coastal flooding are major drivers of wetland degradation, a pattern also evident in the Ilaje landscape.

### 5.6. Landuse Projection to 2035 and Implications

A landuse change forecasting was carried out using the observed rate of change from 1995 to 2025( 30 years). The rate of change was used in stochastic projection method to obtain the landuse condition in the year 2035. The result of the projection is presented in table 4. It was predicted that waterbody will significantly increase in 2035 to 11,281ha from the current 9,090 ha. This shows an increased incursion of waterbody into the marshland. This also confirmed the work of Fabiyi and Enaruvbe (2014) that coastal subsidence is actively impacting the coastal zone of Ilaje Local Government. Anthropogenic activities is also a major factor of landuse change and marine ecosystem depletion. Human Settlement is expected to increase from 19,887ha to 22,035 ha in 2035.

Table 4: Landuse change projection from 2025 to 2035

Landuse Classes	1995 Area(ha)	2025 Area (ha)	Annual Rate of Change	% Contribution	Projection 2035
Water Body	2517.81	9090.70	219.10	14.84	<b>11281.66</b>
Human Settlement	13442.08	19887.00	214.83	14.55	<b>22035.30</b>
Sandy Beach	660.85	3134.87	82.47	5.59	<b>3959.54</b>
Marshy Land	19899.91	16108.60	-126.38	-8.56	<b>14844.84</b>
Marine Vegetation	61357.88	44995.90	-545.40	-36.94	<b>39541.91</b>
Light Forest	44803.44	53447.85	288.15	19.52	<b>56329.32</b>
<b>Total</b>	<b>147992.56</b>	<b>147992.56</b>			<b>147992.56</b>

Source: Authors' analysis 2025

## 5.7. Conclusion

This study assessed the spatial-temporal dynamics of wetland resources in Ilaje Local Government Area of Ondo State, Nigeria, over a 30-year period (1995-2025) using geospatial techniques. The results revealed significant transformations in the wetland ecosystem driven by both climate-related and anthropogenic factors.

Wetland resources, particularly marshy land and marine vegetation, which dominated the landscape in 1995, have undergone substantial decline and fragmentation. The findings show a net loss of more than 20, 000 hectares of wetlands between 1995 and 2025, mainly due to settlement expansion, sea level rise and over-exploitation of wetland resources. While some recovery of marine vegetation was revealed in 2025, overall ecological integrity remains threatened.

NDVI analysis confirmed shifts in vegetation health and density, reflecting pressures from both human settlement expansion and recurrent coastal flooding. Human settlement expansion and resource extraction continues to reduce the buffering capacity of wetlands, exposing local communities to flooding, salinity intrusion, and loss of livelihoods.

The landuse projection suggested that in 2035 the water body will significantly increase due to sea incursion into the marine ecosystem and the coastal subsidence. Human activities is also increasing depleting forest ecosystem and reducing significantly the wetland in the study area.

The study highlighted the micro effects of sea-level rise on the wetland resources of Ondo state coast. Within 30 years of consideration, Wetland resource reduced significantly while water body increased confirming sea level rise and coastal subsidence as established by Fabiyi and Yesuf (2013), Fabiyi & Enaruvbe (2014), study highlights that Ilaje wetlands are undergoing rapid transformation, with implications for biodiversity conservation, carbon sequestration, climate resilience, and socio-economic sustainability. Without urgent interventions, these vital ecosystems may experience further degradation, undermining the ecological and livelihood support services they provide.

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