Original Research Article

ASSESSMENT OF ALTERATIONS OF ESTUARINE ECOSYSTEM IN SOUTHWEST NIGERIA

Abstract

The estuarine ecosystem provides services that are economically and ecologically indispensable. These services offer support to human well-being. However, uncontrolled human activities have altered the ecosystem goods and services provision, thus resulting in numerous irreversible environmental impacts in the wetlands. Globally, studies have used many approaches and paradigms to manage estuarine ecosystems, yet a limited management mechanism exists in the Nigerian estuarine ecosystems. This study investigated the alteration of the estuarine ecosystems in Southwest Nigeria over 20 years and the implication of the alterations to inform decision-making to stimulate education, build capacity, and develop the workforce for sustainability. This study used remotely sensed space and time data as references for the estuarine ecosystems. A combination and analysis of the reference and Nigerian wetland data were conducted. The coverage and alterations in the estuarine ecosystems were determined using the Maximum Likelihood Classification. The study also conducted a qualitative assessment with concerned management agencies to understand the questions of the environmental, ethical, governance, economics, decision making and policy implementation that shape estuarine ecosystems management. The result of this study indicates that 6405 hectares (38.1%) of the estuarine coverage in 2001 has been depleted in 2021. The drivers of alterations are mainly anthropogenic activities and climate change. The implications include loss of valuable fish species, pollution, habitats and biodiversity loss. Therefore, this study used the Ecosystem-Based Management approach to determine all essentials of the success or failure of ecosystem goods and services use efficiency and stability in Southwest Nigeria.

Keywords: *estuarine ecosystem, ecosystem services, ecosystem-based management, estuarine alterations, drivers of alterations.*

Introduction

Estuaries have been highly valued because of their abundance of rich resources such as soil, harvestable food, fish, and habitats (Bilkovic, Mitchell, Mason, & Duhring, 2016). Indeed, over 40% of the world's population lives within 100 km of the coastline, and the world's coastal urban population has nearly doubled in the last 40 years (Martínez, et al., 2007) (Pesaresi, Melchiorri, Siragusa, & Kemper, 2016). Estuaries face increasing threats from rising sea levels and stormwater discharge under climate change (Mo, Kearney, & Turner, 2020) and alterations by anthropogenic forces. Estuaries are wetlands of great value that play a significant role in wildlife conservation, serve as a source of organic material and nutrients, and are vitally important for a wide range of plant and animal communities (Giuliani & Bellucci, 2019).

They are considered man's life support systems (Costanza, et al., 2014). The estuarine ecosystem provides goods and services that are economically and ecologically indispensable, categorized into a three-wide variety of habitats and wildlife, significant commercial and recreational benefits, and environmental, economic, and social values (NSW Department of Planning, Industry and Environment, 2018). They support food production such as edible plants and animals for humans' direct consumption and livestock growth (Shepard, et al., 2011). Other benefits from the ecosystem that support human welfare include the movement of nutrients, water purification, raw materials, maintenance of biodiversity, biological production, and more (Daily, 2000). The estuarine ecosystem also supports marine transportation, oil and gas recovery, fisheries, aquaculture, and mariculture, among many others (National Oceanic and Atmospheric Administration, 2017). Another regulatory assistance is pollution control, nutrient and water cycling, and flood and storm protection. They provide cultural functions, primarily non-physical and concerned with spiritual enrichment. They are concerned with pleasure, emotions, and feelings, directly or indirectly derived from humans' activities (Jacobs, et al., 2013).

Despite the numerous high-value ecological services they provide to humans, estuaries are among the most vulnerable and threatened habitats globally (Weis, Segarra, & Bernal, 2017). Many global estuaries face severe degradation, including erosion, land use change, pollution, and invasive species (Nichols, et al., 2007). The steadfastness of estuaries keeps reducing over the years due to urban, agricultural, and industrial development (Bishop, et al., 2017). The loss rate is rapidly rising, even though their enormous value has been recognized globally (Chirol, Haigh, Pontee, Thompson, & Gallop, 2018). They are adversely affected by invasive species, overfishing, land reclamation and filling of wetlands, eutrophication due to excessive nutrients from fertilizer, sewage inputs, human and animal wastes, pollutants, and damming for flood control or water channelling/diversion—and impair the provision of the ecosystem goods and services (Jennerjahn & Mitchell, 2013).

Although accurately calculating and quantifying these losses is rigorous, due to lack of data, it is estimated that the global current estuarine ecosystem loss is 1-2% annually (Duarte, Dennison, Orth, & Carruthers, 2008) (Foster, Hudson, Bray, & Nicholls, 2013). Areas with large populations and high dependence on the coastal ecosystems are the hotspot of depletion (Halpern, et al., 2019). Rapid industrialization and exploding population in coastal areas have made the increase in demand for freshwater increase drastically. As such, estuaries are at the receiving end of poor management practices (Igu & Merchant, 2017). The current management interventions in such areas, locally and internationally, are insufficient (Sarika & Zikos, 2020). This will continue to be a significant problem in coastal management if there is no paradigm shift to intensive interventions on anticipating and mitigating the impacts of anthropogenic pressures and climate change on coastal wetlands (Lee & Kim, 2018).

The social dimension of coastal management has further significant implications for sustaining the vital resources and services of the estuarine ecosystem (Lee & Kim, 2018). Any management decision made today may have long-term consequences that go way more than expected and last even in future centuries (Shepard, Crain, & Beck, 2011). Therefore, the conservation of estuaries is not a simple matter. A thorough understanding and balance of the processes that drive their deterioration and development is required to protect and preserve them (Townend, Fletcher, Knappen, & Rossington, 2011) (Giuliani & Bellucci, 2019). This necessitates evaluating the dynamics of natural systems and understanding before any intervention is designed to conserve the ecosystem services the estuaries provide (Chirol, Haigh, Pontee, Thompson, & Gallop, 2018).

The Nigerian coastline is about 853 kilometers long, and the population of the coastal is 49 million, which is a quarter of the Nigerian population (NBS, 2017). The major Nigerian southwestern coastal states are Lagos and Ondo, with 14.8 million inhabitants. Estuaries are found in both coastal states but are majorly predominant in Ilaje, a local government in Ondo State (Popoola, et al., 2019). Ilaje has its headquarters in Igbokoda and is made of a group of distinguished Yoruba people with a distinct dialect. The population of Ilaje was 290,615 at the 2006 census, and it is projected to reach 463,487 at the end of 2021 using a 3.18% growth rate (NIPOST, 2017). This implies that this population will depend on the goods and services from the coastal ecosystems, especially the estuaries. Ilaje is blessed with mineral and oil deposits—the coastal ecosystems in Ilaje faces threats, including dredging, oil spill, and sand filling of wetlands for construction (Popoola, 2021).

The current conservation needs are enormous, and the situation worsens with rapid population growth and global change (Jeffery, 2002). The delivery of estuarine ecosystem services will be hindered if restoration and maintenance efforts do not use spatiotemporal analysis to identify conflict hotspots and inform decisions to minimize alterations (Barbier, et al., 2011). There is a need for emerging views that connects space and time data with the real world and interact with stakeholders to understand any associated tradeoffs and achieve sustainability (D'odorico et al., 2018). Therefore, this study intends to assess the alterations in the estuarine ecosystem in Ilaje over 20 years and support decision-making to ensure reliability and resilience.

Research Methodology

Study Area: Ilaje

Ilaje is a local government area located in Ondo State, Nigeria (see Figures 1 and 2). Ilaje has its headquarters in Igbokoda. Ilaje is made of a group of distinguished Yoruba people with a distinct dialect, and this group is made of 4 geopolitical entities, namely Ugbo, Mahin, Ekitan, and Aheri. To the north, Ilaje is bounded by the Ikales and the Apoi and Arogbo to the northeast. The Atlantic Ocean borders it to the south, Itsekiris, and Ijebus to the east and west. It has an area of 1470.55km^2. Throughout Nigeria, the people of Ilaje are one of the most enterprising as they are well known for their aquatic proactiveness and productiveness even in harsh geographical environments (NIPOST, 2017). Ilaje is situated in the tropics and thus experiences a fluctuating climate, ranging from the humid tropical in the south to the subhumid in the northeast (NigeriaGalleria, 2021). The area's relief comprises lowlands and rugged hills with granitic outcrops in several places whose heights are less than 15 m above the mean sea level. The annual rainfall is between 2834 and 4500 mm, while the average monthly temperature is 26°C (Eludoyin, et al., 2016).

Ilaje is blessed with an abundance of natural deposits of high-quality silica sand. This silica sand could be found in almost every part of the Ilaje local government.

Boatbuilding is one of the lucrative businesses in Ilaje as it is a riverine area. Essentially, the Ilajes build boats through collective efforts. The boats are built for transportation and fishing since about 75% of the local government is riverine. Ilaje has crude oil—oil wells and fields spread all over the local government, both offshore and onshore. Nigeria's foremost oil companies were operating in Ilaje, including Texaco Nigeria Ltd, Shell Petroleum Development Company of Nigeria, Chevron Nigeria Ltd, Allied Energy Oil Company, Exxon-Mobil, Cavendish Oil Company and many others (Ondo State Government, 2020). The wetlands in Ilaje include mangrove and estuaries, river and aquatic ecosystems, freshwater swamps and lowland rainforests (Popoola, et al., 2019). Estuaries mainly exist in 7 of the communities along the coastline of Ilaje, which are Agbala, Agerige, Ogogoro, Ago-Idajo, Ugbonla, Upe, and Ajapa (see Figure 3).

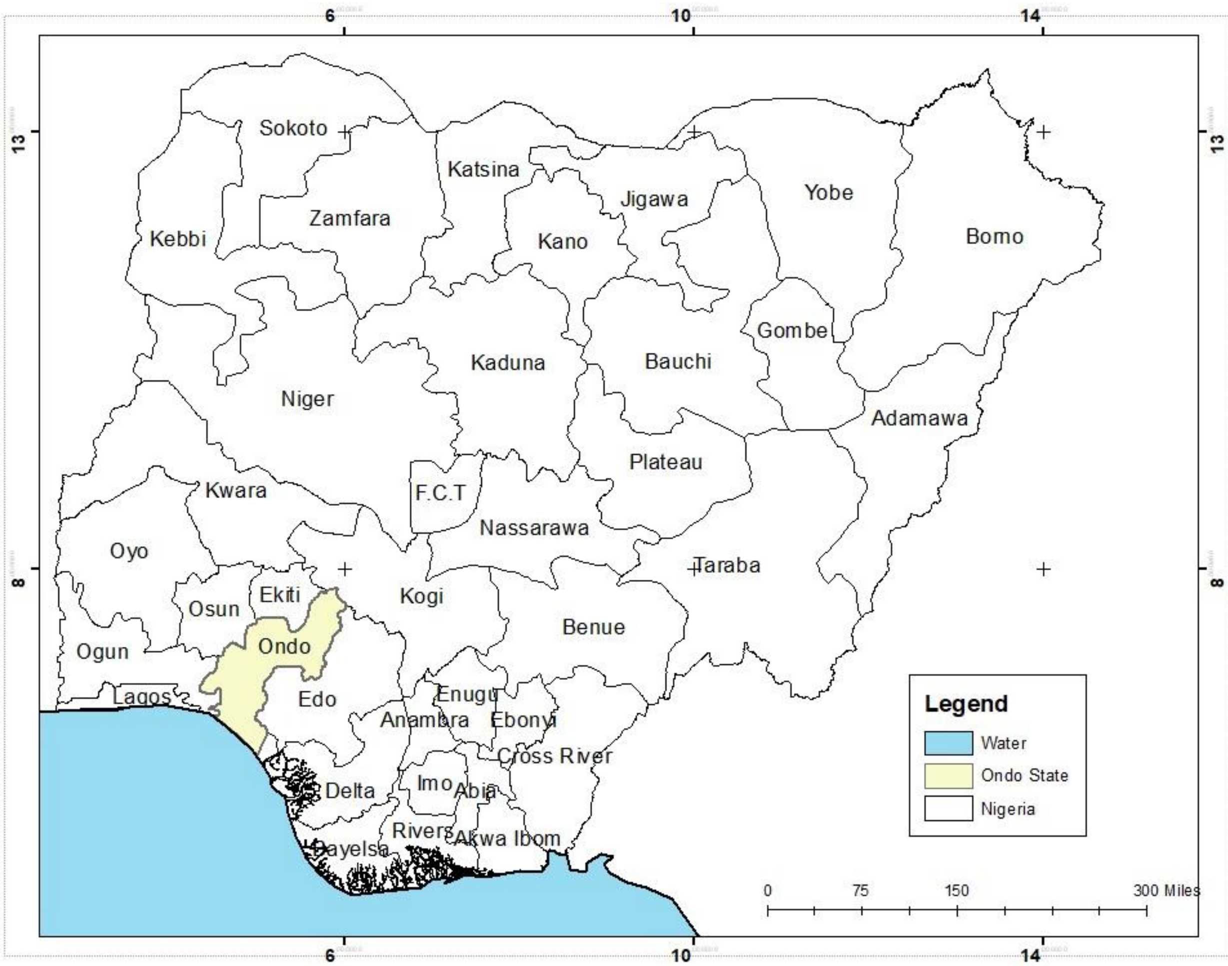

Figure 1: Map of Nigeria showing Ondo State.

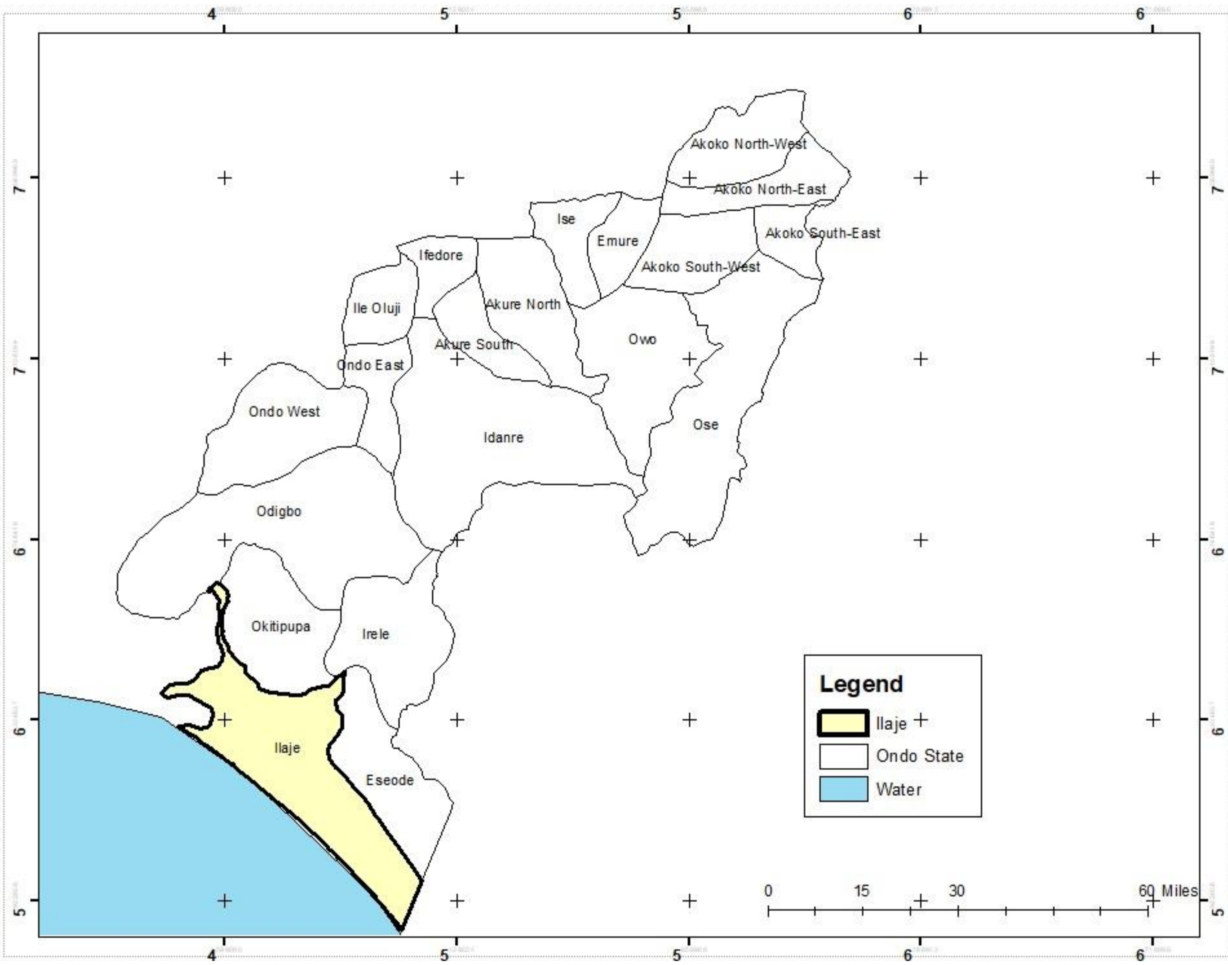

Figure 2: Map of Ondo State showing Ilaje.

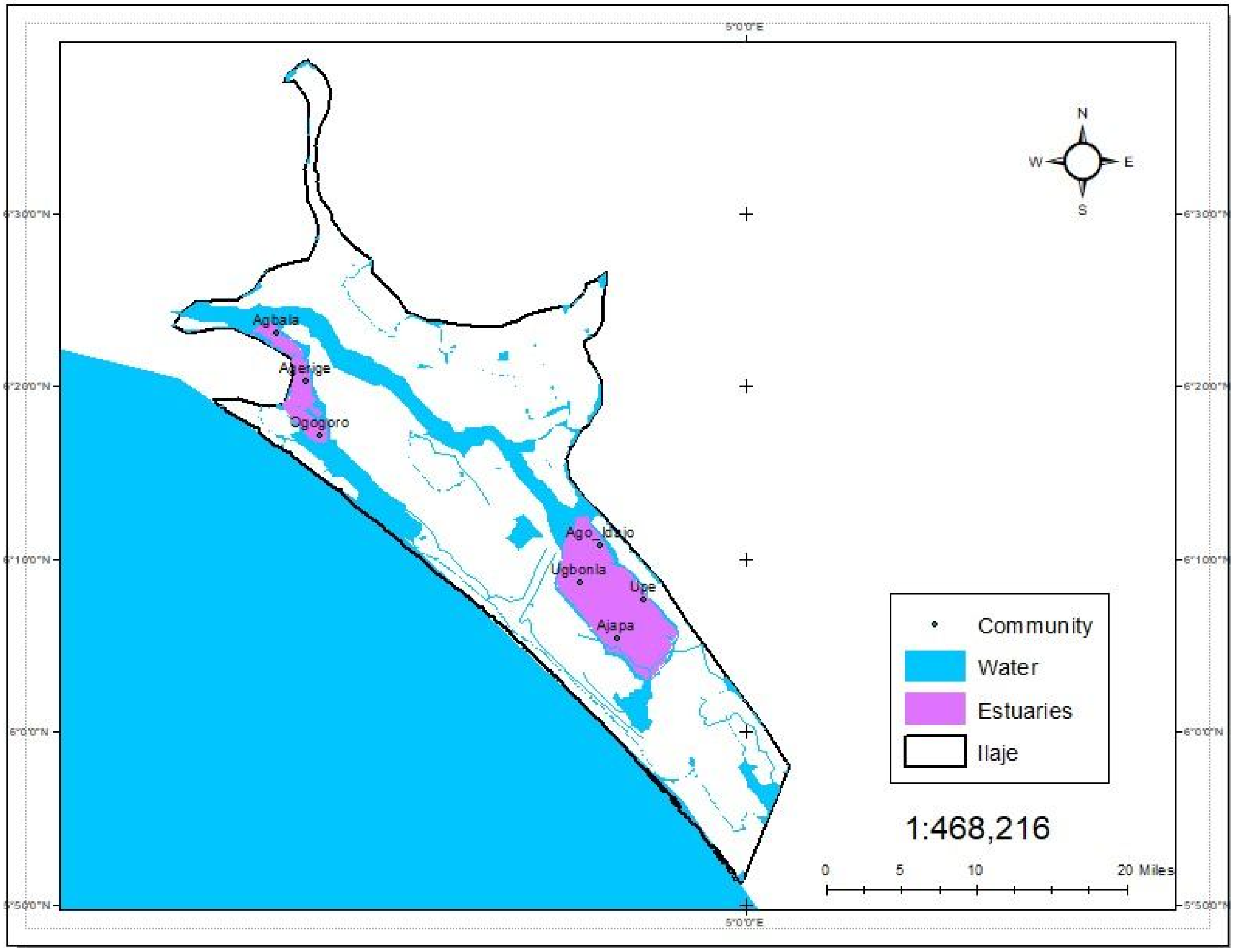

Figure 3: Map showing estuarine ecosystems in Ilaje communities.
Source: Author's field work, 2021.

Sources of Data

Data used for this research were obtained from secondary sources. The Land Satellite (Landsat) imageries of the study area for 2001, 2011, and 2021 were obtained from the United States Geological Survey (USGS), and a high-quality spatially generated ecosystem dataset from Global Lakes and Wetlands Database (GLWD) for use in GIS (Lehner and Döll, 2004). The Landsat imageries used are highlighted in Table 1. A literature search was done in this research. Information was collected through journals, newspapers, thesis, and reports, especially to examine the link between urbanization, anthropogenic pressure, climate change, and estuarine ecosystem depletion. Furthermore, semi-structured interview guides were used to collect information on the existing laws and regulations guiding development in the area from the local planning authorities, agencies, and ministries. These agencies include the Ondo State Oil-producing Areas Commission (OSOPADEC), Ministry of Housing and Development, Ilaje Area Office, Local Planning Authority, Ilaje, and Niger Delta Development Commission (NDDC). This stage identified both direct and indirect drivers of alterations and ascertained the existing planning policies and management activities that have been put in place in Ilaje.

Table 1: Landsat Imageries for the study

Dataset	Year	Instruments
Landsat-8	2021	Operational Land Imager (OLI)
Landsat-7	2011	Enhanced Thematic Mapper
Landsat-7	2001	Enhanced Thematic Mapper

Research Procedure

This research delineated the study area by extracting Ilaje local government using ArcGIS. It then acquired the baseline information of the total land area and ecosystem coverage using the combined historical Landsat imagery of 2001 and wetlands datasets in the study area. The historical Landsat imageries of 2001, 2011, and 2021 were obtained from USGS Earth Explorer (30 meters resolution - path 189, row 056; path 190, row 056), and change detection analysis was conducted on the imageries. The imageries were acquired in February to avoid seasonal and cloud cover variation for proper comparison and change detection. The Band Composition tool in ArcGIS was used to compose the bands from the acquired Landsat imageries to produce a colored infrared map to show land uses and land cover in the study area. Bands 1, 2, 3, 4, 5, 7, and 9 were combined for Landsat OLI, and bands 1, 2, 3, 4, and 5 were combined for Landsat ETM 2001 and 2011. A supervised classification using training samples by selecting relational and representative sites. The Maximum Likelihood Classifier (MAXLIKE) operation in ArcGIS accounted for the land cover classes in the study area.

Six major land covers were identified from the classification. They include built-up areas, sparse vegetation, swamp/dense vegetation, estuaries, bare land and water bodies. This classification was informed by Anderson's land-use land cover classification system, supported by the Lehner & Döll (2004) wetlands classification. The area of each land cover class was calculated and expressed in hectares and percentages using 2001 as the base year and 2011 and 2021 as reference years to identify the changing trend.

Results and Discussion

Overview of changes in estuarine ecosystems between 2001 and 2021 in Ilaje.

A baseline analysis was carried out on the estuaries in Ilaje, using 2001 as the base year. This analysis identified the ecosystems in the area and defined their coverage area in hectares. As of 2001, the ecosystems present in the study area include estuaries, swamp forests, rain forests, woodland, grassland, mangrove, and water. The analysis also takes account of the built-up area in the study area, as there were existing built-up areas near the estuaries at the base year. The analysis shows that the estuarine ecosystem covered 12.63%, which was 16818.3 hectares in land area. Other is shown and depicted in Table 2 and Figure 4. Swamps, rain forests, and woodlands—classified as other ecosystems covered 18.5%, vegetation covered 28.67%, bare land covered 6.45%, while water and built-up areas covered 12.14% and 21.61% of the total land area, respectively.

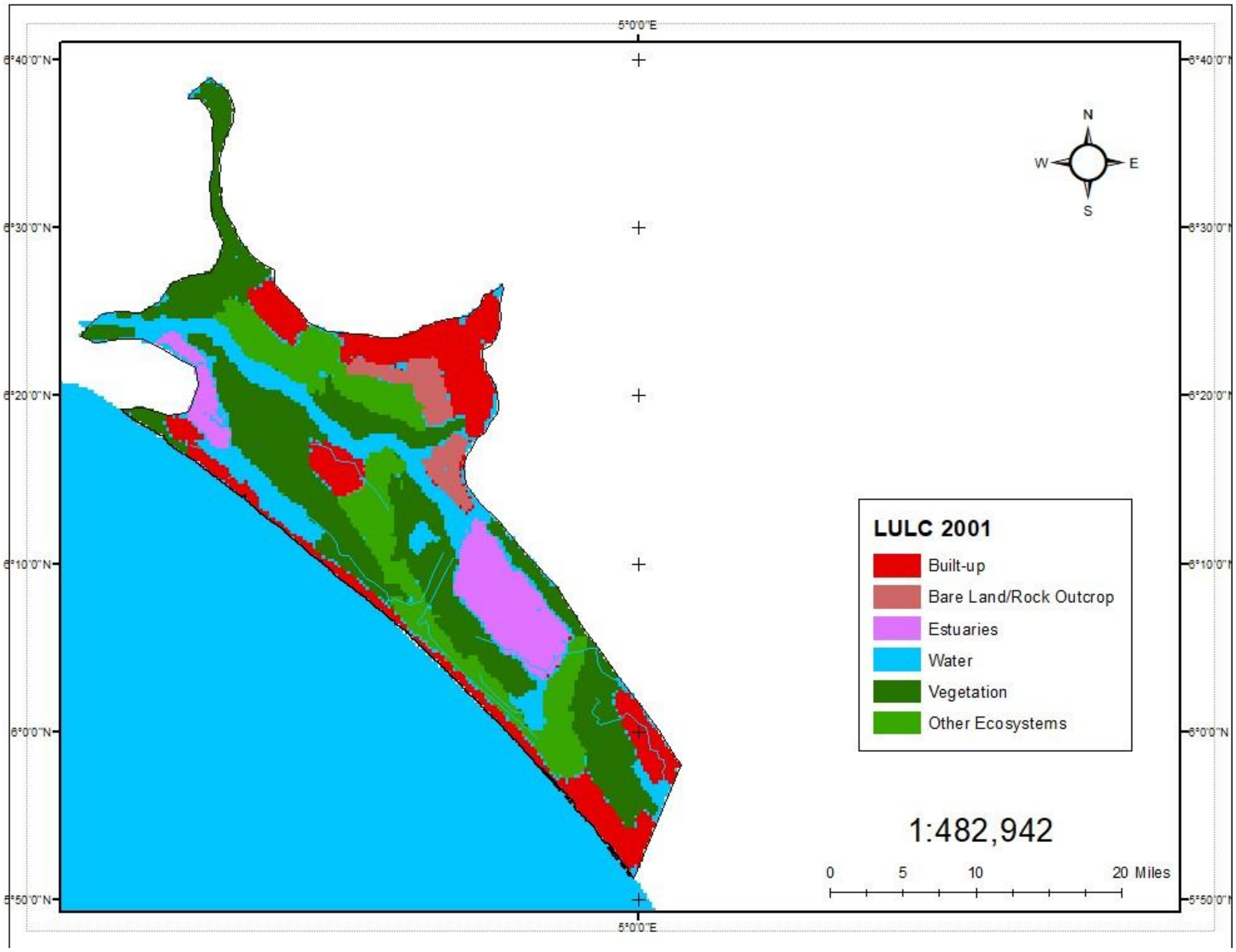

Figure 4: Map showing estuarine ecosystem coverage in the year 2001.
Source: Author's field, work 2021

Table 2: Land Use and Land Cover in Ilaje from 2001 to 2021

Ecosystems	Land Area in 2001		Land Area in 2011		Land Area in 2021	
	ha	%	ha	%	ha	%
Built-up	28776.2	21.61	39242.8	29.47	55528.3	41.7
Bare land/rock outcrop	8588.9	6.45	8402.4	6.31	6871.1	5.16
Estuaries	16818.3	12.63	13888.8	10.43	10413.3	7.82
Water	16165.9	12.14	15326.9	11.51	15193.8	11.41
Vegetation	38177.5	28.67	35421	26.6	28137.1	21.13
Other ecosystems	24634.9	18.5	20879.8	15.68	17018.1	12.78

Source: Author's field, work 2021

Figure 5: Land use/land cover changes in the study area from 2001 to 2021
Source: Author's field, work 2021

From the analysis, it is noticeable that significant changes have occurred. The estuarine ecosystem coverage has reduced drastically from 12.63% to 7.82% within 20 years. This implies that 38.1% of the estuarine ecosystems have been depleted. The coverage of built-up areas increased nearly 2-fold since 2001. It increased from 21.61% in the base years to 41.7%, while the vegetation cover reduced from 28.67% to 21.13%. These drastic changes in the land cover result from urbanization and oil exploration in the coastal area of Ilaje. Swamps, rain forests, and woodlands also reduced by 30.9% of their total coverage. This implies that significant parts of the coastal ecosystems and estuaries have been sand-filled and converted for residential, commercial, and public land uses. Such uses include building constructions, agricultural farms and oil exploration facilities. Residents also erected elevated shelters made of wood, bamboo, and hays on the estuaries. In contrast, water bodies have remained relatively unchanged over the period. However, this does not mean the water quality has not been compromised. The extent of these changes is presented in Figures 6 and 7.

Alterations in the estuarine ecosystems in Ilaje

The Landsat imageries of 2001, 2011, and 2021 were classified and analyzed to reveal the estuarine ecosystem depletion over 20 years. The results of the analysis are displayed using figures and tables. (See Figure 5, 6, and 7; and Table 3). From the base year to the first reference year of 2011, the estuarine ecosystem in the area covered 16818.3 hectares which were 12.63% of the total land area. The loss analysis revealed that 2929.5 hectares were depleted between 2001 and 2011, which amounted to 17.42% of the total estuarine ecosystem. From 2011 to 2021, 3478 hectares (20.63%) of the total coverage was lost. Overall, nearly 6405 hectares (38.1%) of the 16815.5 hectares of total estuarine ecosystem cover in the study area have been depleted within 20 years. Therefore, this brings the remaining estuarine ecosystem coverage to 10413,3 hectares, implying that over a quarter of the initial ecosystem coverage was lost in 20 years. The calculation puts the average yearly percentage loss in the estuarine ecosystem at 1.90%—due to human activities and physical development.

Table 3: Estuary coverage depleted in the study area from 2001 to 2021

Year	Total Coverage (ha)	Loss (ha)	Loss (%)	Loss Rate (%)	Coverage Area Left
2001	16818.3	0	0	0	16818.3
2011	16818.3	2929.5	17.42	17.42	13888.8
2021	16818.3	6405	38.1	20.63	10413.3

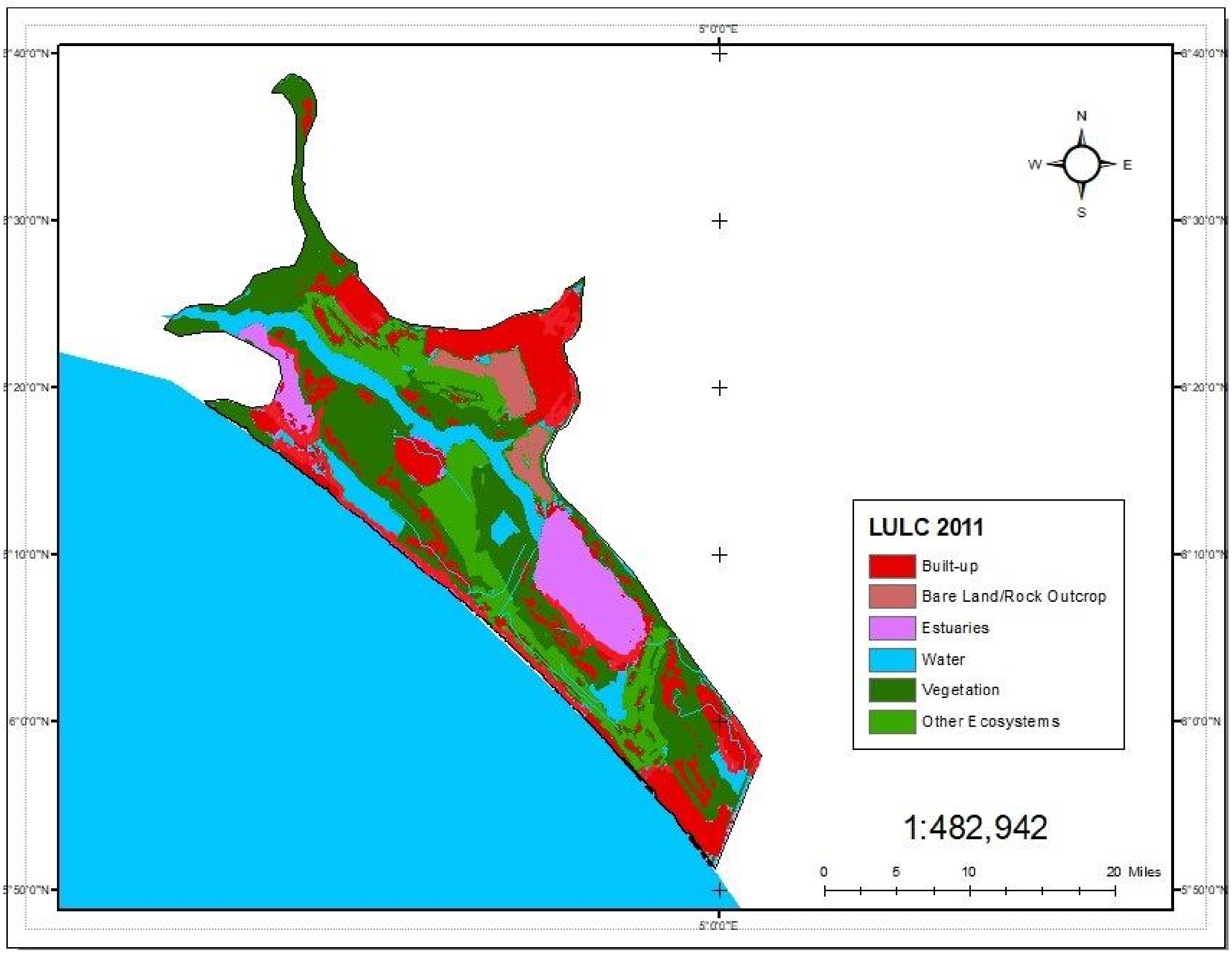

Figure 6: Map showing estuarine ecosystem coverage in the year 2011.
Source: Author's field, work 2021

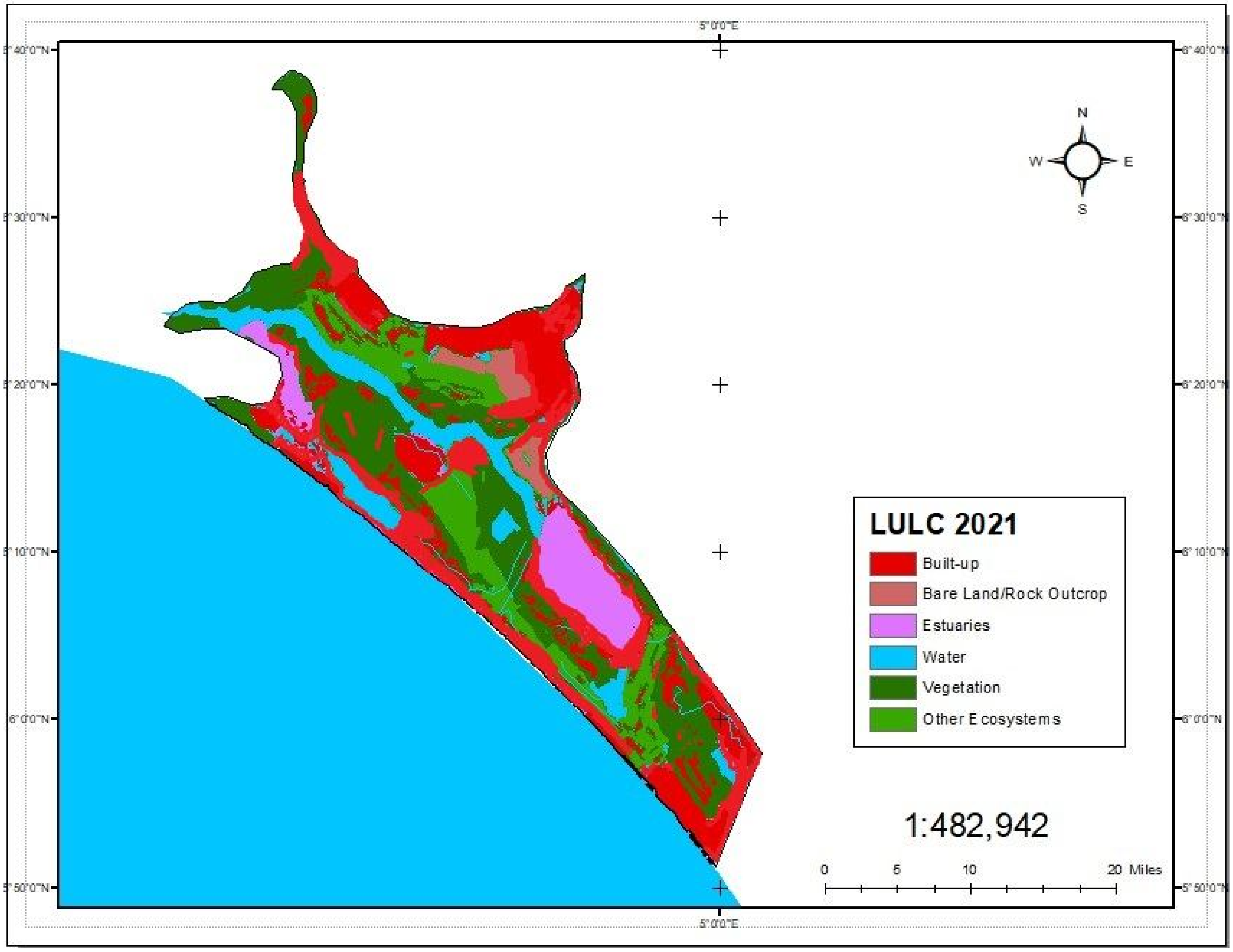

Figure 7: Map showing estuarine ecosystem coverage in the year 2021.
Source: Author's field, work 2021

The increasing human quest for physical development has depleted the estuarine ecosystem coverage by 2021, as the analysis shows the rapidly increasing urbanization rate in the study area. During the base year, the total land covered by urban development was 21.61% and had exploded to 41.7% in 2021, approximately an 100% increment in the initial coverage. The quest for urbanization brings about constant and continuous physical development. Pollution, over-exploitation, agricultural practices, invasive species, and deforestation played a significant role in the estuarine ecosystem depletion.

The implication is a severe loss of provisioning, recreational, cultural, and regulatory ecosystem services that are beneficial to human well-being. It can be deduced from the study that the estuarine ecosystems have lost 38.1% of their water quality and air quality regulation power. It also lost over a quarter of its habitats, and the nursery birds and species communities have been compromised. The essential food production function, which includes fish, crops, fruits, and animals, has also been compromised for 20 years. In terms of the raw materials provisioning, for over 20 years, a significant capability of the estuarine ecosystem to produce lumber and fuel has been compromised. It is imperative to note that the trend should not be allowed to continue. There is an urgent need to design and adopt management interventions and environmentally friendly measures in conserving ecosystems. Hence, the need to integrate ecosystem conservation, especially in the physical planning of Ilaje, to restore, protect and preserve the declining ecosystems.

Governance, economics, decision making and policy implementation in the coastal area of Ilaje.

The information obtained from the agencies attributed the rising anthropogenic activities in the study area to anthropogenic forces and mining and oil exploration. The information received explicitly revealed that capital-intensive construction projects have been ongoing in the study area. Such projects include roads, buildings, facilities and other infrastructure. Responses received and analyzed from the interview guide revealed that no sophisticated measure is geared towards managing and improving the estuarine ecosystem resilience. The Niger Delta Development Commission (NDDC) and Ondo State Oil Producing Areas Development Commission (OSOPADEC) made it known there is no management strategy guiding the use of the estuarine ecosystem, specifically in addressing oil spillage from mining activities. On the other hand, the Area Town Planning Office and Niger Delta Ministry (NDM) have policies guiding physical development and plan approval in Ilaje. These policies discourage physical development near the water banks and shorelines to protect the shore and reduce the strength of waves coming from the ocean.

The present policy structure fails to give utmost concern to the management of the estuarine ecosystem agencies, and there is no synergy between the agencies. Lack of information is a key impediment to management activities and public participation in Ilaje. When the information becomes abundant between the agencies, it becomes easy to make it available to the residents. Furthermore, the means of information and communication need to be specific to the socio-economic condition of the residents to help improve the transparency of information (Boesch, 2006). The agencies do not consider the relationship between humans and ecosystems. Therefore, it is difficult to investigate and document the linkages within and across the ecosystems in the study area. This has caused the lack of the full range maintenance of components and processes of ecological interactions to aim for resilience rather than for desired end-points.

The agencies do not improve or put the existing management strategy into consideration; instead, they invent other strategies. This, somehow, leads to the discontinuity of the management strategies. Thus, the agencies must build broad political commitment on common issues and harmonize separate institutional responsibilities, regulations, and management structures to manage estuarine ecosystems. The estuarine ecosystems have not received the due management attention needed. However, claims of laid down regulations to protect wetlands in southwest Nigeria are yet to be implemented. Therefore, there is an urgent need to measure resilience and reliability using the ecosystem-based management approach and identify tradeoffs to conserve and restore the estuarine ecosystems in southwest Nigeria to ensure resource use efficiency and ecosystem security.

Conclusion

The estuarine ecosystem goods and services are essential to the sustenance of human well-being by offering numerous services that support life. This research has identified the baseline condition and has assessed the extent of depletion of the estuarine ecosystem coverage in Ilaje. For the 20 years under study, there were massive depletions in the ecosystem coverage. The Ecosystem-Based Management approach is useful in making key recommendations to help integrate estuarine ecosystem management into spatial planning activities. It could be used to understand the management context and establish estuarine reserves to improve the resilience of the ecosystem. This reserve will limit the interaction between the estuarine ecosystem and alien environmental processes not originally from the estuarine ecosystem. The challenge of reversing the degradation of ecosystems is not easy. However, an attempt can still be made to re-plant lost species and restore functions of the depleted ecosystems using EBM. This study suggests that degraded areas should be identified and mapped using GIS and Remote sensing techniques to help put restoration and conservation in place. To achieve steady and continuous estuarine ecosystem management discipline, principles, and measures, it is essential to have a decentralized body that oversees the management of the estuaries. It is recommended that the government establishes and delegates power to a physical planning department to manage and take control of the estuarine ecosystem management. This department should be multidisciplinary, as the effective management of the estuarine ecosystem cuts across all professions.

Other recommendations include developing a biodiversity database, public sensitization about the potential impact of ecosystem loss and enactment of estuarine development policies, integrating the ladder of citizen participation in policy formulation, ecosystem management training, and leveraging, incorporating social, cultural and economic values, leverage all relevant forms of traditional, local, natural and scientific knowledge, and identifying uncertainty and planning for adaptive management. Integrating the ecosystem-based management of estuarine ecosystems into spatial planning activities to help make informed decisions will create a balanced ecological and societal systems interaction.

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