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Comparative Assessment of the Changing Pattern of Land cover along the Southwestern Coast of Nigeria using GIS and Remote Sensing techniques

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A B S T R A C T

The changing pattern of land cover is increasingly becoming of global concern in the sustainable management of environmental resources. Different facets of the natural ecosystem continue witnessing devastation orchestrated by rapid population growth and urban expansion in the face of climate change. This study examined the contribution of human's to the global environmental change by assessing the dynamics of land cover between 1984 and 2017 while predicting the future extent of land cover pattern for 2047 at the Epe and Igbokoda areas on the coast of southwestern Nigeria. Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) imageries of 1984, 2002, and 2017 respectively were acquired from the USGS to analyse the land cover changes. Supervised classification was done using the maximum likelihood classifier of Terrset version 18.31. The Change Demand Modelling of Land Change Modeller (LCM) in Terrset integrates the Markov chain for future predictions for 2047. The Epe area which typifies a rapidly urbanizing coastal environment recorded an 84.6% increase in built-up area extent between 1984 and 2017, while the built-up area of the Igbokoda area increased by 103.8% for the same period. This increment corresponds to a decrease in the spatial extent of the forested wetlands with an increase in water bodies. Expansion of water body extents indicates the interaction between the elements of climate change such as incessant flooding and anthropogenic activities like deforestation, urban expansion through sand mining and dredging. Future prediction into 2047 connotes further worsening of the situation. Therefore, solution-based sustainable coastal management practices are recommended to salvage the impoverishing coastal ecosystems from further impairment.

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Introduction

Recent population explosions and increasing urbanization rates have inspired the concerns to investigate the different facets of natural and built environments [12,20]. Urban growth has occasioned land reclamation from the water body and the transformation of natural vegetation into impervious surfaces [21]. A prominent contributor to the global environmental change is the incessantly changing land use and land cover which is a product of man's exploration and exploitation of biophysical resources to meet his infinite needs ([11,12]. Human modification of the environment to satisfy his needs has given rise to the clearing of natural vegetation, biodiversity loss, air quality impairment, sediment yield, global warming and increasing frequency and severity of natural disasters as well as observable land use pattern over time [28]. For instance, the built-up area in Lagos State, Nigeria increased between the years 2002 and 2013 by 10.66% and shrubland by 193.06%, with a general decrease in vegetation cover of 50.28% [28]. Apart from this, the maximum rate of expansion of the mangrove vegetation of 25.91m yr^{-1} exceeded the contraction maximum of -22.45m yr^{-1} of the the mangrove boundaries of the shorelines of the Persian Gulf towards the Oman sea over a thirty year period [15].

Coastal zones which represent the interface of land and sea are noted for profound economic advantages, significant ecological productivity and settlement of human population. The potential of these zones for development is often characterized by corollary changes in the land use pattern. Over half of the population of the world reside within 60 km of the coast and this tends to get up to three quarters in 2030 as posited by Anon [6]. However, Yagoub and Kolan [30] emphasized the vulnerability of coastal land areas to frequent changes due to the accompanying trend of rapid industrialization and urbanization.

As recognized by UNEP [29], the greatest propeller of changes in coastal and marine environments are land use, loss of natural habitats, fish harvesting, pollution and climate change. The link between coastal land use dynamics and climate change has been identified [3,4,8,9,27]. Considering the intrinsic interaction between the atmosphere, the hydrosphere and the lithosphere in coastal ecosystems, the transformation of vegetal cover to urban surfaces encourages not only the disruption of the carbon cycle and hydrological processes but also alters the fluxes of energy between the atmosphere and the land [16]. In the same respect, Adefisan *et al* [3] recognized that an 18.45% reduction in vegetation cover within 30 years exerted a profound influence on the microclimate and land surface temperature of coastal communities in southwestern Nigeria. Fashae et al. [10] also posited that physical changes in land use/land cover and population density within a river's watershed usually have an impact on the hydrology and water quality of the river.

Lagos which is popularly known to be the economic capital of Nigeria is characterized by extensive reclamation of wetlands and encroachment of ecological resources [1]. A typical illustration of this phenomenon is the Lagos/Lekki Lagoon system which occupies about 71% of the total area of Lagos State, and is currently experiencing severe developmental pressure as some of the fringing marshlands have been transformed in recent years (Obiefuna *et al*., 2012). Urban sprawl has been documented as a persistent land use agent in this Lagoon system causing swamps to decrease in spatial extent from 344.75 km^2 to 165.37 km^2, and built-up areas significantly increasing from 48.97 km^2 to 282.78 km^2 between the year 1984 and 2006 (Obiefuna *et al*., 2012). By contrast, the Igbokoda coastal axis typifies an area of reluctant rate of developmental emergence. This region is essentially under the influence of primary economic activities such as fisheries and farming. Despite the essential rural characteristics and swampy nature of this environment, increasing human activities have been documented in recent times. For instance, developmental activities which accounted for just 7.50% of the entire spatial extent of Igbokoda township in 1986 increased to 14.97% in 1999 and 24.52% in 2013, as most of these activities find their expression in most, especially in areas of relatively high altitude and sand-filled areas adjoining roadsides [5].

However, coastal areas are generally at risk as they are subject to the possible impacts of climate change as reported by Tijani et al. [27] wherein the reduction in crop and livestock production, quantity and species of fish harvested and decreased income are prominent consequences of climate change on inhabitants of the Lagos coastal environment. Land cover dynamics is one of the basic concerns in global environmental change and sustainable development [31]. Quantifying the spatial pattern and processes responsible for these changes will provide a potentially viable medium for establishing the capacity of the natural ecosystems to exhibit fundamental functions in support of human livelihood [14].

The role of remote sensing (RS) and geographic information system (GIS) techniques in the monitoring and assessment of the coastal environment cannot be overemphasized. Fashae and Onafeso (2009) examined the historical trend in the coastal extent of Lagos, Nigeria by projecting the potential impact on coastline change using GIS techniques coupled with scenario-based climate change predictions. Cham et al. [7] on the other hand used a combination of multitemporal remote sensing and digital evaluation model with a tidal correction to detect shoreline evolution for multiple years from 1965 to 2018. The tidal correction improved the accuracy of shoreline evolution analysis while revealing a combination of complex erosional and accretional processes in the north and south of Cua Dai estuary. Therefore for an adequate understanding of the coastal processes, especially in the studies of erosion-accretion processes, there is the need for the integration of both RS and GIS techniques for the accurate demarcation and monitoring of shoreline evolutions and projections. Hence, this research seeks to examine the nature and of changes in the land cover and extent; predict the extent of changes in land cover for a future period of 2047 and assess the ecological implication of these changes; in the Epe axis of Lagos State and the Igbokoda axis of Ondo State on the southwestern coast of Nigeria.

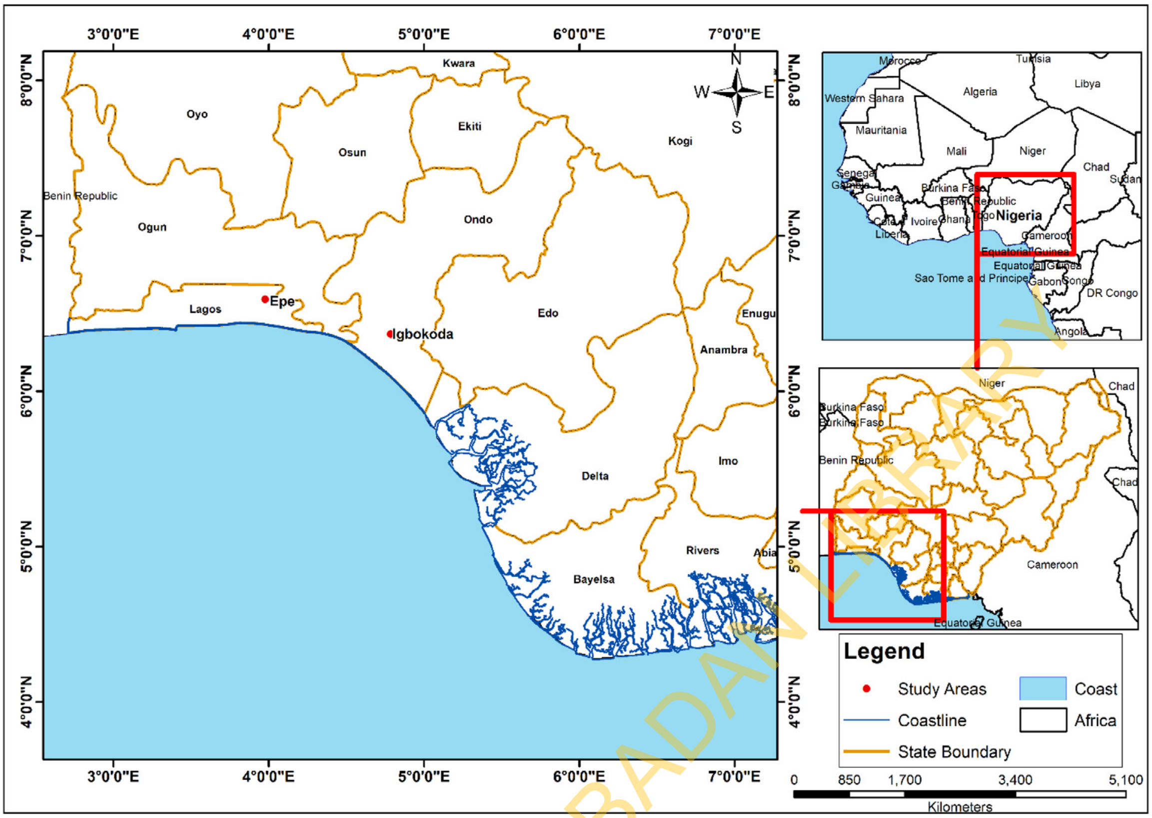


Fig. 1. The southwestern coast of Nigeria showing the study communities.

Study area

The study area lies on the Nigerian coastline of Nigeria between Latitude 4°10′ to 6°20′N and Longitude 2°45′ to 8°32′E (Fig. 1).

The coastline of Nigeria is extensive and it is about 850 kilometres which extend from Lagos in the southwestern part through Ondo state and Delta State respectively before terminating at Cross river in the South Eastern region. It is a coastal lowland that is bounded in the south by the Atlantic Ocean. Within this zone, two study sites were identified for study: the Epe axis of the Lagos coast and the Igbokoda coastal axis of Ondo State. The study area is largely a wetland region that is dominated by freshwater and mangrove swamp forests. The climate is marked by two seasons (dry and wet seasons). The dry season spans between November and March, while the wet season occurs between April and October. However, the wet season is usually characterized by light showers due to the effect of continentality, that is, proximity to the sea. Mean temperature ranges between 22.1°C and 33°C and hence a low rate of evapotranspiration. The topography of the area rises about 1 m along the coastline to about 55 m at the inland location, while the geology is characterized by the extensive sedimentary sequences of Dahomey Basin chiefly consisting of localized alluvial sediments of the Cretaceous and Tertiary periods. Rapid urban expansion is evident on the Epe coast as natural ecosystems are rapidly transformed into built-up land. Notable activities in this area include construction, recreation and tourism, commerce, fishing and land reclamation. The Igbokoda coast typifies a rural setting where farming, coastal fishing and aquaculture, cottage manufacturing are the dominant activities.

Data source

The data used for this study was extracted from one scene (path/row: 190/56 and 191/55) of Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) satellite images of November 1984, December 2002, and January 2017 for Epe and Igbokoda areas. The images were Landsat level-1 data products acquired from the U.S. Geological Survey Landsat series of Earth Observation satellites (USGS). All images were in Universal Transverse Mercator projection, Zone 31, Datum WGS84. Fieldwork was also conducted using a Global Positioning System (GPS) to locate and capture the locations of the landcover classes before conducting the supervise classification on the satellite imageries (Fig. 2).

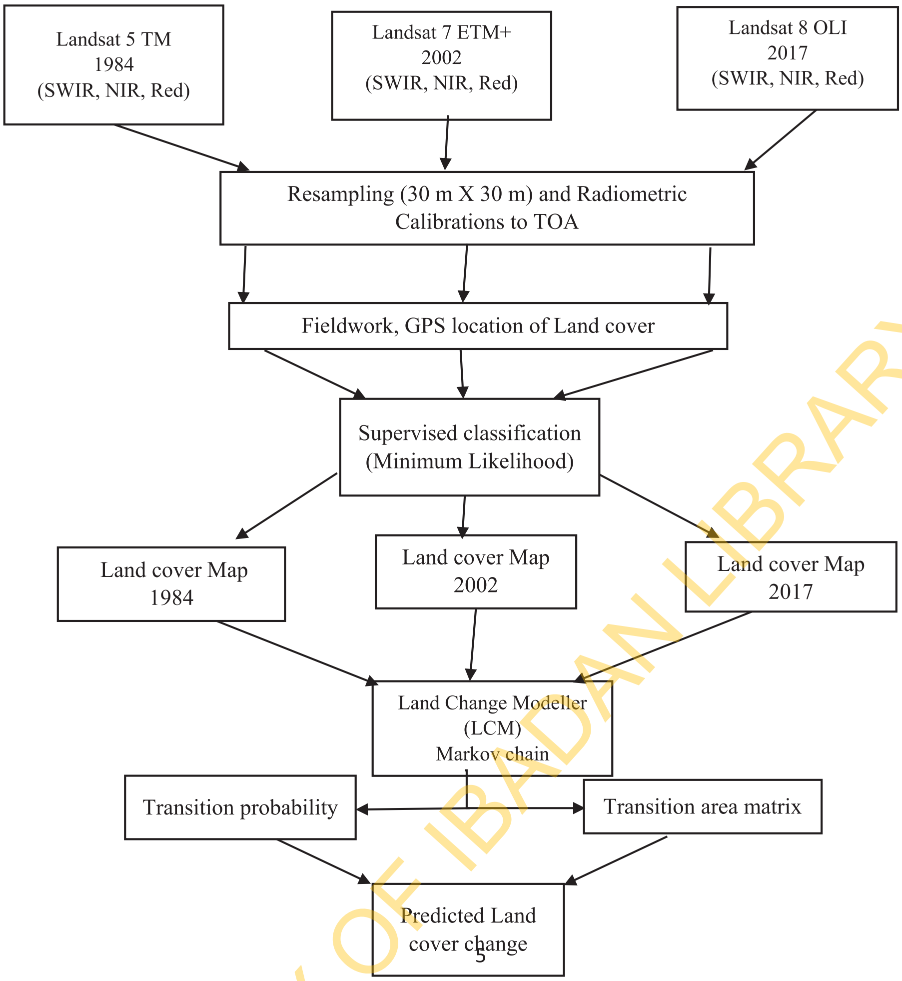


Fig. 2. Schematic diagram showing the Geospatial procedures used for the study.

Data preprocessing

Landsat images (TM, ETM+, and OLI) have different radiometric properties because various sensors collected them. Therefore, image calibration was done to improve the interpretability of images using the Terrset version 18.31 Landsat archive import module. The images were rescaled and converted to Top of Atmosphere (TOA) radiance and the IDRISI rst format using the parameters found in the metadata MTL text file. These images were already georeferenced and geometric correction remained unchanged from the data source for this image classification (Fig. 2).

The 30-meter SWIR, NIR, Red bands selected from each epoch were chosen because they interact better with objects on the ground for this study, as a result of their wavelength ranges that give a natural colour rendition of the earth's surface for classification. The bands were composed to create a single raster for each year for visual interpretation before going out for field data collections.

Image classification

Based on prior knowledge of the study area, visual interpretation was used to interpret the images into five categories. Then 50 points were generated using a random sampling tool with ten points for each class identified from the visual interpretation. The generated points were used to create a 30 × 30 meters plot size to match the spatial resolution of Landsat. All the plots were tracked and located on the field with a Trimble Juno handheld GPS receiver. The plots were mapped, and each plot's most dominant landcover class was used to generate the spectral signatures. The spectral signature from the plots were then split into 70% as training data and 30% as test data for accuracy assessment [2]. Maximum likelihood supervised classification was performed for each epoch for both the training and test data. Maximum likelihood was used because it minimizes the unbiased variance estimators as the sample size increases. An error matrix analysis was performed under IDRISI image processing in the Terrset software using the classified maps from the training data against the classified maps of the test data. The overall accuracy was calculated using the formula below.

$$Overall\ accuracy = \frac{Number\ of\ correctly\ classified\ pixel}{Total\ number\ of\ reference\ pixel} \quad (1)$$

Future land cover prediction

The Change Demand Modelling of Land Change Modeller (LCM) in Terrset version 18.31 was used for future prediction. The modeler uses the Markov chain to define the probabilities that a landcover class would change into another type based on the past and present classified landcover maps. It is mainly used to study the transition probability between an initial state and a final state to determine the transition trend among different land-use states [19]. The results form a transition probability and a transition area matrix to predict a specified date. The transition probability matrix evaluates the chance of a land cover class changing into all other classes. While the transition areas matrix accounts for the number of pixels that are estimated to change from one land cover class to all other classes over the specified period. Landsat TM of 1984 was used as the past image, and Landsat OLI of 2017 was used as the present image, while a prediction of thirty years from 2017 was made. Using the Markov chain modeler, cross-tabulation of Landsat TM of 1984 and Landsat OLI of 2017 was done in tune with a proportional error, to derive the transition probability matrix. Also, the column in the transition probability matrix was multiplied by the number of cells of the equivalent landcover in the later image to produce the transition areas matrix. A simple power rule of the base matrix (X^1) was used to calculate the transition probability matrix because the forward projected date was an even multiple of the training period from 1984 to 2017 [26].

Results and Discussion

Image Accuracy Assessment

The Error Matrix (Table 1 and 2) was used to quantify accuracy for image classification for the Lagos and Ondo axis. The columns represent the test map while the row represents the training map. The diagonal cells show where there was a match, or in other words where there were no errors. The overall accuracy was 90% and 89% for Lagos and Ondo, respectively.

$$\text{Overall accuracy} = \frac{659499 + 2223361 + 3286 + 2194531 + 2215777}{8087248}$$

$\text{Overall accuracy} = 0.90221717 * 100$

$\text{Overall accuracy} = 90\%$

$$\text{Overall accuracy} = \frac{28843 + 2144083 + 510189 + 223119 + 178176}{3473570}$$

$\text{Overall accuracy} = 0.8880 * 100$

$\text{Overall accuracy} = 89\%$

Land cover dynamics along Epe axis of the Lagos Coast

Considerable land cover changes have been experienced in the Epe coastal axis of Nigeria. This is not unconnected to the rapid increase in the built-up areas through population increase and the need to reclaim marginal lands for developmental activities. The result of the land cover classification analysis revealed five types namely; built-up land, forested wetland, sand fill, water body and agricultural land. Thus, the forested wetlands and the agricultural lands have been captured by urban expansion and several land reclamation schemes while trying to create drier lands for human activities with subsequent increase in the urban area. For instance, between 1984 and 2002, the areal extent of the built-up land increased from 447.3 km^2 to 572.6 km^2, which amounts to about a 28% increase.

Specifically, by 2017, more urban activities, economic development and the need to construct more structures to accommodate the influx of people in this environment pushed the spatial frontier of the Epe coastal axis to an extent of 951.02 km^2. This implies that an increase of 66.1% was observed between 2002 and 2017. In total, built-up areas in Epe increased by 4.61% between 1984 and 2017 as illustrated in Table SM1.

On the other hand, the forested wetland and the agricultural land suffered a similar fate of shrinking, inflicted by the rapidly advancing built-up area. The forested wetland which was dominated by freshwater and mangrove swamp vegetation, reduced from 1831.9 km^2 in 1984 to 1243.8 km^2 in 2002 and 116.1 km^2 in 2017 while sand-filled land occupied only 21.53 km^2 in 1984. Increasing demand for land encouraged further sand filling with areal extent increasing to 145.61km^2 in 2002. A drastic reduction was observed for 2017 with an extent of 29.18 km^2. With rapid urban development areas hitherto classified as sand-filled land have acquired significant prominence and have transited to built-up land. Hence. it is quite difficult to draw a clear-cut margin between these two situations. Projection in 2047 reflects a further decrease by 6.05 km^2 (Figs. 3 and 4) and Fig. SM1. Numbere [21] recognized sand filling as a significant component of land reclamation wherein sand mined from the river bottom during low tide are heaped ashore to form sand mountains which are usually abandoned

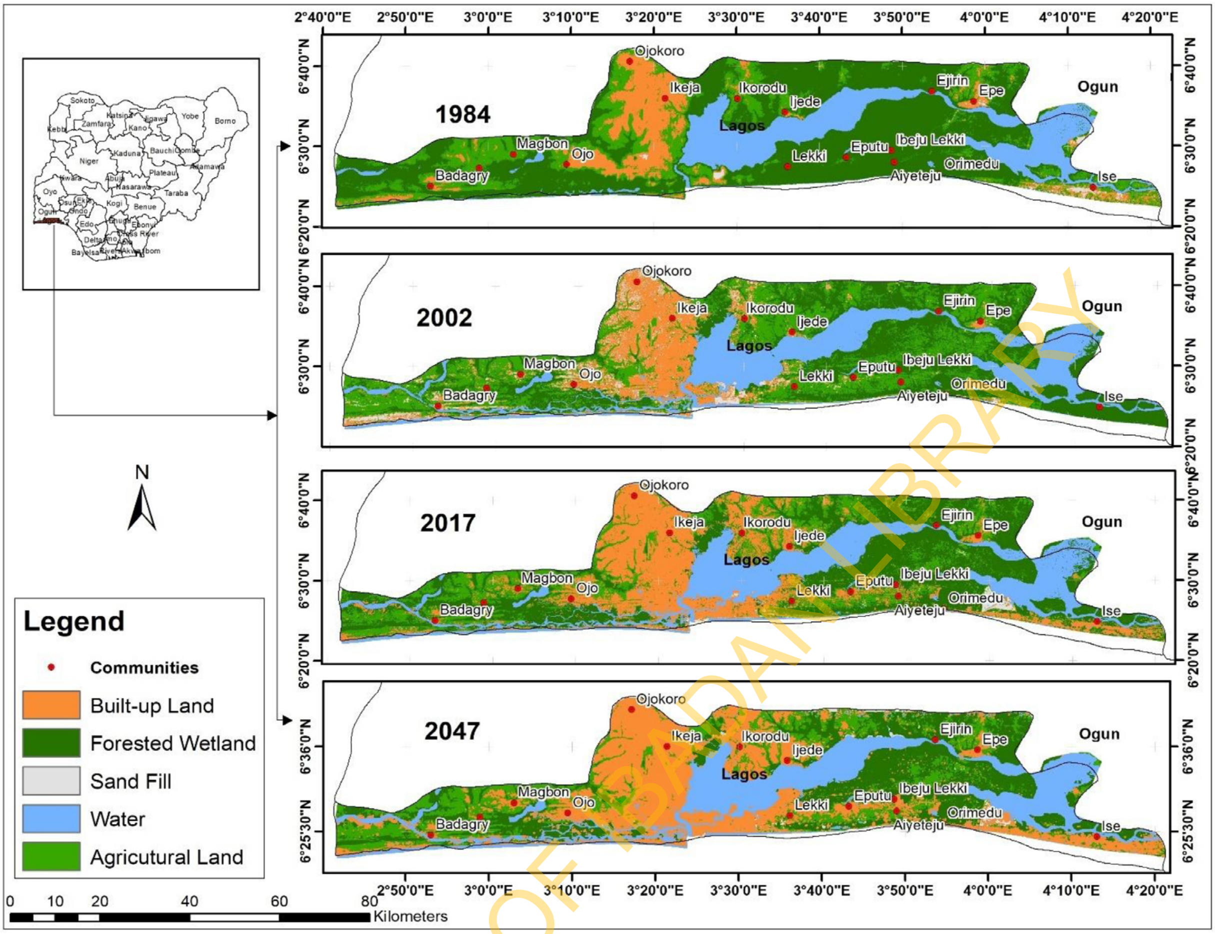
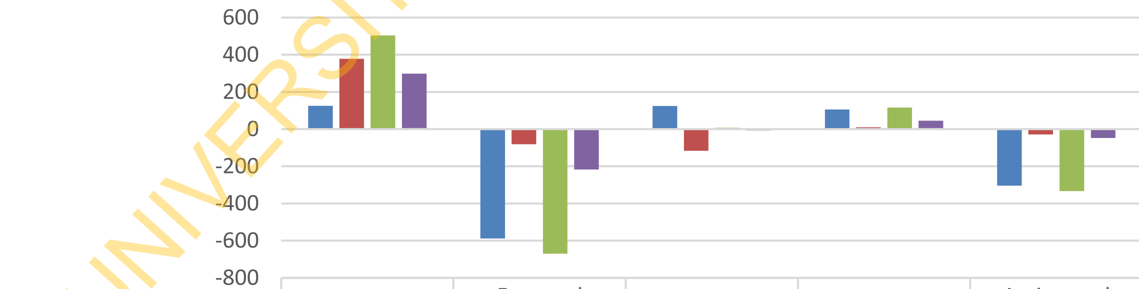


Fig. 3. Map of land cover of Epe coast, Lagos State. (Adapted from [27]).



	Built-up Land	Forested wetland	Sand Fill	Water	Agricutural Land
Change 1984-2002 (km2)	125.2611	-588.0906	124.0875	105.6051	-304.5681
Change 2002-2017 (km2)	378.4644	-81.6975	-116.4321	10.2663	-28.8954
Change 1982-2017 (km2)	503.7255	-669.7881	7.6554	115.8714	-333.4635
Change 2017-2047	297.846	-217.6425	-6.048	45.2151	-47.9394

Change 1984-2002 (km2) Change 2002-2017 (km2) Change 1982-2017 (km2) Change 2017-2047

Fig. 4. Change in land cover extent for Epe coast, Lagos State.

permanently. This practice often eliminates the flora and fauna of such an environment and transforms the coastal terrain from a swampy to a sandy one. Since sand-filled sites are a precursor to any urban development, then, it could be deduced that the reduction in the sand mined land by the year 2017 might be a result construction of buildings and other urban facilities.

There is a general increasing trend in the extent of water bodies from 684.65 km^2 in 1984 to 800.52 km^2 in 2017, with a future increase of 45.2 km^2 in 2047. This is a clear indication of the effect of climate change on the coast. Rising sea level is accompanied by a corresponding advancement of water into the land to inundate or permanently submerge hitherto dry fringing areas. Also, urban development has led to the removal of the vegetation on river floodplains thereby increasing overland flow that encourages creation of larger channel capacity or volume. In addition, depletion of the vegetal cover promotes bank instability thereby encouraging an increase in water body extent.

It is expected that agricultural land extent depleted from 1074.6 km^2 in 1984 through 770 km^2 in 2002 to 741.1 km^2 in 2017. The area extent was further predicted to reduce to 693.2 km^2 by 2047. This is a result of the incessant expansion of built-up land due to the demand for land for residential, commercial and recreational land.

The observed dynamics of land cover is in tandem with Tijani et al. ([22,27] who attributed an increase in the built-up area alongside a decrease in forested wetland and agricultural land in the entire coastline of Lagos metropolis to the influence of urban expansion and rapid population growth and the accompanying deforestation to accommodate the developmental activities like housing, roads and other infrastructural needs.

Land cover dynamics along Igbokoda coast of Ondo State

The land cover classes identified along the Igbokoda coast in Ondo State are far different from the Lagos coast. These classes include built-up land, forested wetland, agricultural land, wetlands, and water body (Fig. 5). These land cover types slightly differ from those of the Epe coast due to the existence of extensive wetland areas and the absence of sand filling activities thereby suggesting that the level of urbanization is quite low. The dominant land cover type in this axis is the forested wetland, a biologically diverse forest that is permanently inundated by water. Dominant plant species in this ecosystem are *Rhizophora racemosa, Rhizophora mangle,* and *Rhizophora harrisonii, Avicennia Africana*, among others.

It is worthy to mention that forested wetland provides wood for building, and for boat and canoe construction; they also serve as excellent fuel as they combust even when wet. Although the spatial extent of this ecosystem undergoes reduction between 1984 and 2017, the rate of devastation is not as significant as that of the Epe coast (Fig. 4). As illustrated in Fig. 5, the forested wetland, which occupies 1513.89km^2 in 1984 underwent a reduction of 202.44 km^2 between the period and 2002, and a further reduction of 100.78 km^2 by 2017.

It was predicted that by 2047, the forested wetland will still be occupying an area extent of 1194.89 km^2, hence, a low depletion trend is expected owing to the low rate of population growth and urban development around this axis of the Nigeria coast. The low rate of urban expansion is further evident in the spatial extent of the built-up land as depicted in Fig. SM2 and Fig. 6 and Built-up land slowly increased from 23.08 km^2 in 1984 through 32.97 km^2 in 2002, to 56.92 km^2 in 2017. More development is anticipated in this area and an expansion of built-up land by 9.03 km^2 is predicted by 2047. The increase in agricultural land from 786.05 km^2 in 1984 to 969.79 km^2 in 2017 might be attributed to an increase in food demand by the relatively increasing population and the need to intensify commercial farming which informs intensive land clearing. The 183.74 km^2 increase in agricultural land use extent is directly related to a corresponding decrease in forested wetlands and wetlands as they must be cleared to give way to farmlands.

Consequently, it is not surprising that the area extent of wetlands decreased from 259.8 km^2 in 1984 through 314.7 km^2 in 2002 and finally to 449 km^2 in 2017. A further decrease of 156.5 km^2 was predicted for 2047 (Table SM2). The land cover class of wetland in this regard relates to light vegetation of shrubs and small trees under hydric substrate condition. They are not as robust as the forested wetland due to anthropogenic disturbances like deforestation and shifting cultivation. Waterbody increased from 44.04 km^2 in 1984 through 87.86 km^2 in 2002, to 152.23 km^2 in 2017. This increment could be attached to the global trend of sea-level rise which causes more hitherto dry lands to be submerged by water from the sea on the one hand, while creeks and river banks are sometimes expanded to accommodate navigational activities, trade, and construction as reported by Numbere [21]. A future reduction of 85.5km^2 has been predicted between 2017 and 2047.

Analysis of land use/ land cover transitional and probability matrices

The output of the Land Change Modeler (LCM) Markov chain is a probability matrix between 2017 and 2047, which indicates the probability of landcover change from one period of time to another period. From Table SM3 and Table SM4, the transition probability and area matrices of Lagos coastal axis at Epe are given that between 2017 and 2047. 80% (842,779 km^2) of build-up land is expected to be preserved, 2% (25,521 km^2) will probably change to forested wetland, 0.2% (2,316 km^2) to change to sand-filled areas, 1.1% (11,069 km^2) to water and 17% (175,005 km^2) to agricultural land respectively. In summary, the adoption of transition matrices in the study has helped to quantitatively estimate the rate of change of land use. The emphasis of transition probability and area matrix revealed that the most striking of the transition along the Lagos coastal axis is the transition of the forested wetland, sand-filled areas, water area and agricultural area to built-up land.

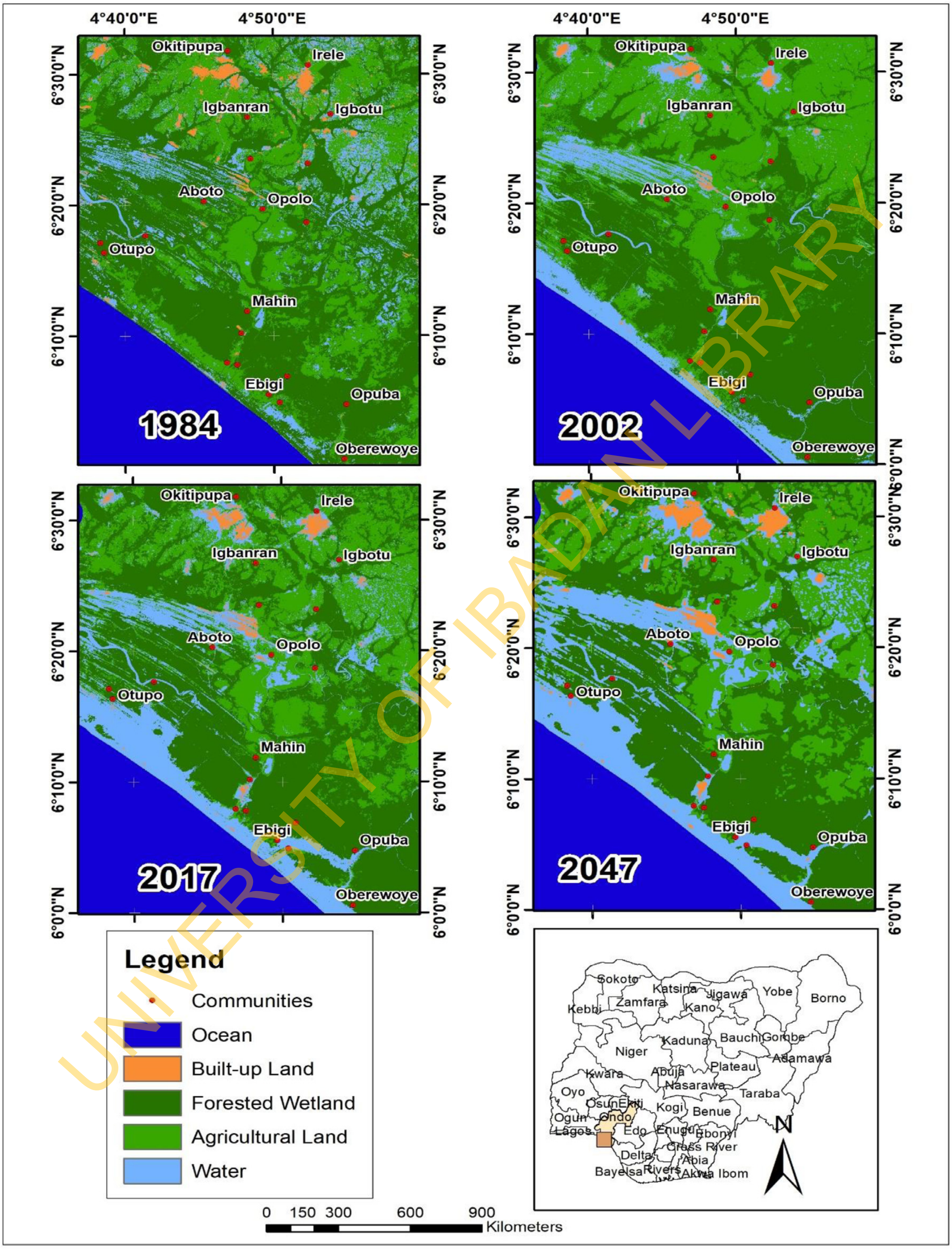


Fig. 5. Map of land cover for Igbokoda coast, Ondo State.

	Built-up Land	Forested Wetland	Agricultural land	Wetlands	Water
Change 1984-2002 (km2)	9.8829	-202.443	48.2976	54.8739	43.8246
Change 2002-2017 (km2)	23.9571	-100.778	135.4419	134.2782	64.3707
Change 1982-2017 (km2)	33.84	-303.221	183.7395	189.1521	108.1953
Change 2017-2047 (km2)	9.03	-15.77	-187.21	156.47	-85.51

Change 1984-2002 (km2) Change 2002-2017 (km2)
Change 1982-2017 (km2) Change 2017-2047 (km2)

Fig. 6. Change in land cover extent for Igbokoda axis, Ondo State.

On the other hand, the Ondo coastal axis at Igbokoda revealed a similar landcover change. 28% (10,146 km^2) of build-up land is expected to be preserved, 9% (3,128 km^2) to probably change to forested wetland, 11% (4,094 km^2) to change to agricultural land, 51% (18,808 km^2) to wetlands and 1.2% (454 km^2) to water in 2047 (Table SM5 and Table SM6).

It is evident from the analysis of the probability and transition matrices of the Ondo axis that the wetlands will increase by 51% which is at variance to the Lagos axis where the built-up area is projected to increase. The probable increase in the wetland area of the Ondo axis might be as a result of its tangential location in the Atlantic Ocean. This allows for an upsurge in the rain-bearing wind into the area and an influx of ocean water into this coastal zone.

Ecological implication of changing land cover pattern of the coastal environments

Although the management of water and ecosystem resources is emphasized by the Sustainable Development Goals (SDGs) for sustainable and equitable development, coastal environments are still experiencing devastation from human-induced and climate-induced changes [27]. Evident from the comparison between Epe and Igbokoda coasts is that the former is a rapidly developing urban center that is beset by the rapid transformation of the natural environment due to the need to reclaim land for human habitation and other developmental activities.

Igbokoda on the other hand is a rural area though increasing in spatial extent, yet there are limited economic activities that can trigger a corresponding change in its ecological productivity. According to Numbere [21], land reclamation along the southwestern coast of Nigeria transits through five stages namely: removal of the mangrove vegetation, compaction of the swamp with heavy machines, white sand pumping from the sea bed unto the shore, sand filling of reclaimed land, and construction activities such as buildings, roads, parks and industries. Each of these stages goes a long way in impairing the coastal ecosystem and its ecosystem services. Sea level rise informed by the global trend of climate change plays an important role in expanding the spatial extent of water bodies in the two coastal locations. As documented by the IPCC Fourth Assessment Report, the 20th century witnessed an average global rise of 1.7 mm in sea level [17]. In addition to increasing the risk of flooding of coastal zones, Hadley [16] reported the potential of rising sea levels at reconfiguring the shape and nature of coastlines. Such modifications are likely to be accompanied by changes in sedimentation and erosion patterns as well as the nature of the coastal ecosystem.

Furthermore, the expansion of agricultural land is also an important driver of land cover change as illustrated in Fig. 3 and 5. This assertion is supported by the findings of Ligate et al. [18] who recognized this as a common trend in the coastal zones of sub-Saharan Africa. The agricultural lands are mosaic of small farm holdings where arable crops are cultivated for sustenance and commercial consumption. On the Igbokoda coast, the land is usually transformed to shrubland when abandoned to fallow. Shrubland succession has also been reported by Fetene et al. [13] and Ligate et al. [18]. The removal of natural vegetation during farming activities significantly impacts the infiltration of water into the soil and percolation into the groundwater system (Ryan et al. 2016). Increased area extent of agricultural lands will subsequently affect the wetlands and increase the extent of open water bodies [24] as observed in Epe and Igbokoda coastal zones. However, deforestation to accommodate developmental activities escalates the risk of flooding [18,23].

Communities in these coastal zones, especially in the Igbokoda axis considerably depend on fuelwood as an energy source, a corollary of which is forested wetland disturbance and degradation. Fuel woods are used by households and cottage industries for cooking, lighting and, heating and combustion. Other drivers of coastal forest loss as identified by Ligate et al. [18] in the coastal region of Tanzania include land clearance for sand mining and salt extraction, coastal aquaculture and livestock pressure. The modification of the morphology of water bodies through sand mining and dredging alters the hydrological regime and flow dynamics of river systems. These anthropogenic activities hollow out the sea bed, eliminate the benthic species community, and dehydrate the intertidal regions leading to the death or migration of amphibious species [21]. Developmental activities such as the construction of the Eko-Atlantic city and Dangote refinery among others on the rapidly urbanizing coast of Lagos Epe suggest the need to evolve an effective framework for sustainable management of coastal land use and water resources [27].

Solution-based Sustainable Coastal Management practices

The alarming effects of urbanization coupled with unstoppable changing climate which is driving incessant flooding of the coastal cities along the West Africa coasts requires a rethink and strategies for sustainable coastal management. The Southwestern coast of Nigeria which this study emphasized has revealed the comparative land cover changes with accompaning rapid urbanization at the Lagos end of the study area. The observed changes are not different from other parts of West Africa coast and other coastal cities of most developing countries worldwide. Overall, this study suggest that to prevent further degradation, sustainable coastal management approach that involve wider coastal zone in terms of people and their environment livelihood, social and cultural well-being, safety from coastal hazards, as well as minimising environmental impacts is necessary [25].

A well-engineered ecological control, flood plain and buffer zone protection, deep and shallow drainage system and proper waste / effluent management should be a critical part of the coastal cities to ensure sustainable management of the coastal zones, most especially for a densely populated city like Lagos, Nigeria.

More importantly, these would be helpful as an adaptive strategy for climate change, especially for impacts mitigation and management. Developing a legal framework that will ensure policy implementation and enforcement for proper regulation of the above drivers for sustainable coastal zones management will be an overall goal.

Conclusion

The incessant modification of the natural environment to accommodate urbanization, population growth and the attendant demand for environmental resources continue to be a subject of global challenge. In a bid to evaluate this situation, this study analysed the dynamics of land cover and predicted future extent land cover pattern at the Epe and Igbokoda areas on the coast of southwestern Nigeria. In particular, the findings show that the severe devastation of forested wetlands is welcome by a corresponding increment in the spatial dimension of built-up lands, while agricultural lands respond to the pattern of population growth and food demand. Water bodies are significantly influenced by the joint operation of sea-level rise and flooding which is are agents of climate change and human activities like deforestation, land reclamation and sand mining. The observed situation of changing land cover patterns in coastal areas is usually accompanied by the impairment of environmental quality. This may become more severe in the absence of proper land use development planning. The existing situation warrants proper adherence to the various sustainable coastal zones management options with emphasis on ecological conservation and protection policies to preserve the impoverishing coastal environments. The enforcement of land use and development planning regulations is pertinent in curtailing the rapid urban expansion and wetland devastations.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2022.e01286.

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