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THE ENVIRONMENTAL IMPACT OF SHORELINE CHANGES AND LAND USE/LAND COVER CHANGE DETECTION IN THE NIGER DELTA REGION USING GEOSPATIAL TECHNOLOGY

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ABSTRACT

Managing resources in marine areas necessitates a thorough understanding of coastal processes. This study examines the changes to the shoreline between 1990 and 2021 and assesses how those changes have impacted land use and land cover (LULC). In Yenagoa, Bayelsa State, Nigeria, over a period of 31 years, shoreline changes in the Ikoli River, River Nun, and Oxbow Lake revealed notable oscillations caused by erosion. In particular, band ratios are used to classify LULC maps for each district across the relevant years. The shoreline along the River Nun ranges from 31% to 35%, with 2013 being the highest; along the Ikoli River, it is 33% to 35%, with 2021 being the highest; and along Oxbow Lake, it is 21% to 35%, with 2021 being the highest, according to accurate evaluations of the United States Geological Survey datasets using ArcGIS software. Due to sand mining, boat traffic, heavy rain, fish farming, and oil and gas operations in the area, LULC predicts a sharp decline in vegetation and bare land from 1990 to 2021 and an increase in built-up areas and waterbodies. The socioeconomic risk from environmental stressors and climate change is identified by LULC. Geospatial is useful in coastal defenses and sustainable landuse strategies.

Contribution/ Originality: There are few geospatial mapping tools that can depict zones of shoreline accretion and erosion over time. Coastal managers can effectively plan coastal zone management for the region by using maps of shoreline evolution and LULC created by understanding the area's vulnerability to changes.

1. INTRODUCTION

Shoreline represents the border between land and water body, which is prone to change resulting from the many coastal processes, e.g., nearshore circulation, waves, currents, tides, storm surges, accretion, erosion, and anthropogenic activities such as dredging, mining, water extraction, construction, etc. Boak and Turner [1]. According to Pandian, et al. [2] to reach equilibrium, shorelines have the propensity to change shape over time in line with their capacity to retain or lose sediments. Therefore, in the context of coastal vulnerability, eroding coastlines and accreting coastlines are considered highly vulnerable and less vulnerable, respectively because accretion provides additional land area seawards while erosion results in loss of land and other natural and manmade resources along the shoreline. Land use describes how the land has been utilized (such as settlements, infrastructure, industry, agriculture, etc.) Land cover, on the other hand, refers to the physical features on the earth's surface of an area, defined in terms of the distribution of vegetation, water, soil and other features [3].

Consequently, a healthy shoreline is critical to the quality of life (humans, plants, and animal species) habitation along the coast. Therefore, monitoring changes in the shoreline allows the identification of nature and processes (both natural and anthropogenic) prevailing and responsible for the land use/land cover changes in different areas of the shoreline. This will help in preferring management measures. Shoreline delineation is an important exercise for coastal zone management, watershed definition, flood prediction, etc. Although common ground surveying methods are known to be more accurate for shoreline delineation, they are often time-consuming and prove to be nearly impossible for a large coastal belt [4]. On the other hand, data from Remote Sensing (RS) can offer reasonably accurate information due to their spatial and temporal scales. Geographical information systems (GIS) can be used to analyze such data by measuring and comparing previous and current shoreline locations.

Several writers have utilized geo-informatics to investigate morphing coastlines and related issues. Muttitanon and Tripathi [5] examined LULC variations around Ban Don Bay in Thailand using data from Lansat 5 TM. Siddiqui and Maajid [6] conducted a multi-temporal principal component analysis (PCA) of coastal evolution in Pakistan between 1973 and 1998 using data from the Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM). Tracking the geomorphologic change in Iran's Hendijan River Delta required the use of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data, according to Ghanavati, et al. [7]. The coastal erosion and accompanying shoreline change along the Chandipur coast in the Balasore district of Orissa were studied by Mukhopadhyay, et al. [8] using multi-temporal satellite imagery from 1990 to 2010. The pattern of erosion and accretion along the Mangalore coast was studied by Kumar and Jayappa [9]. In western India, a shoreline detection exercise was conducted from Karwar to Gokarna by Choudhary, et al. [10]. Gupta [11] used RESOURCESAT-1 Linear Imaging Self Scanning (LISS)-III to monitor shoreline changes in the Gulf of Khambhat. In the context of Bayelsa state, Nigeria, Landsat TM and ETM+ images were analyzed using GIS to study shorelines in the State Adebola, et al. [12]. Bariweni and Andrew [13] identified logging as the primary cause of decreasing land cover in the Wilberforce Island of Bayelsa state, in a study that involved a primary source (Questionnaire) and a secondary source (analyzing Landsat 7 and Landsat 8 images using Quantum Geographic Information System (QGIS)) of data.

To be able to examine and forecast the extent of ecological and geomorphological changes that have taken place and would take place, respectively, a huge number of site-specific investigations of shorelines and environs are required due to their associated complexities, even at the regional scale [14] The current LULC of an area is a cumulative output of the interaction between variables and processes that are both natural and anthropogenic. Researchers have shown that remote sensing (RS) and geographic information systems (GIS) can be useful for assessing the spatial and temporal dynamics of LULC and other natural processes [5, 6, 15-19]. In this way, the resources allow for the creation of data stores that improve decision-making across a range of coastal zone applications.

Despite the economic importance of the Ikoli River owing to its strategic location within the capital city of Bayelsa state, no specific records on its shoreline dynamics can be recognized in the literature. Consequently, this study aims to achieve two key goals. In order to identify zones of accretion and erosion along the shoreline for the time periods of 1990, 2013, and 2021, it is first necessary to analyze the shoreline evolution along the Ikoli River in Bayelsa State, Southern Nigeria. The LULC for the same time periods is then quantified and categorized. Understanding the area's susceptibility to changes required identifying the LULC of the region. Once more, the study's major goal is to create shoreline evolution and LULC maps that coastal managers may use to efficiently plan coastal zone management for the region.

1.1. Study Area

The Ikoli River extends from within Yenagoa and Local Government Area (LGA) Area to parts of Ogbia LGA, both in Bayelsa State, southern Nigeria. The river lies within latitudes 4⁰53'00" N and 4⁰58'30" N, and longitudes 6⁰13'30" E and 6⁰17'30" E (Figure 1). However, this study focused on the Yenagoa part of the river. The area lies within the freshwater geomorphic unit of the Niger Delta sedimentary basin [20]. Yenagoa LGA can be accessed through the East-West major road and several other minor roads from smaller bordering villages as well as creeks and tributaries of the River Nun and Orashi River. These flow channels including the Ikoli River drain Yenagoa and empty into the Atlantic Ocean.

Yenagoa lies within the lower delta plain thought to have developed during the Holocene period from the accumulation of Quaternary sedimentary deposits, with alluvium being the major geological characteristic of the area. Yenagoa LGA is within the Niger Delta basin known by three Tertiary subsurface lithostratigraphic units (Akata, Agbada, and Benin Formations), with inconsistent superficial Quaternary sediments [21]. From bottom to top, the Akata, Agbada, and Benin Formations demonstrate a gross coarsening-upward deposition, of marine, deltaic, and fluvial environments, respectively [21, 22]. The top Benin Formation is the water-bearing unit of the Niger Delta basin [23] with its clay intercalations creating a multi-aquifer arrangement with shallow unconfined aquifer occurring at depths of about 20 m to 40 m [20, 24, 25].

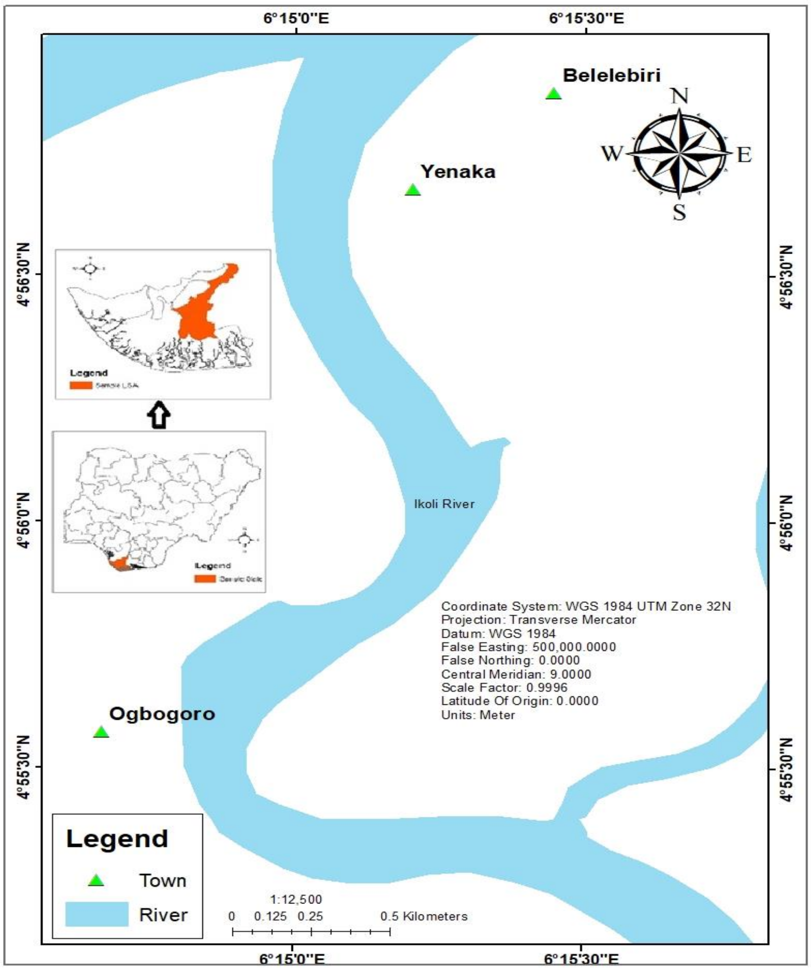

Figure 1. Map of the study area.

2. MATERIALS AND METHOD

Geographical Information System and Remote Sensing techniques are applied by using image classification and the Extract tool and Microsoft excel.

2.1. Limitations

Cloud cover in the Niger Delta region couldn't allow good access to Landsat 5 and 7 for 2000.

2.2. Data Collection

For 30 years, from 1991 to 2021, the Ikolo River's coastline was analyzed for how it may evolve. Satellite images taken at a variety of times throughout the year are analyzed to determine how the coastline has changed during three separate periods. The United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/) was used to compile the multi-temporal Landsat satellite data shown in Table 1. The data presented in Table 1 covers the years 1991, 2016, and 2021. Using satellite data in December and January is ideal for avoiding atmospheric issues like mist and haze. Therefore, December and January satellite data were gathered for each research year.

Table 1. List of data satellite collected.

Satellite Data	Date	Spatial Resolution (m)	Source
Landsat 5	28/02/1990 Path: 189, Row: 57	30	https://landsate usgs.gov
Landsat 8	26/12/2013 Path: 189, Row: 56	30	https://landsate usgs.gov
Landsat 8	6/1/2021 Path: 189, Row: 56	30	https://landsate usgs.gov
Google Earth Imagery	06/02/2021	3m	https://google.com/earth

2.3. Data Processing

Stage 1

The area of study was selected using Google Earth Pro before setting ArcGIS software in a projected coordinate system in World Geodetic System (WGS) Zone N32 and importing the area selected from Keyhole Markup Language (KML) into the ArcGIS environment, where selection and clipping are done to get the area of study.

Stage 2

The technique employed for land use map changes is the Post Classification method, which is employed for this study. This approach involves rectification of the classified images independently followed by the generation of thematic maps for the area under study. A comparison of corresponding labels is then carried out to identify the areas where change has occurred. If the classification result is properly coded for time T1, T2 and T3 change maps which show a complete matrix of change can easily be obtained. Using this method, series data from at least two dates is separately classified, thereby minimizing the challenges of normalizing data for sensor and atmospheric differences. ArcGIS for the processing of land use maps uses image analysis tools, layer stake, and band combination, dataset composite of near-infrared (5), red (4), and green (3), subset and defining of the training sites, extraction of signatures from the image, and then classification using supervised classification. Finally, Maximum Likelihood Classification (MLC) methods were applied to analyze land-use changes and study the changes in terms of sand mining before exporting the data and importing it into the Microsoft environment for statistical analysis.

Stage 3

Extraction of shoreline was done by converting raster to polygon by using the conversion tools in the Arc tools box and then clipping by using the selection tool before exporting.

Stag 4

The qualitative data collected, were analyzed with the aid of Tableau software and Microsoft excel to provide statistics and the formation tables, plotting of pie charts, bar graphs, etc.

3. RESULTS AND DISCUSSION

3.1. Land Use/Land Cover Change

The remote sensing images acquired and analyzed using the GIS tool are presented in Figure 2. To identify the shoreline changes and LULC evolution that have occurred over time, the study area is classified into four bands: water bodies, bare land, built-up areas, and vegetation.

As previously stated, the Ikoli River cuts through the capital city (Yenagoa) of Bayelsa state, which was established in 1996. Several communities are located along the coastline of the Ikoli River. Before 1996, these communities were very small settlements, like hamlets and fishing camps, and most of the land area were bare or covered by vegetation as can be seen from the LULC image of 1990 in Figure 2. However, over the years these communities have continued to expand as their population constantly grows since the creation of Bayelsa state in 1996. New homes have progressively been developed to accommodate the population influx to the area and other infrastructural development have also been built. Economic activities have also expanded around the coastline. As a result, the built-up area has steadily increased as the bare land and vegetation areas decreased as demonstrated by the 2013 and 2021 satellite images in Figure 2.

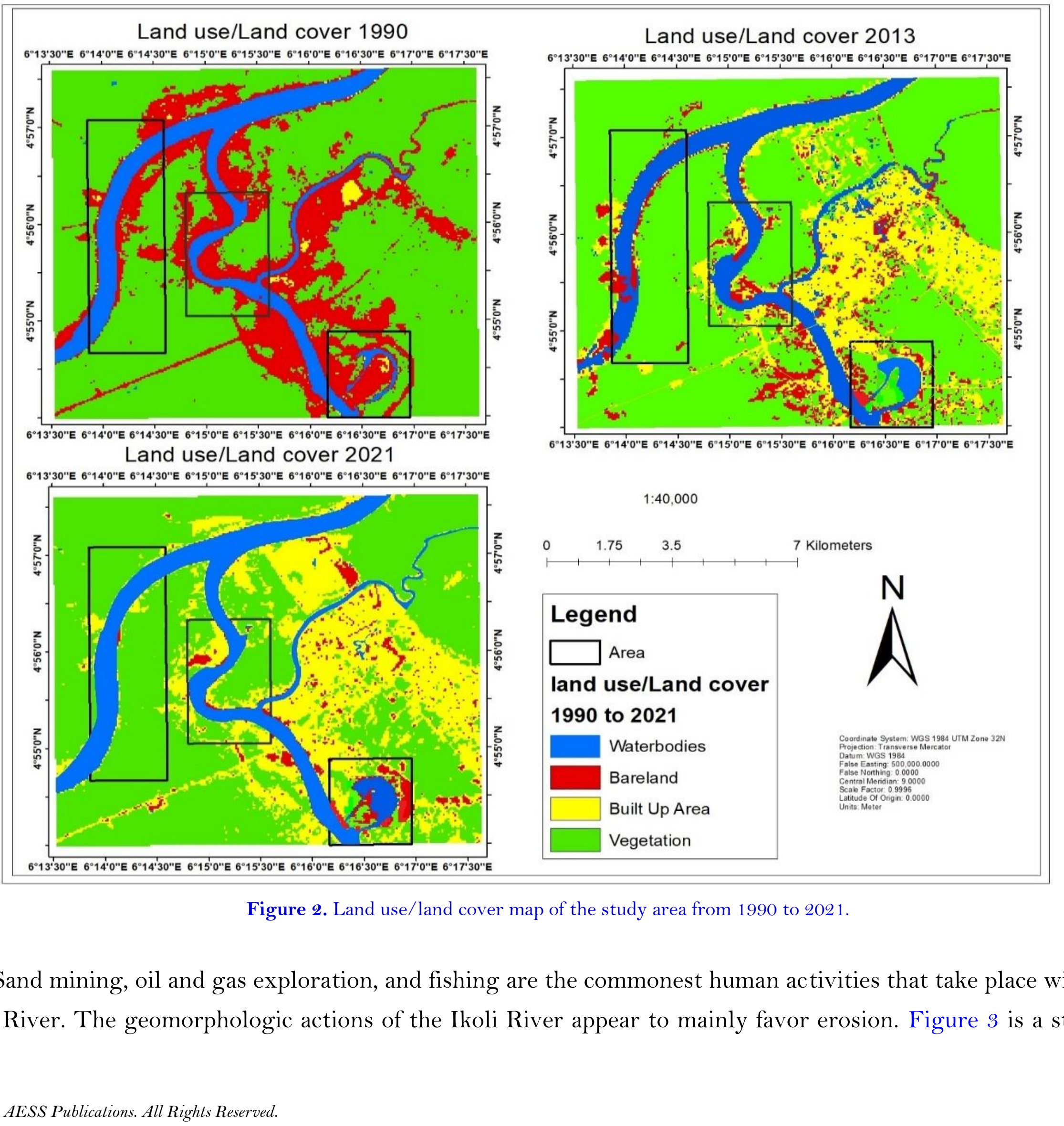

Figure 2. Land use/land cover map of the study area from 1990 to 2021.

Sand mining, oil and gas exploration, and fishing are the commonest human activities that take place within the Ikoli River. The geomorphologic actions of the Ikoli River appear to mainly favor erosion. Figure 3 is a statistical illustration showing the changes occurring in the four bands classification. It can be seen from the waterbody has steadily expanded over the years under review. It is suggested that the activities of sand mining as well as natural river actions are responsible for the shoreline degradation that has resulted in the increasing waterbody from about 5 km^2 in 1990 to about 6 km^2 in 2021 (Figure 3 and Table 2) representing a change from ~10 % to ~12 % of the total area, respectively (Figure 4 and Table 3).

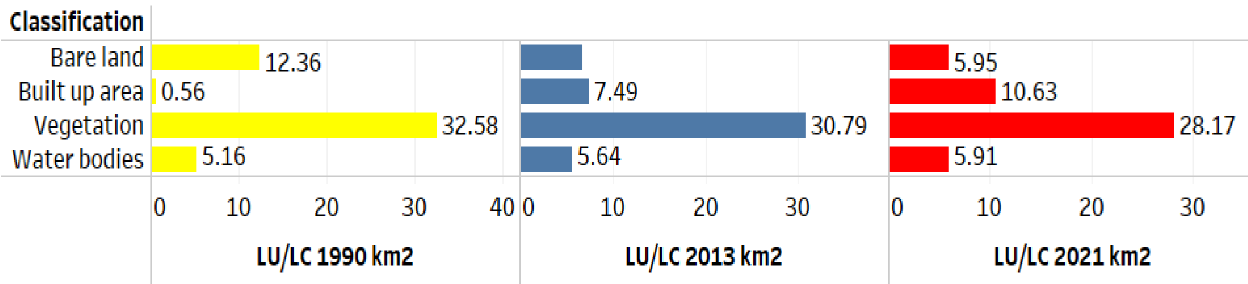

Figure 3. Bar chart showing statistical results from land use/land cover classification from 1990 to 2021.

Table 2. Statistical results from landuse/land cover classification from1990 to 2021.

Classification	LU/LC 1990 km²	LU/LC 2013 km²	LU/LC 2021 km²
Water bodies	5.16	5.64	5.91
Built up area	0.56	7.49	10.63
Bare land	12.36	6.74	5.95
Vegetation	32.58	30.79	28.17
Total area	50.66	50.66	50.66

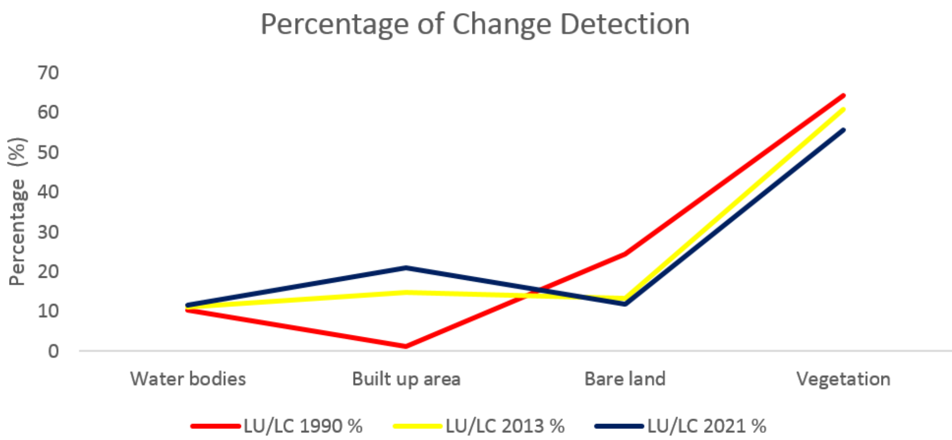

Figure 4. Graphical presentation of the percentage of landuse/land cover change detection.

Table 3. Percentage of landuse/land cover change detection from 1990 to 2021.

Classification	LU/LC 1990 %	LU/LC 2013 %	LU/LC 2021 %
Water bodies	10.19	11.13	11.67
Built up area	1.11	14.78	20.98
Bare land	24.4	13.3	11.74
Vegetation	64.31	60.78	55.61

3.2. Shoreline Detection

Changes in the coastline should be detected as soon as possible since they have far-reaching consequences for marine ecosystems, such as the creation of shallow marine topography, the disappearance of land, and the impossibility of navigation during the dry season. The resultant flooding causes human and material casualties. Therefore, Table 4 shows that the coastline in 1990 was 5.16 km2 (31.03%), in 2013 it was 5.61 km2 (33.73%), and in 2021 it will be 5.86 km2 (35.24%), and Table 4 , Figure 5 and 6 demonstrate that the shoreline has grown from 1990 to 2021, showing a loss of land.

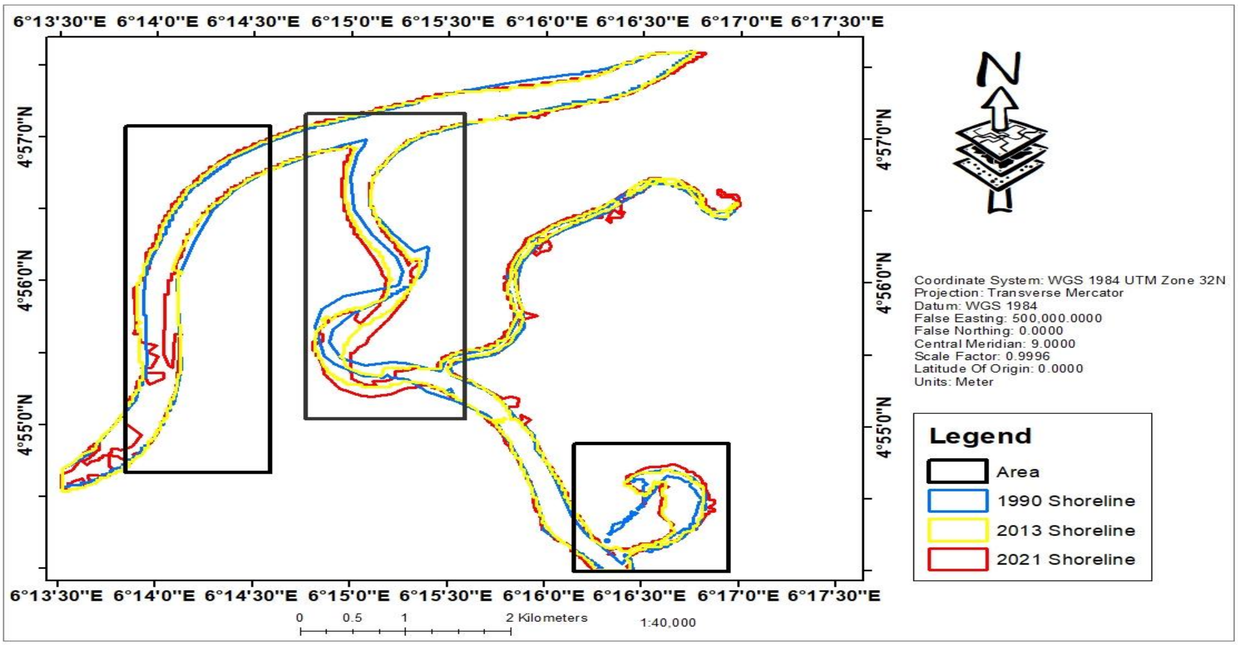

Figure 5. Shoreline change along River nun, Ikoli River, and Oxbo Lake in yenagoa, Bayelsa State from 1990 to 2021.

Table 4. Result of shoreline changes in area and percentage in the study area from 1990 to 2021.

Shoreline Changes	Area (km2)	Percentage (%)
Shoreline 1990	5.16	31.03
Shoreline 2013	5.61	33.73
Shoreline 2021	5.86	35.24

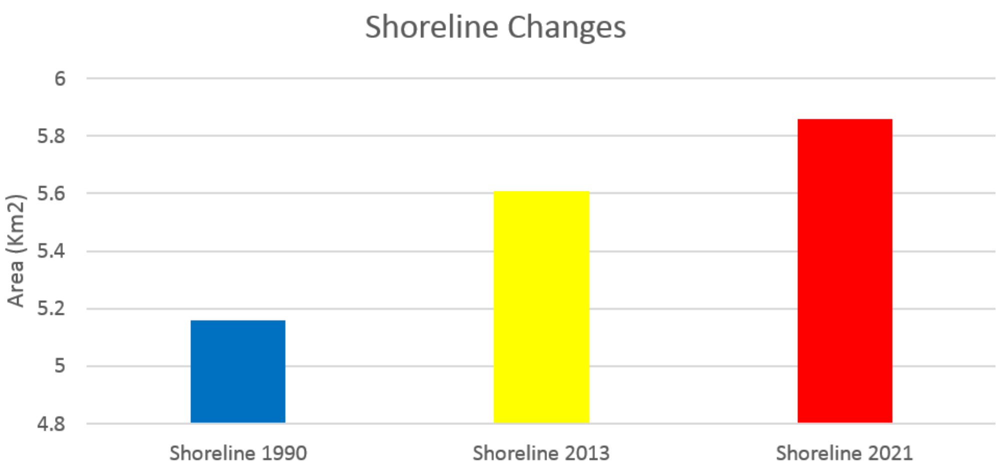

Figure 6. Bar chart showing statistical results from shoreline changes from 1990 to 2021.

3.3. Shoreline Changes of River Nun, Ikoli River and Oxbow Lake

The analysis of shoreline changes from Landsat imagery is vital for shoreline changes over time, and it is used in the monitoring of shoreline changes that may be a result of human activities such as sand mining, movement of boats, oil and gas operational activities due to the action of waves on the shore, flooding, etc., resulting in the loss of infrastructure such as buildings, roads, and even electricity poles, which may result in death. The result of the analysis of shoreline changes in Tables 5 to 6 were studied for 31 years to understand the changes that have taken place over the years in Ikoli River, River Nun, and Oxbo lake in Yenagoa, Bayelsa State Nigeria as a result of sand mining activities. The result in the major area of the shoreline changes was mapped into three segments indicated in Figure 7, 8, and 9. Therefore, in Table 6 and Figure 11 , from 1990 to 2021 in River Nun, the percentage of the area of the shoreline is 34% for 1990, 25% for 2013, and 31% for 2021 this shows that there is more erosion in 2013 than in 1990 and 2021 in Figure 10. The area in Ikoli river contain 1.41 km of 20% in 1990 in Table 6 and Figure 12, while in shoreline 2013 contain 1.59 km2 of 33% and 1.74 km2 of 37% in 2021 which indicates more erosion activities are present in 2021 than in other years and finally Oxbo lake in 1990 area of the shoreline is 0.3 km^2 of 21% in Figure 13 and Table 5. While in 2013 is 0.52 km2 of 35% and in 2021 is 0.65 km2 of 44% this implies that the shoreline area increased drastically from 1990 to 2021 indicating the effect of oil and gas operation activities and sand mining in the area.

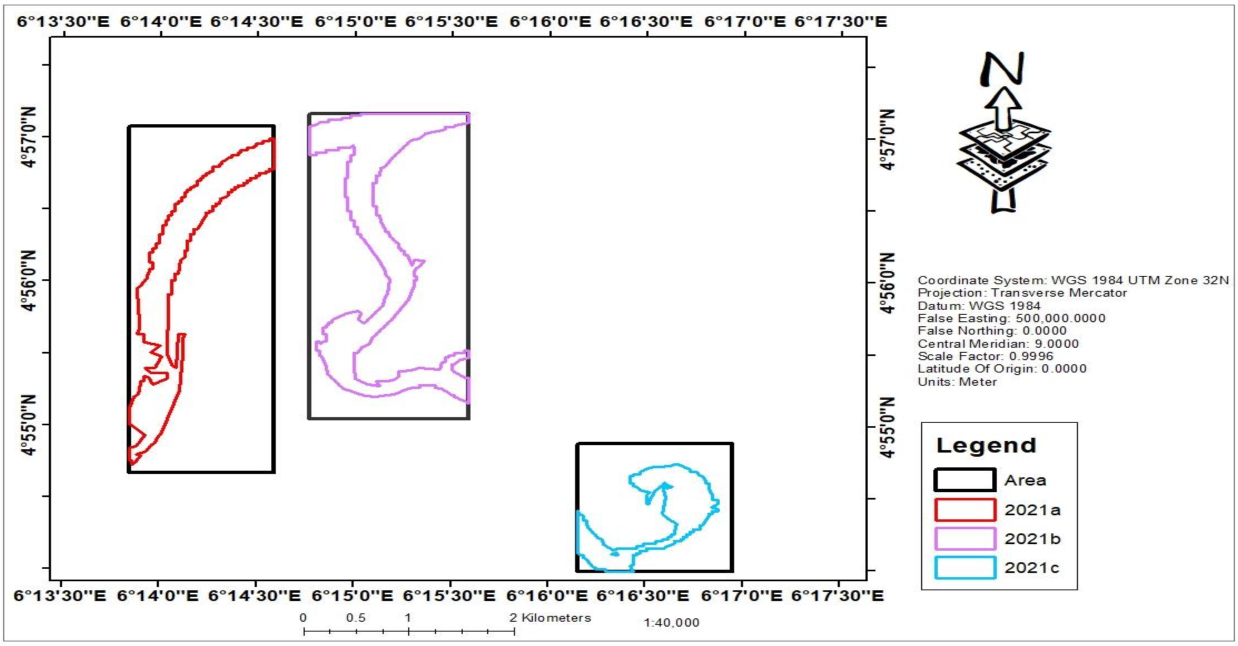

Figure 7. Shoreline changes from 1990 to 2021 group a.

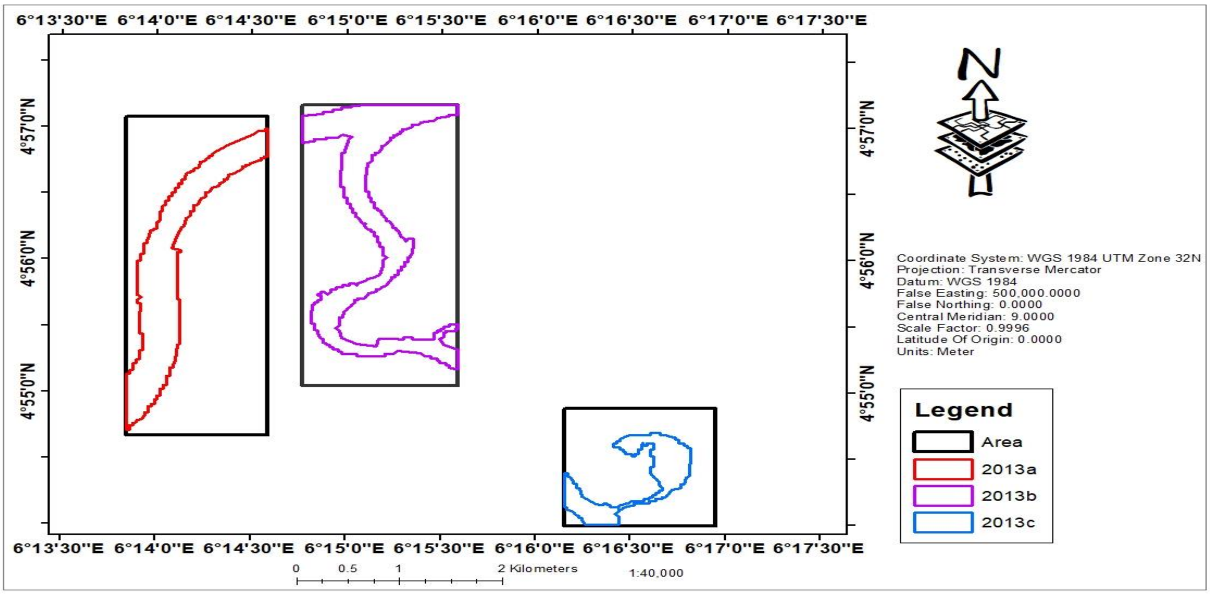

Figure 8. Shoreline changes from 1990 to 2021 group b.

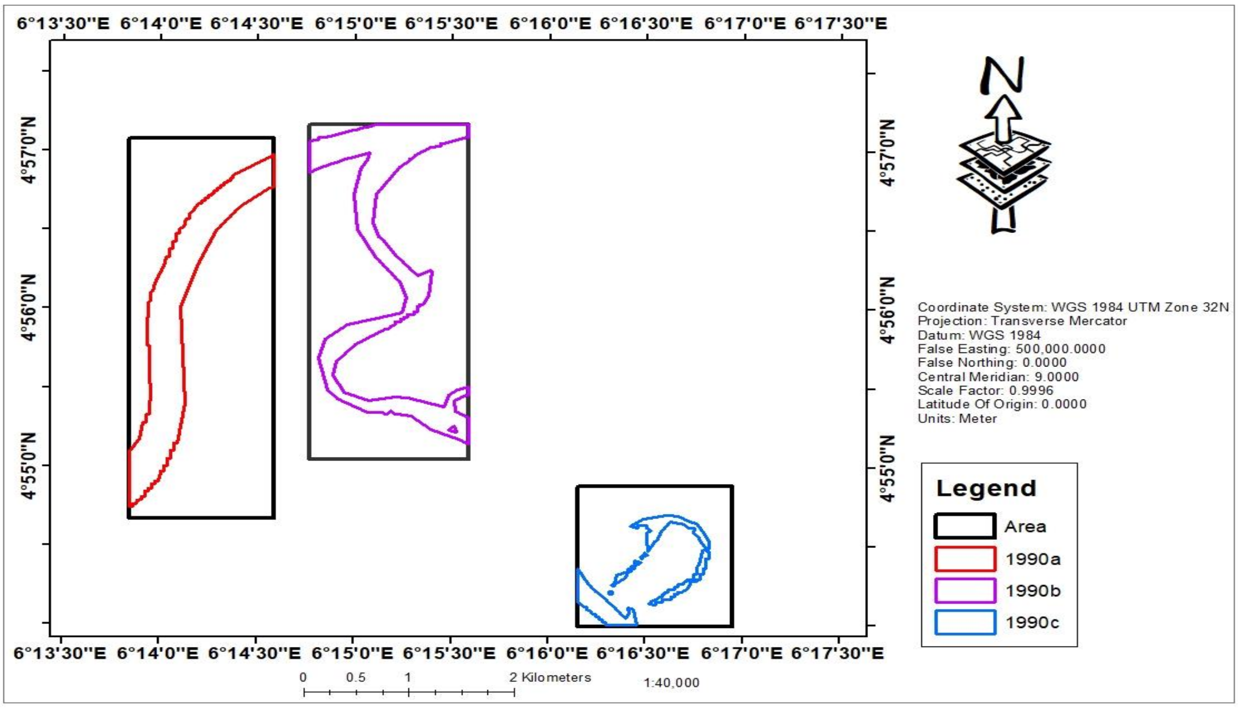

Figure 9. Shoreline changes from 1990 to 2021 group c.

Table 5. Statistical results from shoreline changes from1990 to 2021 in each group.

Shoreline Changes	Area (km2) in River Nun (a)	Area (km2) in Ikoli River (b)	Area (km2) in Oxbo Lake (c)
Shoreline 1990	1.34	1.41	0.3
Shoreline 2013	1.42	1.59	0.52
Shoreline 2021	1.25	1.74	0.65

Table 6. Percentage of shoreline changes from1990 to 2021 in each group.

Shoreline Changes	Percentage (%) in River Nun (a)	Percentage (%) in Ikoli River (b)	Percentage (%) in Oxbo Lake (c)
Shoreline 1990	33.42	29.75	20.41
Shoreline 2013	35.41	33.54	35.37
Shoreline 2021	31.17	36.71	44.22

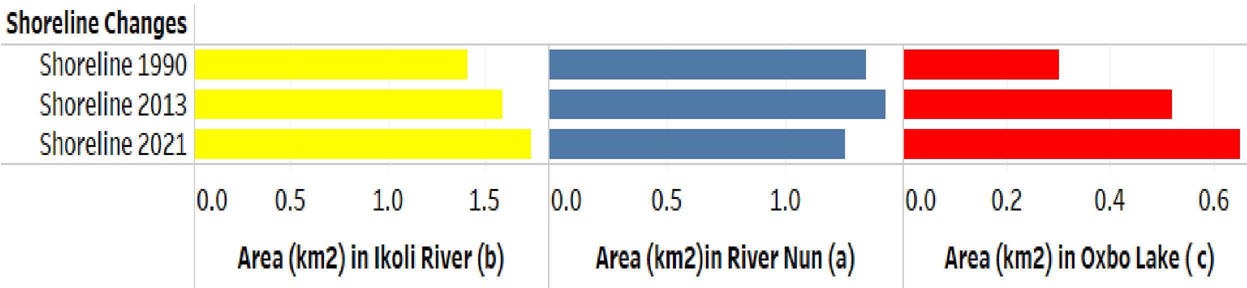

Figure 10. Bar chart of shoreline changes from1990 to 2021 in each group.

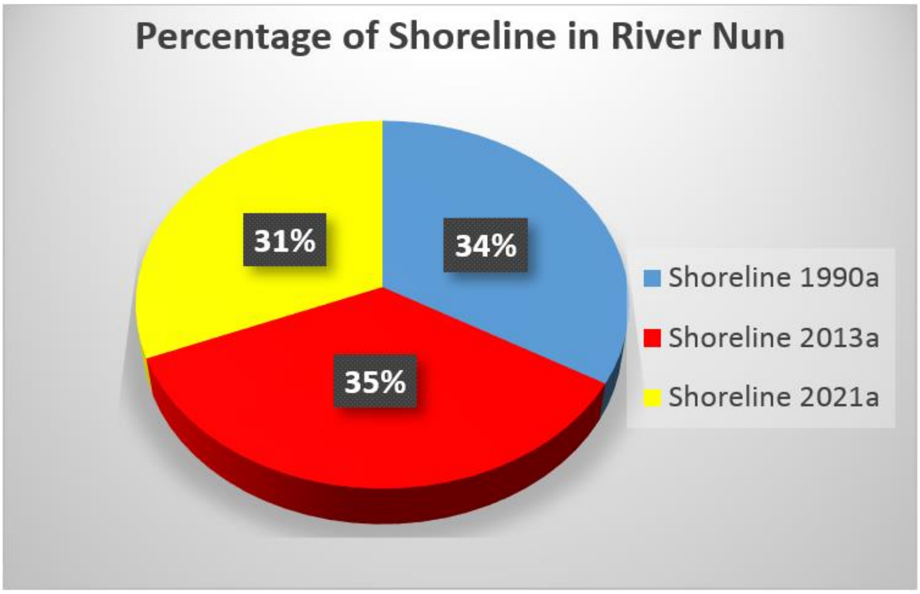

Figure 11. Percentage of shoreline changes in the group a.

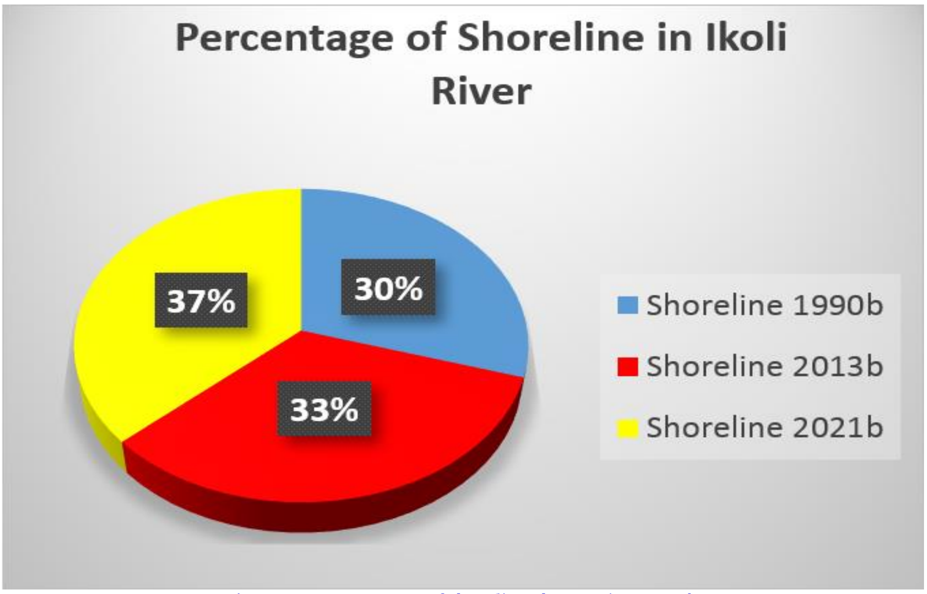

Figure 12. Percentage of shoreline changes in group b.

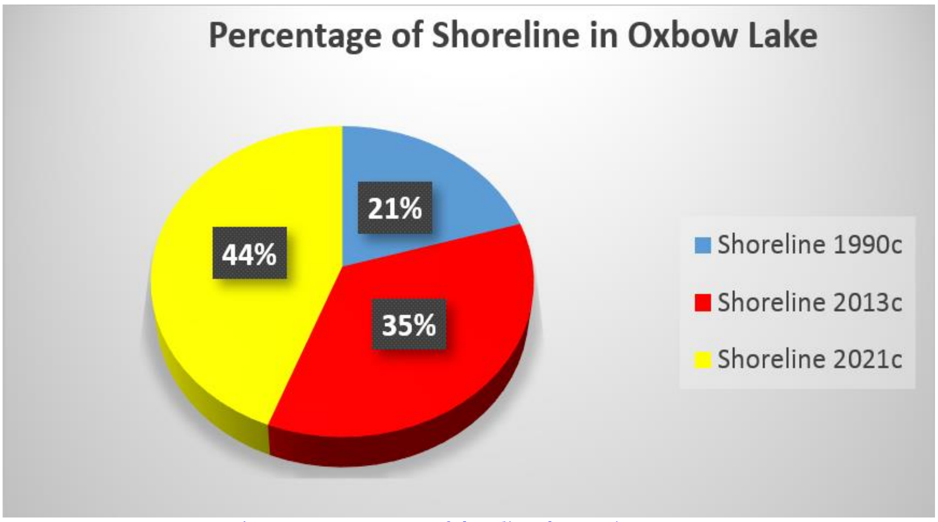

Figure 13. Percentage of shoreline changes in group c.

4. CONCLUSION

The purpose of this research was to investigate the dynamics of shoreline alteration along the Ikoli River, River Nun, and Oxbow Lake in Yenagoa, Bayelsa State, Nigeria, and to assess potential causes. According to the data collected for this research, diminishing shorelines pose a serious threat to future generations. It is clear that urbanization puts enormous strain on the coastlines close by for all of these categories. In addition, future environmental deterioration along these beaches might disturb the regular functioning of the environment, as shown by the LULC maps, which demonstrate that these groups cover vulnerable mudflat habitats. The development of a workable strategy for the conservation and restoration of these natural systems requires a better understanding of these regions, and it is proposed that enhanced remote sensing (high resolution data) and GIS tools, in addition to field surveys and numerical modeling, can achieve this goal. Finally, decision-makers will be able to identify susceptible locations and create more effective responses to coastal challenges with the aid of the current study of shoreline changes and the mapping of LULC.

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Authors' Contributions: All authors contributed equally to the conception and design of the study.

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