Diminishing Coastal Vegetation in Parts of Rivers State：An Emphasis on Mangrove Depletion

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Abstract
Mangrove vegetation in the Niger Delta has been rapidly declining due to anthropogenic activities. Estimating the extent of mangrove depletion has become a major theme amongst environmentalist in this region. The study was designed to show the extent of mangrove depletion in Eagle Island in Port Harcourt Rivers state, Nigeria between 1993 and 2013. To achieve this, geospatial tools and techniques were deployed and utilized during the analysis. Landsat TM images for 1993, 2003, and 2013 were used for this study. The images were analyzed to classify the land use in the area; examination of land use and land cover changes between 1993 and 2013 ultimately showed that there were significant changes due to the depletion of mangrove cover within this coastal environment. A supervised classification method was adopted to classify the Landsat imageries into six (6) classes or categories using ArcGIS ArcMap 10.2 and Erdas Imagine 9.1 GIS software. The investigation shows that especially mangroves have been impacted profusely as a result of human activities. Between 1993 and 2003 there was a 14% decrease in mangroves, a 34% decrease in mangroves between 2003 and 2013, and a 47% cumulative decrease between 1993 and 2013. This investigation rightly points out that there is a significant loss of mangrove forests hence an urgent need for a balance between human development, land use planning, and conservation of biodiversity elements as the area faces several environmental challenges fueled partly by the pressures caused by human activities such as housing development, road construction, economic development and demographic changes. Therefore, recommendations such as mass sensitization and awareness on the demerits of unstructured development, encouraging community participation, and instituting an integrated coastal zone management program were highlighted to mainstream sustainable use of coastal biodiversity resources.
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1. Introduction

The Niger Delta Mangrove forest is the 4th largest mangrove ecosystem all over the world, behind those of Indonesia, India and Brazil (Onwuteaka & Uwagbae, 2018). It occupies a total land area of about 7,386kmsq, and stretches from the Cross Rivers (Southern Nigeria) to the Badagry River (South-western Nigeria), with a total shore length of about 853km (Nwilo & Badejo, 2005; Oyebade *et al.,* 2010). Situated along the Gulf of Guinea, its tidal dynamics are influenced by the daily rhythm of the Atlantic Ocean. This key ecotype is well known as a precursor to the effects of global warming and ozone layer depletion (Taillardat *et al.,* 2020; Das, 2023; Zimmer & Helfer, 2023). This is due to its ability to sequester carbon compounds both in the leaves and in the soil, as compared with other forest vegetation (Inoue, 2009). Additionally, it serves as a habitat to certain critically endangered fauna species, provides several ecosystem services in the form of food, fuel and tannin provision, shoreline protection, and fish breeding site, and has a great potential for ecotourism (Akanni *et al.,* 2018). Despite these tremendous benefits to the region, this ecosystem has been on the decline since the period of industrialization. Anthropogenic activities such as irrational wood harvesting both as fuel wood and for construction, land reclamation for agriculture and road infrastructure, and crude oil pollution from oil mining activities are just but a few of the activities that are threatening the sustainability of this ecosystem. The need for assessment of biodiversity has remained one of the major themes of environmentalists for many years. However, after the Rio's Earth Summit, it has become the main theme for not only ecologists but the whole biological community, environmentalists, planners, and administrators (Ronnback *et al.,* 2007). As many countries including Nigeria are party to the Convention on Biological Diversity, each nation has the responsibility to assess, document, and monitor the species of plants and animals occurring in their respective countries, evaluating the biodiversity properly and evolving suitable management strategies for conserving the biodiversity which is often described as the Living Heritage of Man (FAO, 2003). This has not been the case as, despite their significance in providing ecological and economic services, mangroves are being lost at the rate of about 1% per year globally (FAO, 2005). Remote sensing, GIS, and associated data methods have been used and applied globally for studying, evaluating, and mapping mangrove ecosystem distribution, health status, and changes within mangrove ecosystems (Giri *et al.,* 2011; Kuenzer *et al.,* 2011). The ability to assess biodiversity forecast land use and land cover change and ultimately predict the consequence of change will depend on our ability to understand the past, present, and future state of land use and land cover change (Oyinloye *et al.,* 2011). Additionally, this system (GIS) has been applied to land use and land cover change analysis, detection, and monitoring all over the world (Giri *et al.,* 2015). Mattikalli (1995), applied Remote Sensing and GIS to the land use of the River Glen catchments in England by acquiring data from 1931 to 1989. His work revealed that much of the grassland changed to arable land during the study. Similarly, Xiao *et al* (2006) used image processing and analysis in a GIS environment to assess spatial change in urban land use patterns and population distribution. More so, Onwuteaka *et al.* (2016) deployed some selected GIS tools in delineating available mangrove areas in Asarama community in Rivers State. This effort though laudable had a limited scope and cannot be used as a yardstick to make predictions about the current state of mangrove vegetation in the state. Hence, this study aims to reveal the extent of mangrove destruction and availability in Rivers State with the use of GIS.

2. Material and Method

2.1 Study area

The study was conducted at Eagle Island which is located on the south-west of Port Harcourt, bounded on the north by the Rivers State University of Science and Technology, Nkpolu-Orowurukwu area of Diobu Port Harcourt, and surrounded by the Elechi Creek. It is located at the upper reach of the Bonny estuary of the eastern Niger Delta, Nigeria, and lies within longitude 40 35" and 40 5" N and latitude 70 00" and 70 53" E (Fig 1 & 2).

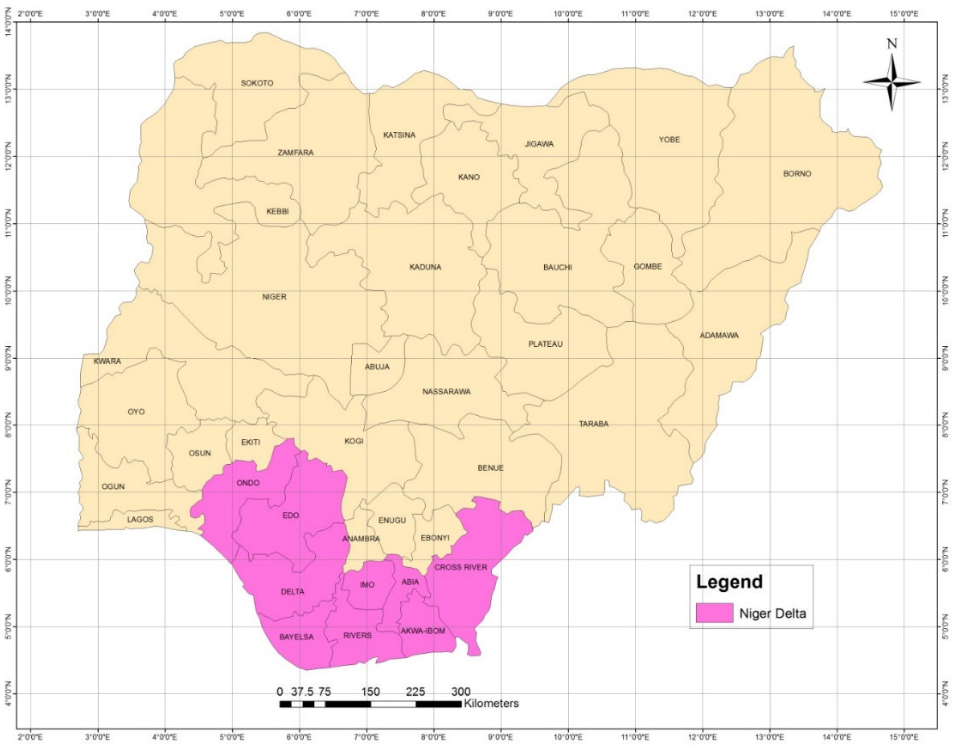

Figure 1: Map of Nigeria showing the Niger Delta

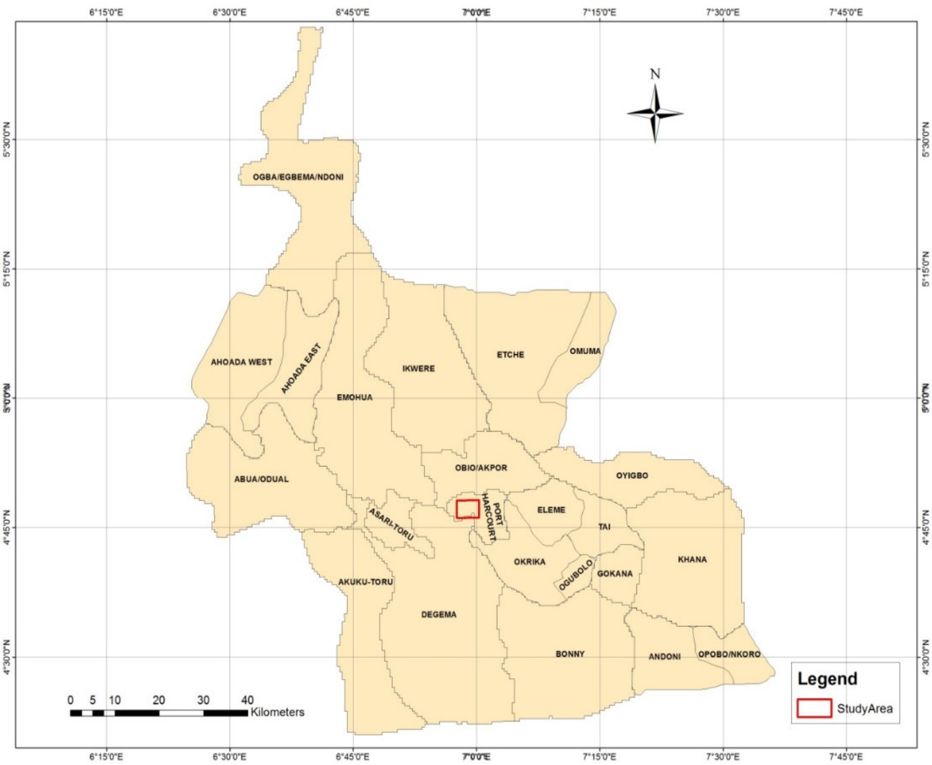

Figure 2: Map of Rivers State showing the study area

The surrounding creek is an estuarine system and is usually influenced by tidal fluxes. The configuration of the creek widens in some regions and narrows in some other areas. At the shores of the creek were stretches of shanty human settlements marked with various human activities such as dredging and construction activities, timber sawing, abattoirs, waste disposal dumps, frequent defecation points, land reclamation efforts via dumping of wastes and wood pellets.

The vegetation of the area is predominantly mangrove, with the dominant species being red mangrove (*Rhizophora racemosa*), white mangrove (*Avicennia africana*), and black mangrove (*Laguncularia racemosa*). The area is also inhibited by other plants such as Nipa (*Nypa fructicans*), ferns such as *Achrostichum aureum* and grass e.g. *Paspalum vaginatum*, and animals example mud skipper *Periopthalmus sp*., fiddler crabs (*Uca tangeri*), periwinkles and a host of other numerous invertebrates whose presence, among others, provides a significant contribution to the dynamics of the mangrove community as a whole.

The climate of the area is that of equatorial rainfall with rainfall occurring throughout most of the year except for the months of December, January, and February which comprise the dry season. The annual rainfall in the area was about 2,405.2 mm (Gobo, 1988). Annual mean air temperature is 31.1^0C with the highest monthly mean of 29.7^0C (in August), and the lowest monthly mean temperature of 27.5^0C (in January) (Gobo, 1988). The estuarine surface temperature values range between 25.9^0C and 30.6^0C, with salinity ranging between 8 and 20%. The tidal range is between 0.43 m and 1.67 m, with a mean tidal variation of 0.9 m. The current flows are unidirectional flooding (inundation) during high tide receding at low tide regime. The mud (sediment) has a dark appearance with hydrogen sulfide as the major byproduct of Sulphur bacteria. Economic activities in this area are mainly fishing, trading, and transportation and more importantly serves as a major residential area.

2.2 Nature and sources of data

This study undertook an analysis of land use –land cover changes particularly to show the extent of mangrove depletion. The satellite imageries used were visually interpreted to determine the distribution of changes in extent over the period 1993-2013, evaluated in 3 epochs 1993, 2003, and 2013. This composite was used to identify the drivers of change in land cover and land use change. The assessment of change was linked to obvious shreds of evidence of change in mangrove extent and this evidence was categorized. The selection of these categories was in line with those found in the literature of previous studies (Valiela *et al.,* 2001; Fromard *et al.,* 2004).

The first step involved the identification of the variables needed to assess environmental change. The variables consist of socioeconomic and environmental information, including the extent of human settlement (population), water bodies, and forest types (mangroves). This process continued with the design of data matrices for the variables covering the various periods from 1993 and 2013.

For the study, Landsat satellite images of River State were acquired for three Epochs; 1993, 2003, and 2013. All three periods 1993, 2003, and 2013 were Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images. The Landsat TM and ETM+ satellite data were processed Using the ArcGIS ArcMap 10.2 and Erdas Imagine 9.1 GIS software. Global Land Cover Facility (GLCF) an Earth Science Data Interface and Google Earth imageries were useful tools during the analysis as they served as comparison tools. It is also important to state that Port Harcourt and its environs which were carved out using the local government boundary map and Nigerian Administrative map were also obtained from Landsat thematic mapper ™ imageries.

2.3 Development of a classification scheme

Based on prior knowledge of the study area and a sound reconnaissance survey with additional information from previous research in the study area, a classification scheme was developed for the study area. The classification scheme developed gives a rather broad classification where the land use land cover was identified (Table 1).

Table 1: Land use land cover classification scheme

CODE	LAND USE/LAND COVER CATEGORIES
1	Sparsely built-up
2	Densely built-up
3	Mangrove swamp
4	Water bodies
5	Vegetation

The classification is based on direct observation of the study area and adjacent areas. Observations show that there were sparsely built-up areas, densely built-up areas, mangrove swamps, water bodies, and vegetation, however for the 2013 classified imagery, there is a sixth class representing sand mining areas.

3. Results

3.1 Change detection

Change detection was done using special software (ArcGIS Arc Map 10.2 and Erdas Imagine 9.1) to identify factual changes in the land use and land cover of the study area. This allowed for the clear-cut detection of loss of mangrove swamps and other parameters classified into the six classes used for this study. The change was observed to be either a decrease in the pixel count or area of a class or an increase in the class.

Below are the Classified images (fig 3 – 5)

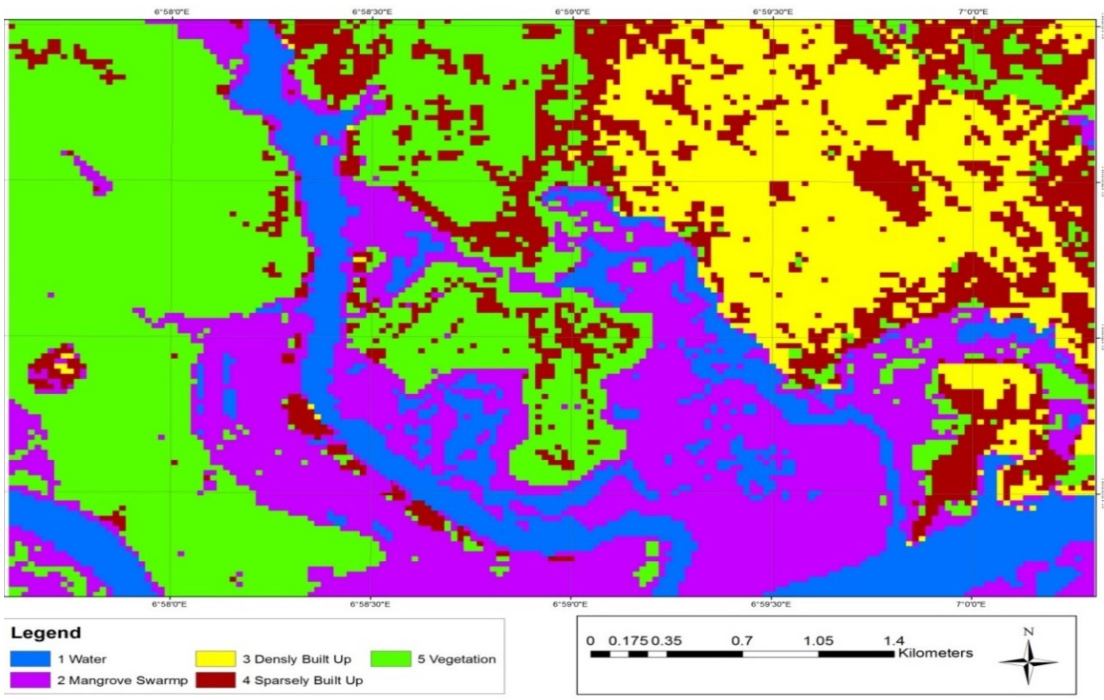

Figure 4: 1993 Landsat classified image of Eagle Island and vicinity

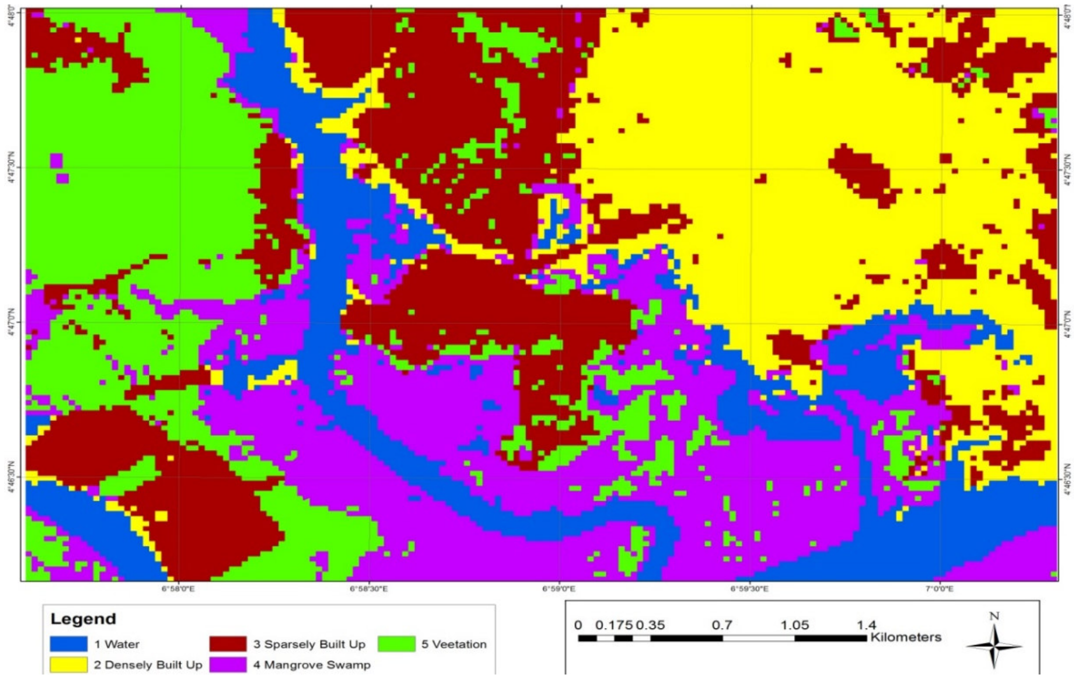

Figure 4: 2003 Landsat classified image of Eagle Island and vicinity

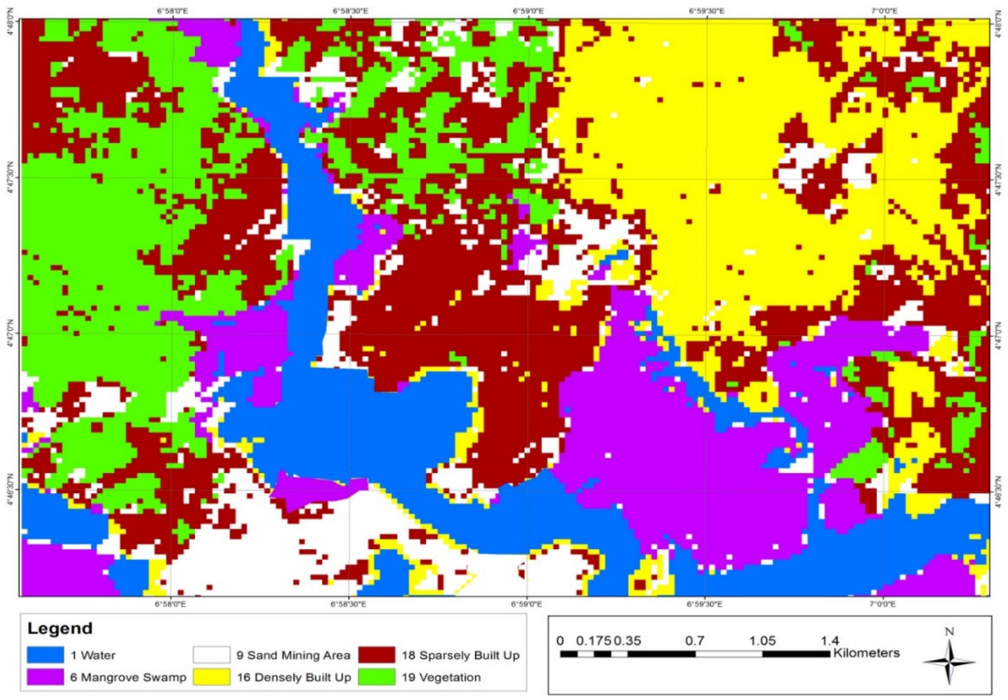

Figure 5: 2013 Landsat classified image of Eagle Island and vicinity

Figure 6 below shows the data or numerical values obtained and used for change analysis. The values represent the area in square kilometers (kmsq). The values are 4.4955 kmsq, 3.8781 kmsq, and 2.385 kmsq for the years 1993, 2003, and 2013 respectively.

Figure 7 shows the pixel counts used in the analysis for the three chosen epochs. In decreasing order, the pixel counts are 4995 for 1993, 4309 for 2003, and 2650 for 2013.

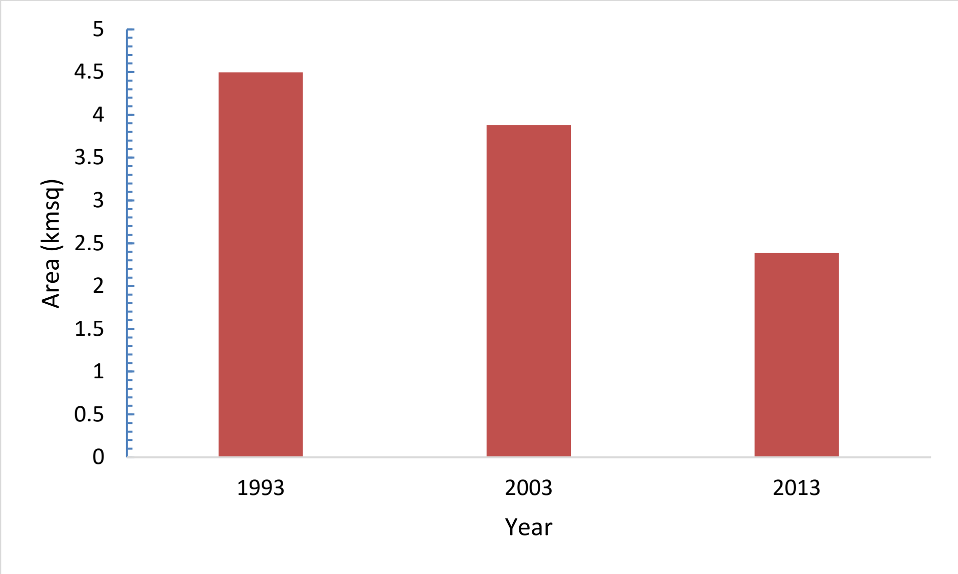

Figure 6: Numerical values (kmsq) obtained and used for change analysis

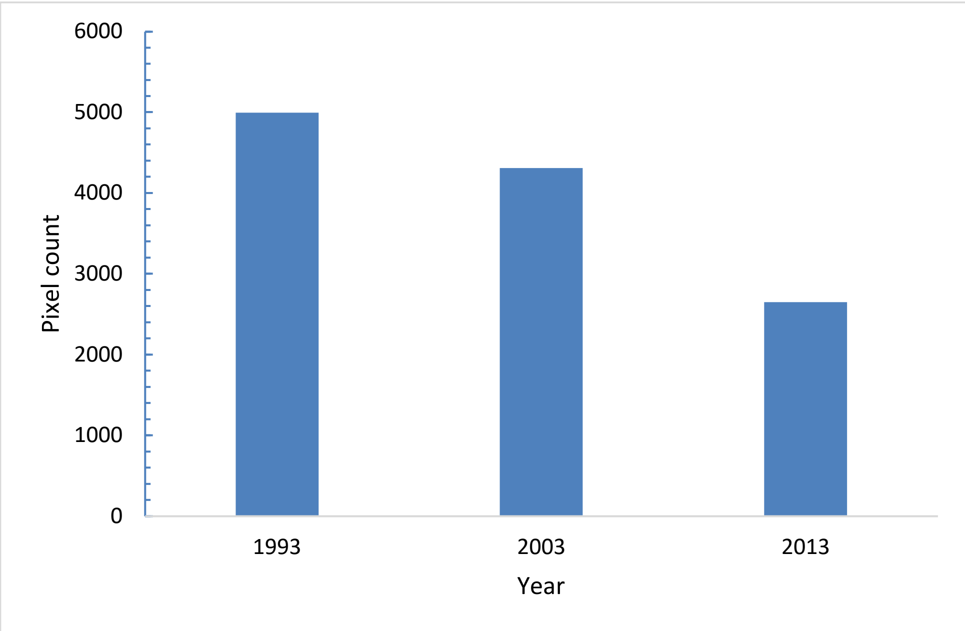

Figure 7: Pixel value for the 3 epochs

Figure 8 below is a graphical illustration of the statistical analysis carried out with the data obtained. It shows the percentage change in the mangrove forest on a decadal basis, beginning from the year 1993 to 2013. The mangrove vegetation recorded a 14% change/loss in the first decade (1993 – 2003), a 39% change in the second decade (2003 – 2013), and a cumulative change/loss of 47% between 1993 to 2013.

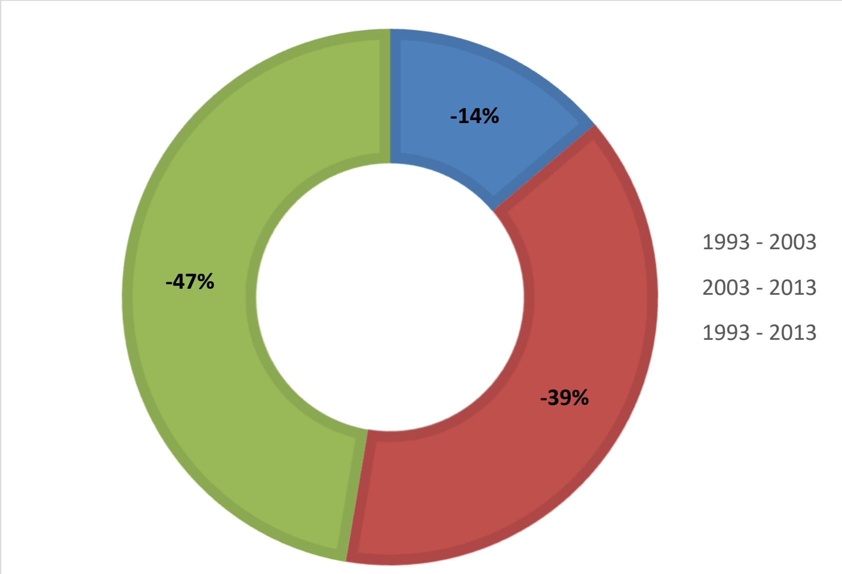

Figure 8: Percentage change from 1993-2003

Figure 9 below is a graphical illustration of the statistical analysis carried out with the data obtained. It shows the change in the area of mangrove forest coverage on a decadal basis, beginning from the year 1993 to 2013. The mangrove vegetation recorded a 0.617kmsq change/loss in the first decade (1993 – 2003), a 1.493kmsq change in the second decade (2003 – 2013), and a cumulative change/loss of 2.111kmsq between the years 1993 – 2013.

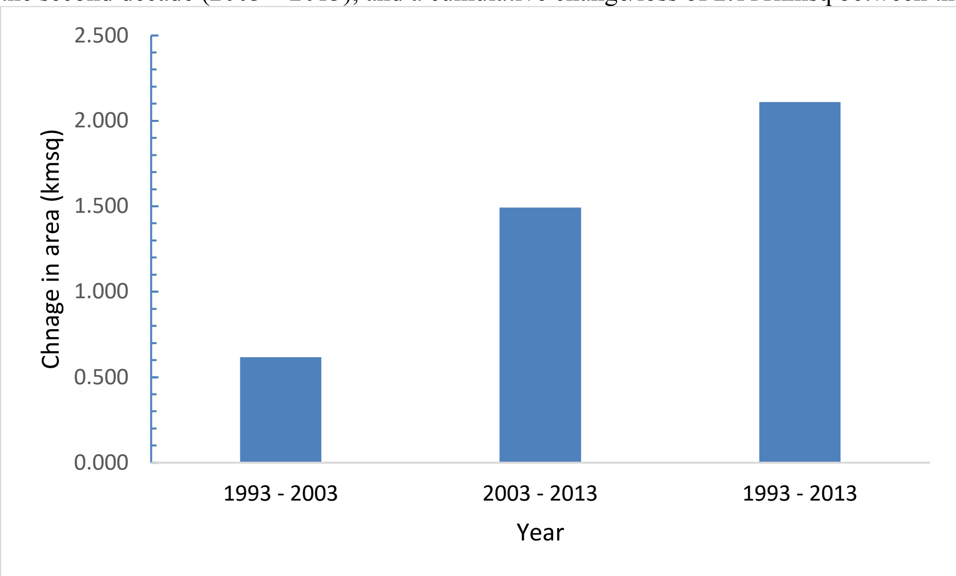

Figure 9: Change in area 1993-2003

4. Discussion

The results have shown a rapid change and decline in the mangrove vegetation of the study area for the period under investigation. The change was assessed both on a decadal and a cumulative basis. Over all the results point to a decline in mangrove forests, and an increase in human settlements which posed a major threat to the biodiversity and natural systems of the area. The percentage change values recorded below are attributable to the area (kmsq). Between 1993 and 2003 there was a 14% decrease in mangrove cover; between 2003 and 2013 there was a 39% decrease in mangrove cover; and between 1993 and 2013, there was a cumulative 47% decrease in mangrove cover in the area. The changes attributed to socioeconomics and environmental variables reflect also a host of other factors. During the period under investigation, there has been an upsurge of infrastructural development in the area in the form of roads, bridges, houses, and land reclamation. This upsurge caused by the rise in human population in the study area has also increased commercial activities, hence the need to develop infrastructure to accommodate the new reality. Unfortunately, this trend might continue gradually turning the area into a densely populated area devoid of essential and critical urban planning and lacking recognition for ecological elements. This will not only threaten the carrying capacity of an already fragile ecosystem but it poses enormous challenges for both environmental and natural resource managers and policymakers in the state and region if not confronted with the urgency it deserves. It will be noted that conservation and sustainability measures must be mainstreamed in the use and exploitation of coastal resources and areas. The effects of human development activities on the biodiversity of the study area are negative, as also documented by Zabbey (2008). According to his study, this ranges from subtle sub-lethal impairment to outright mortality of plants and animals. Undoubtedly, development, environmental degradation, and pollution are like twin brothers. In the study area, human population growth and associated demands are exerting an accelerated pressure on soil and water sources as also observed by (Ikusemoran, 2009). Others such as sand dredging have also undoubtedly led to a major loss of mangrove cover which affected the biodiversity of the study area in many ways. It has caused settled sedimentary particles to enter into suspension, leading to high turbidity of water and reduced photosynthetic activity; many fauna that inhabit sandy sediments are "sucked" and pumped onto land, leading to their deaths; sedimentary plumes are carried by tidal currents inland and become deposited in nursery grounds. When this happens, reproduction success is hampered, and in most of the shallow inland area of the study area where sand dredging takes place, erosion occurs, due to the weakening of the shorelines, and the entire biodiversity elements are impacted deleteriously. This finding corroborates the findings of Ohimain (2004) who observed that during dredging, the soil, sediment, and vegetation along the right of way (ROW) of the proposed site are removed and typically disposed over the bank, and in most cases upon fringing mangroves, and then abandoned. He further observed that abandonment of the resulting dredged material causes several impacts such as altered topography and hydrology, acidification, and water contamination, which culminates in vegetation damage and fish kills.

The study also showed the potency of GIS in cascading issues related to natural resource conservation. Through the aid of the GIS and some form of ground truthing, the result was validated and hence used for the development of this manuscript which would in turn inform restoration and conservation policies targeted at the mangrove forest. Several authors in the Niger Delta have also explored the tools of GIS in promoting and soliciting for mangrove protection and restoration. Lemenkova & Debeir (2023) with the help of the GIS, were able to analyze mangrove vegetation indices from satellite imagery to promote conservation. Onwuteaka and Uwagbae (2018) similarly used GIS tools to discriminate areas occupied by the mangrove against other competing vegetation types, and the outcome was utilized in policy adjudication for mangrove conservation in the Niger Delta. Given the above efforts in the region, it is apparent that GIS tools come veritable at such a time when field research activities in the region are bedeviled by the upsurge of insecurity, especially in the rural coastal areas where the bulk of the mangrove is situated.

5. Conclusion

This study has shown that mangrove vegetation has continued to decline as a result of developmental influx to the area under study. If this is allowed to continue elements of biodiversity will continue to decline until they are completely decimated. Ecotype under investigation takes years to regenerate if replanted and this will require colossal sums of money, restocking and depleting aquatic resources comes at a high cost as well. Biodiversity which is critical to sustaining ecosystem functioning as well as the other important services they provide must be protected and conserved at all costs. This study therefore calls for immediate action to halt this unfortunate spate of declining biodiversity elements and institute adequate and proactive strategies as well as measures to conserve and protect biodiversity elements. More so, this study also showed the potency of GIS technologies in biodiversity conservation and thus advocates for its utility in similar studies. Integrated data analysis using remotely sensed satellite imagery and GIS modeling, facilitated the analysis of the spatial distribution of change involving the mangrove ecosystem and other developmental issues facing the study area and environs. Such information technology is highly indispensable for the decision-makers in Nigeria as they grapple with the future of development activities along the Niger Delta ecosystem in the 21st century. Moving forward, a more comprehensive evaluation of the rate of decline of Niger Delta mangrove would be veritable for informed decision making and for planning a robust mitigation program to the current menace.

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