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ASSESSMENT OF COASTLINE VULNERABILTY FOR SUSTAINABLE COASTAL DEVELOPMENT AND PLANNING IN NIGERIA USING MEDIUM RESOLUTION SATELLITE IMAGES AND GIS

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ABSTRACT
Applications of satellite remote sensing and GIS have provided new insights to the Coastline changes in Mbo. This has also provided a data analysis tools and methods to evaluate the geospatial patterns in short and long term change. In the study area, coastal erosion and accretion which are common features of the south east coast of the Niger Delta coastline were also found to be prevalent. The aim of this study is to assess the vulnerability of the coastline in Mbo, Akwa Ibom State between 1990 and 2000; and 2000 and 2010 using Remote Sensing and GIS approaches. In order to detect the changes of the coastline, remotely sensed satellite images of Landsat Thematic Mapper and Enhanced Thematic Mapper were the main data for this research. Three of such images used for this study are the Landsat Thematic Mapper of 1990, Enhanced Thematic Mapper 2000 and 2010 of 28.5 and 30 meters resolution respectively. Maximum likelihood method of supervised classification was used in classifying the images and six Landcover classes were mapped within the study area. The study area has a varying land mass of 159.878 km^2, 151.025km^2, and 134.571km^2 (i.e. usable land for built-up area, cultivation area and forest) in 1990, 2000 and 2010 respectively while it has a varying water mass of 219.416 km^2, 227.626km2 and 245.198km^2 (mangrove, water body and wetland) respectively. The rate of coastline morphological changes is highly spatial and temporal and is influenced by intensive mining activities at the coast. The geospatial analysis illustrates the significance of landcover/ landuse including variation in coastline position and sediment budget has characterised the Geomorphological vulnerability in the coastal region of Mbo coast.

KEYWORDS: Coastline, coastline changes, Satellite imagery, Remote sensing, GIS, Mbo

INTRODUCTION

Due to the availability of abundant resources around the coast, about a billion of the world's population (40 - 60%) lives within 100 km of the ocean and its marginal seas (Mackenzie, 2003). Coastal zone monitoring is an important task in national development and environmental protection, in which, extraction of coastlines should be regarded a fundamental research of necessity (Rasuly 2003). Coastal zone and its environmental management require the information about coastlines and their changes. The coastline can be geographically defined as a linear intersection of coastal land and the surface of a water body (Kurt et al 2010). Coastline mapping and change detection are essential for safe navigation, resource management, environmental protection, and sustainable coastal development and planning (Di et al., 2004). In order to study the coastline changes, various techniques have been used.

To detect coastline changes some, researchers compare topographic maps (Cowie, 1997) of different periods, some others compare aerial photographs of different periods, too (Gunasekera, 1996, Watters and Wiggins, 1999, Skilodimou, 2002). Moreover, satellite imagery has been used to describe coastal changes (Winarso, 2001, Zhu, 2001), and this method has been proved to be a unique tool for environmental research because the mapping of the coastline is accurate and provides with multiple and update information (Yang el al., 1999, Gatsis et al., 2001). Remote sensing is one of the most preferred and reliable methods in monitoring and managing environment and resources (Karaburun and Demirci, 2009). It plays important role for spatial data acquisition from economical perspective. The use of satellite remote sensing techniques and geographic information systems (GIS) for the identification, mapping and analyses of coastline changes have gained prominence in recent years as high resolution satellite data have become more readily available. Previous works in this direction; Moore (2000), El-Amsar (2002) and Liu et al (2004) have shown that, remote sensing techniques when combined with geomorphologic and sedimentary data can be effectively used to assess coastline changes over time.

In Nigeria, sufficient relevant and timely information about our coastal environment and the changes that have taken place over time along the coastlines is lacking. This development therefore hinders proper coastal zone monitoring, sustainable development and environmental protection. In order to understand what is happening around the Nigerian coastlines, maritime councils and operating authorities require up-to-date and accurate information about the coastal geomorphology. The Mbo coastal zone of Akwa Ibom State, Nigeria lacked the above vital information, hence this research was undertaken as a remedial measure, since the coastal zone has been subject to various degrees of changes physically and ecologically due to human and natural interference during the last decades of the 20th century as a result of a rapid increase in industrialization and urbanization. The aim of this study is to assess the vulnerability of the coastline in Mbo Local Government Area of Akwa Ibom State between 1990 and 2000; and 2000 and 2010 using Remote Sensing and GIS approaches.

THE STUDY AREA

The study area is Mbo local Government Area of Akwa Ibom State. It is located between **Latitude 4° 33' 35"N and 4° 44' 27"N, and Longitude 8° 12' 24"E and 8° 18' 53"E.** It is a coastal zone located on South-Eastern part of Nigeria and bounded in the North axis by Urue Offong/Oruko Local Government Area, in the South axis by Atlantic Ocean and Cameroon, in the East by Udung Uko Local Government Area and in the West by Esit Eket and Ibeno Local Government Areas of Akwa Ibom State (Figure 1,2,and3). Since it borders Nigeria with Cameroon; it serves as the centre for marine commerce between Nigeria and Cameroon. The Population of Mbo according to 2006 Census stood at 55,395 males, 48,617 females; total: 104,012. (Table1). The People of Mbo generally speak Oron language with minor dialectical differences, with strong cultural affinity among the people. The area has a total landmass of 365 square kilometres, Forest resources such as timber, vegetables and fruits Mineral deposits, e.g. crude oil, fine sand, salt, gravel and clay. Their occupation is Marine-based, comprising fishing, marine transportation and subsistent farming.

Table 1: The population figures of the Study area

S/N	YEAR	1991	2006	2021
1	**MALES**	31880	55,395	78,910
2	**FEMALES**	27979	48,617	69,255
2	**TOTAL**	59859	104,012	148,165

Source: Official Gazette of Nigerian Government (FGP71/52007/2,500(OL24) N/B the 2021 was projected using 2.83% Annual growth rate by the Author.

Table 2: Showing Data and their dates of Acquisition

S/N	Data	Path/Row	Acquisition Date	Resolution (m)	Source
1	Landsat TM	187/057	12/12/1990	28.5	Global Land Cover Facility (GLCF)
2	Landsat ETM+	187/057	17/12/2000	30	University of Uyo GIS Laboratory
3	Landsat ETM+	L71 187/057	23/01/2010	30	University of Uyo GIS Laboratory

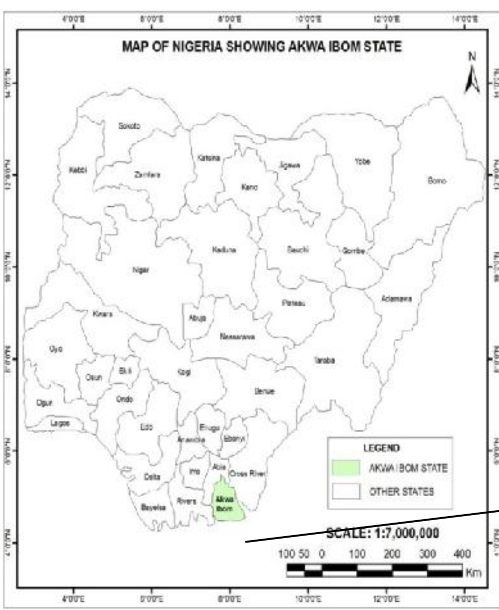

Figure 1: Administrative Map of Nigeria showing the States. showing the study area.

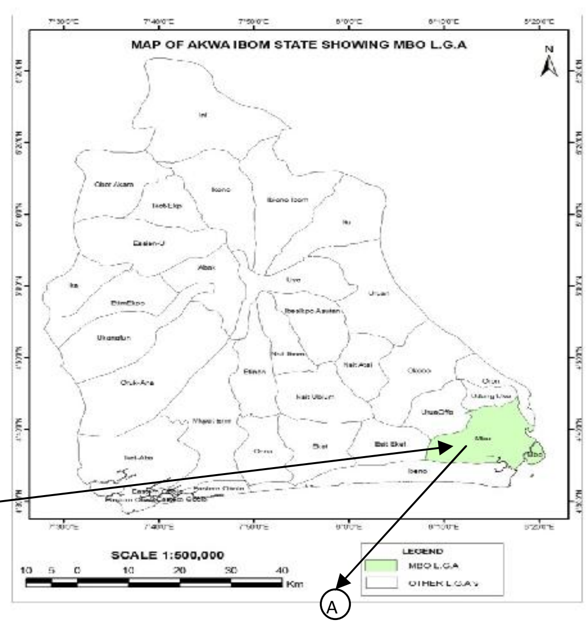

Figure 2: Administrative Map of Akwa Ibom State

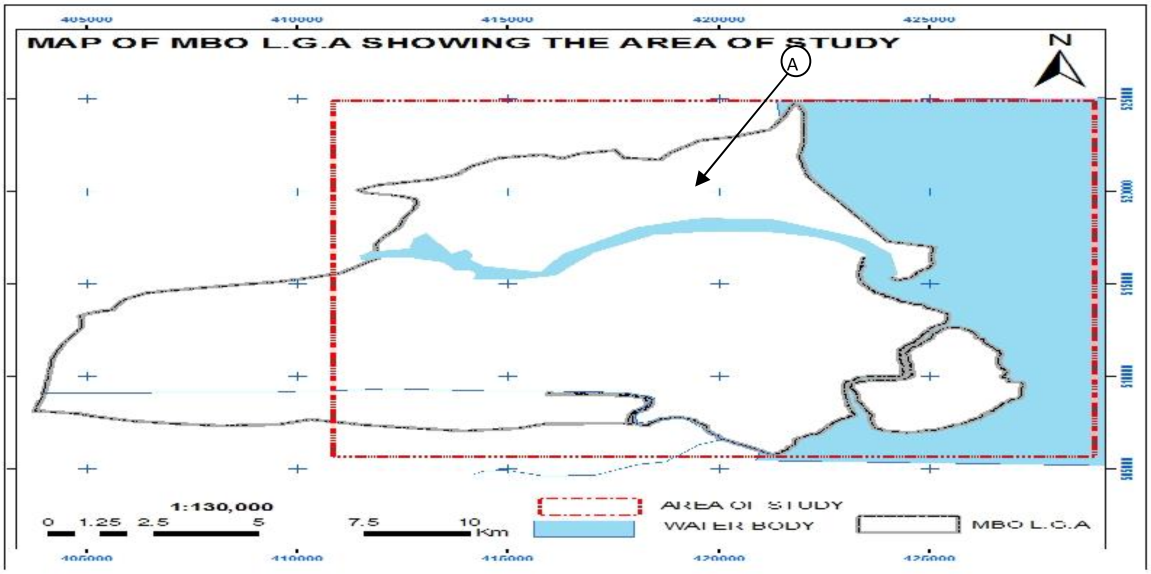

Figure 3: Map of Mbo L.G.A Showing the Study Area

METHODOLOGY

DATA USED

The data used for this research was principally a 30m Landsat TM satellite image of 1990, and Landsat ETM+ image of 2000, and Landsat ETM+ image of 2010 covering study area. Other useful data were obtained from Literatures, statistical files of some Government agencies, existing map sheets, and through field capture and verification exercise.

The Landsat TM image of 2000 covering the study area was downloaded from the internet, while the 1990 and the 2010 images were obtained from the GIS Laboratory of the Department of Geography and Regional Planning University of Uyo; the administrative map of the State was obtained from the Office of the Surveyor General of Akwa Ibom State, while the GPS observation was the direct observation of Northings and Eastings (N,E) of some location within the study area carried out during field visits. The technical data of the satellite images are listed in the table 2

DATA PROCESIING AND ANALYSIS

Remotely sensed satellite images of Landsat Thematic Mapper and Enhanced Thematic Mapper were the main data for this research. Three of such images used for this study are the Landsat Thematic Mapper of 1990, Enhanced Thematic Mapper 2000 and 2010 of 28.5 and 30 meters resolution respectively. Pre-processing activities were carried out in order to enhance the quality of the image and readability of the features. The Landsat satellite images of 1990, 2000 and 2010 were geometrically corrected and the projection was set to Universal Transverse Mercator (UTM) Projection System coordinates zone 32. The spheroid and datum was also referenced to WGS84. The nearest neighbour resampling method was used in resampling and subsetting the Enhanced Thematic Mapper plus (ETM+) images of 2000 and 2010 into a pixel size of Thematic Mapper image of 1990 with a resolution of 28.5m during the image-to-image registration.

The land cover classes of built-up areas, cultivation area, forest, mangrove, water body, and wetland were identified and the layers were recreated, accordingly. For investigating the changes in Land use/Land cover (LU/LC) condition, the total area for each land cover classes for all the three (3) epochs were calculated and the results were compared against one other**.** First and foremost, the supervised classification using maximum likelihood method was used in classifying the images into different classes depending on their reflectance properties. This was followed by a reclassification into two classes of Landcover and watercover to detect possible changes as well as determine the magnitude of changes that taken place between the two epochs of interest and, accuracy assessments were made for all the three images. In the confusion matrix, the overall accuracy level of the Landsat TM (1990), Landsat ETM (2000), and Landsat ETM (2010) was found to be 94.65%, 98.52%, and 97.45%, respectively. The final output of Land use/Land cover (LU/LC) map was prepared for the three different years (1990, 2000 and 2010).

The final Land use/Land cover (LU/LC) classes were classified and mapped. ILWIS 3.7 (Integrated Land and Water Information System which integrates image, vector and thematic data) and ArcGIS 9.3 software were used to perform both the pre-and post image processing and quantification works. The use of satellite remote sensing techniques and geographic information systems (GIS) for the identification, mapping and analyses of coastline changes have gained prominence in recent years as high resolution satellite data have become more readily available

RESULT AND DISCUSSION

The results are presented in the form of maps, graphics and tables

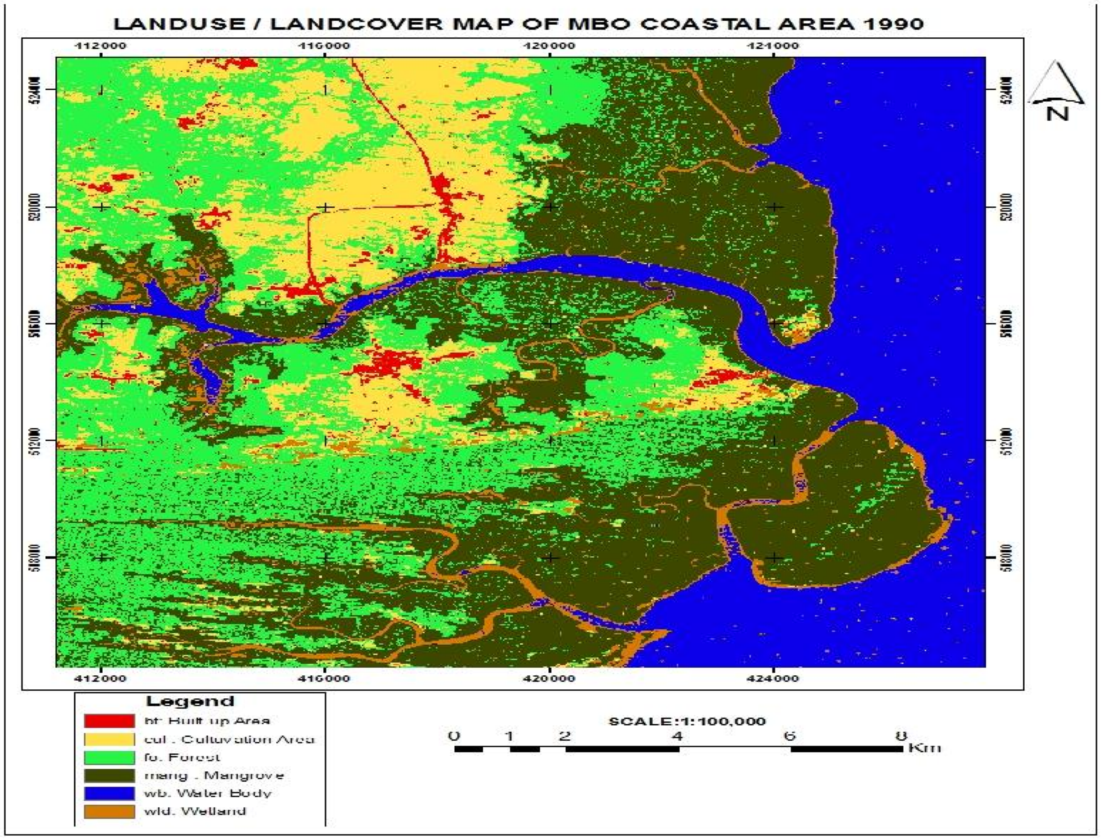

Figure 4 Maximum Likelihood Supervised Image Classification of Mbo 1990

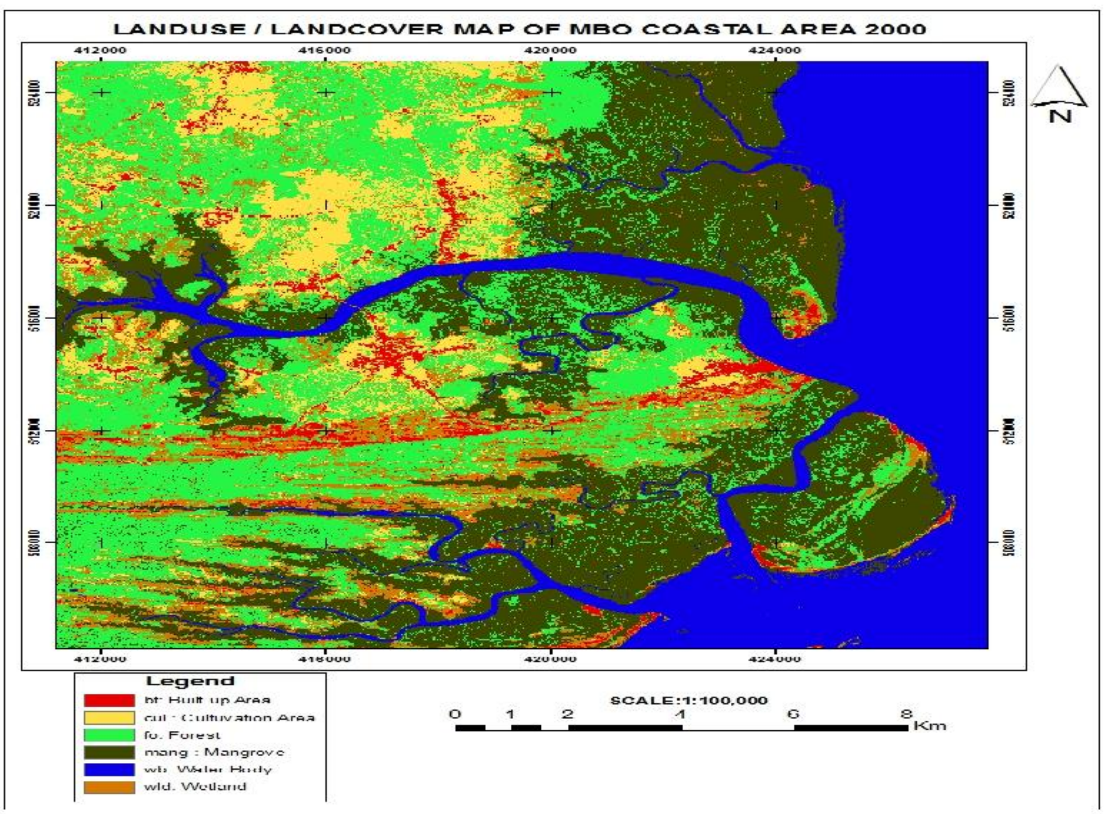

Figure 5 Maximum Likelihood Supervised Image Classification of Mbo 2000

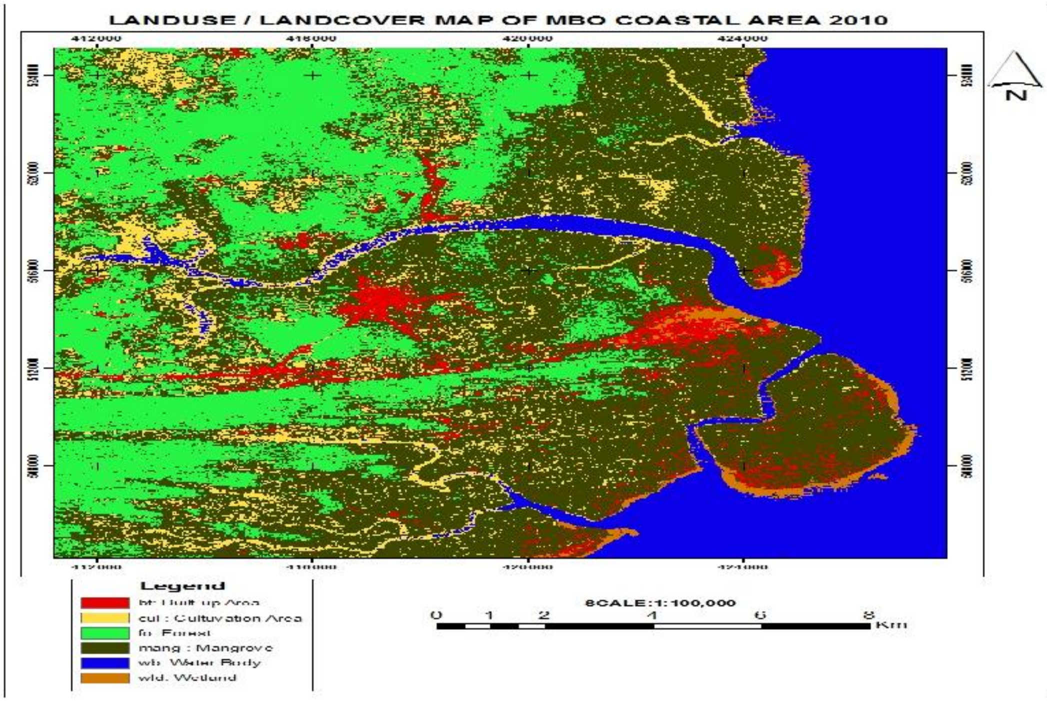

Figure 6 Maximum Likelihood Supervised Image Classification of Mbo 2010

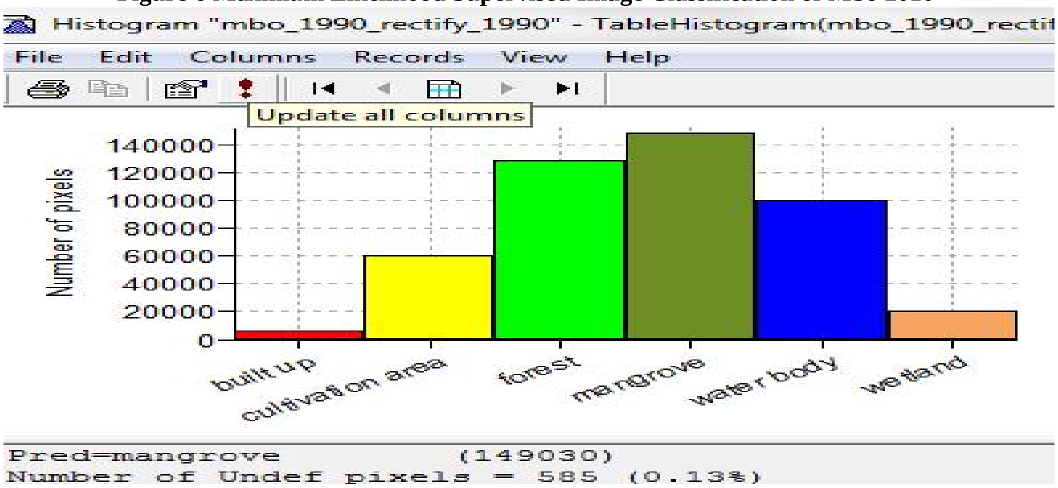

Figure 7 Histogram of Image Classification of Mbo 1990

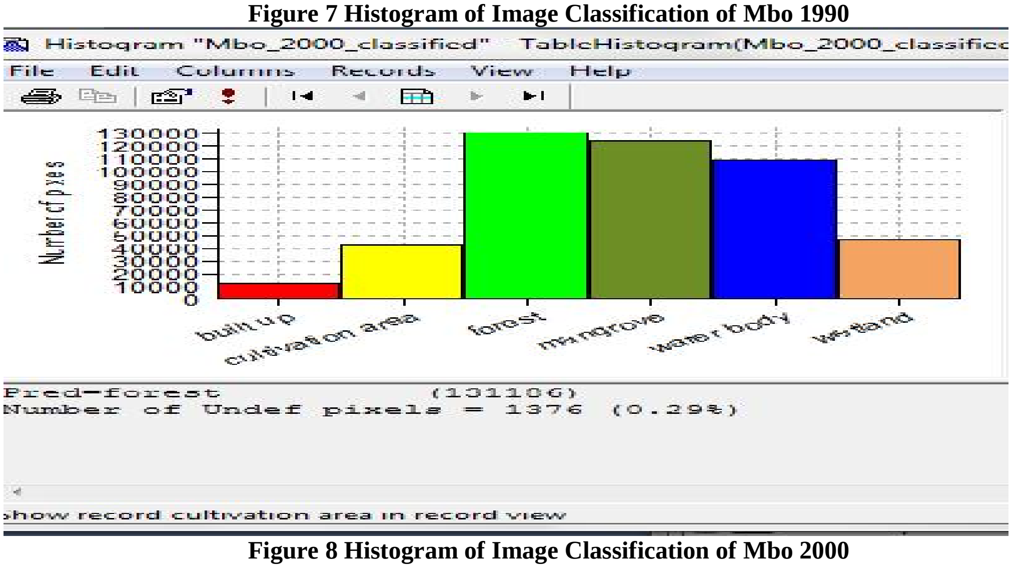

Figure 8 Histogram of Image Classification of Mbo 2000

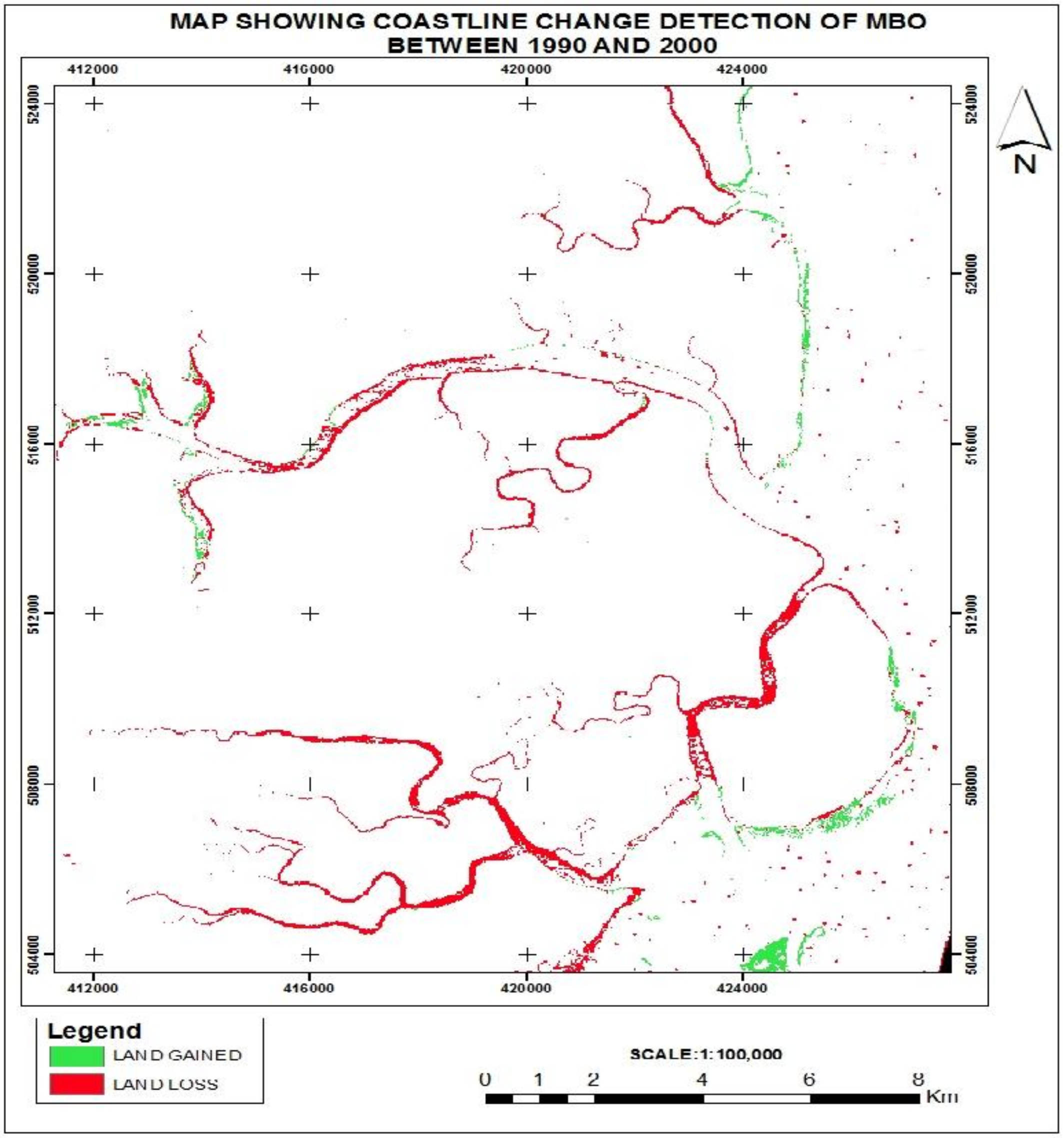

Figure 9 Histogram of Image Classification of Mbo 2010

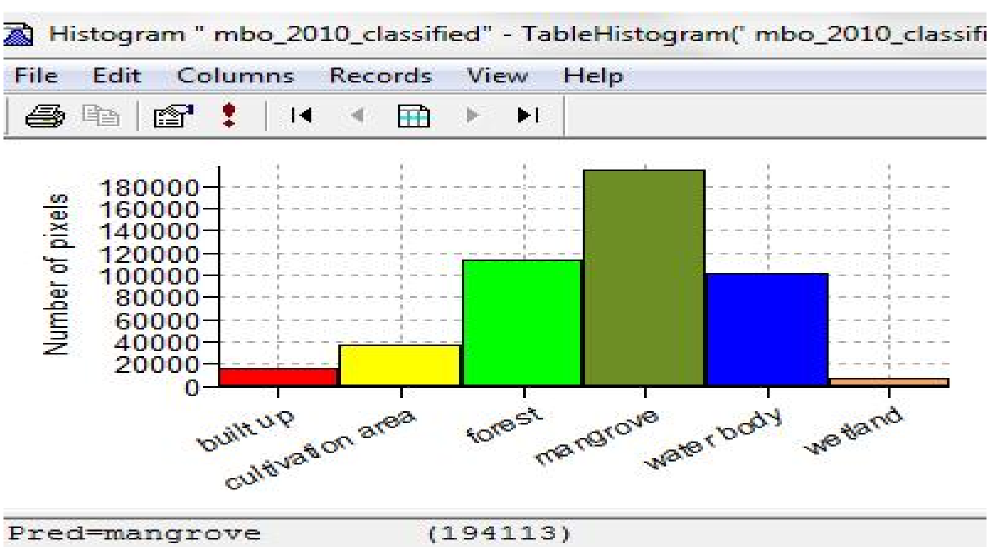

Figure 10 Coastline changes between 1990 and 2000

COASTAL CHANGE DETECTION

Table 3: Showing the Statistic Value of Mbo Coastal Change from 1990 to 2000

mbo_1990_land nature	mbo_2000_land nature	NPix	Area (m^2)	Analysis
land	land	354134	287645341.5	Land Constant
land	Water	10748	8730063	Loss
water	land	2562	2080984.5	Gain
water	water	98147	79719900.8	Water constant

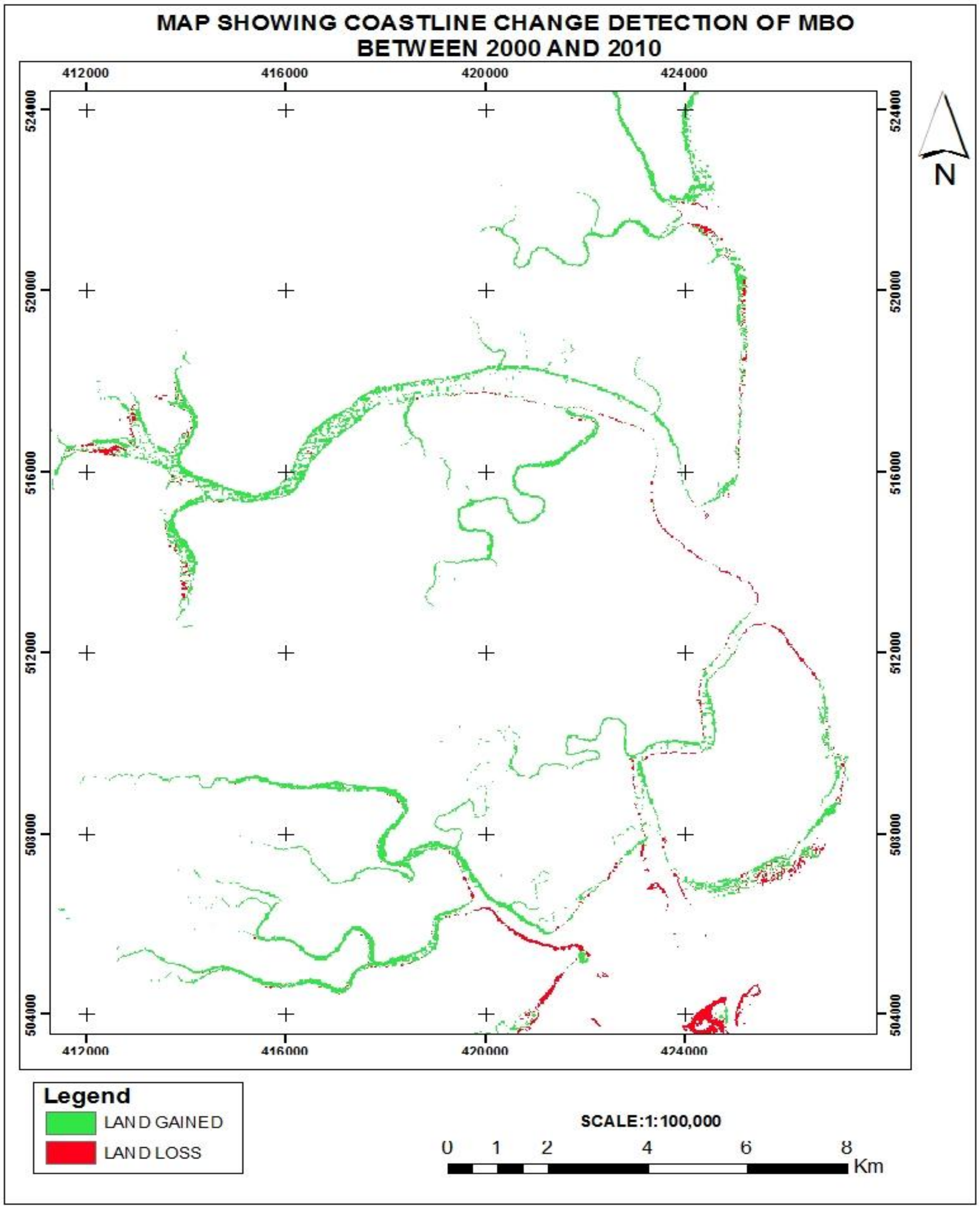

Figure 11 Coastline changes between 2000 and 2010

Table 4: Showing the Statistic Value of Mbo Coastal Change from 2000 to 2010

Mbo land nature 2000	Mbo land nature 2010	NPix	Area (m^2)	Change analyses
Land	Land	354584	288010854	Land Constant
Land	Water	2112	1715472	Loss
Water	Land	10160	8252460	Gain
Water	Water	99320	80672670	Water constant

TABLE- 5 Showing Area of Land Use/Change Category at Different Years – 1990, 2000, 2010

Land use/Change Category	1990		2000		2010	
Classes	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**
Built-up Area	5362474.5	1.41	10190488.5	2.69	12663789.8	3.33
Cultivation Area	49389673.5	13.02	34278574.5	9.05	30297737.3	7.98
Forest	105125456.3	27.72	106555828.5	28.14	91609616.3	24.13
Mangrove	121049617.5	31.91	100641836.3	26.58	157668284.3	41.52
Water Body	81910539.0	21.60	88925130.0	23.48	82499420.3	21.72
Wetland	16456185.0	4.34	38059598.3	10.06	5030264.3	1.32
Total	**379769112.3**	**100**	**379769112.3**	**100**	**379769112.3**	**100**

TABLE 6 Showing Image Analysis (1990 – 2000) AND (2000 – 2010)

Land use/Change Category	1990 - 2000		2000 - 2010	
Classes	**Change in (m^2)**	**%**	**Change in (m^2)**	**%**
Built-up Area	4828014	1.55	2473301.3	0.64
Cultivation Area	-15111099	-3.97	-3980837.2	-1.07
Forest	1430372.2	0.42	-14946212.2	-4.02
Mangrove	-20407781.2	-5.33	57026448	14.94
Water Body	7014591	1.88	-6425709.7	-1.76
Wetland	21603413.3	5.71	-33029335	-8.73

DISCUSSION

Six major land use/land-cover (LU/LC) types were identified on the satellite images between 1990 and 2010 of the study area. These were Built-up areas, Cultivation area, Forest, Mangrove, Water body, and Wetland. The study area has a varying land mass of 159877604.3m² or 159.878 km², 151024891.5m² or 151.025km², and 134571143.4 m² or 134.571km² (i.e. usable land for built-up area, cultivation area and forest) in 1990, 2000 and 2010 respectively while it has a varying water mass of 219416341.5m² or 219.416 km^2, 227626564.6m² or 227.626km2 and 245197968.9m² or 245.198km^2 (mangrove, water body and wetland) respectively. Mangrove and Forest area were the predominant type of LU/LC (Landuse/land cover) between 1990 and 2010 and they covered enormous parts of the study area (Table 7). Forest increases at the rate of 0.42% between1990-2000 but diminishes at the rate of 4.02% between 2000-2010, while Mangrove diminishes at the rate of 5.33% between 1990 and 2000 but grows at the rate of 14.94% between 2000 and 2010. Also built-up area was the smallest Landuse/Landcover within the study area. It grows at the rate of 1.55% between 1990 and 2000 but reduces to the growth rate of 0.64% between 2000 and 2010. Due to the cyclical actions of the ocean current and human activities, in the water body and the wetland area, a decline was discovered in the percentage change of water body and wetland of the study area. The water body increases at the rate of 1.88% between 1990 and 2000, but decreases at the rate of -1.76% between 2000 and 2010, while the wetland grows at the rate of 5.76% between 1990 and 2000 but diminishes at -8.73% between 2000 and 2010. Cultivation area was also on the decrease as it changes at the rate of -3.97% and -1.07% between 1990-2000 and 2000-2010 respectively. The negative change may be attributed to impact of human actions such as population pressure; socio-economic and climatic change etc. This calls for an urgent intervention from administrators/land planners and land policy formulators since the people are also known for peasant farming, the above findings are shown in table 3.3. The change detection analysis also shows that within the period of study, there were periods where portions that were previously land were occupy by water as a result of rise in water level (water gain), and periods where the water decreases (water Loss) and portions that were hitherto water became land (Land gain) and Vice Versa (Figure 10 and 11). The research also reveals that the coastal environment of the study area has undergone changes in pattern and use.

CONCLUSION

The threat of coastal change in Mbo coastal has been highlighted in this study. Remote Sensing and GIS technologies provide effective means of studying coastal hazard. The study of coastline changes is of enormous benefit to the understanding of complex coastal ecosystems. Coastlines are widely used as ports for navigation and maritime commerce. They are therefore of economic value and critical to the socio-economic development of non-land locked nations. The presented method of combining GIS and image processing shows its ability to detect coastline changes over time, in a broad scale using Landsat images. Using statistics allows quantitative analyses of small changes even of about 1 m per year. The bigger changes of few meters per year may be efficiently detected using this method along long segments of coast. Excessive human and anthropogenic activities around the coast was discovered as the socio economic factors which has given rise to decline in the percentage change of water body, wetland and mangrove of the study area.

Land use/land cover map of the study area generated will aid the planners and decision makers for a quick assessment of the potential impact of human activities around the area and initiation of appropriate action to minimize the action. The study helps us know the impact of changes on agricultural land (cultivation area), which practice is also affected as a result of thinning out of agricultural land which has also been taken over by flood in some case and encroachment.

The study suggests the following measures to prevent future haphazard development and encroachment.

i. For proper coastal management and planning in Nigeria, regular monitoring and management of these coastlines must be maintained. Government should encourage its personnel through proper funding so that so that changes in coastline at regular intervals can be detected. Government should fund the coastal research institutions e.g. (NIOMR, Maritime Academy of Nigeria and the Nigerian Navy) so that relevant research can be carried out with modern technology (satellite imagery, GIS and digital equipments) to obtain fast, accurate and reliable digital data or information concerning our coastlines.
ii. Dredging of rivers around the study area should be avoided, if possible. If it is absolutely necessary, then it should be done in stages in order to reduce environmental impact (flooding) down the river.

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