Spatial and Temporal Evaluation of Land Use/Land Cover Change of the Niger Delta Region of Nigeria from 1986-2016

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Abstract

This research evaluates the spatial and temporal dynamics of land use/land cover (LULC) of the Niger Delta Region of Nigeria from historical multispectral remote sensing datasets of Landsat 5(TM), 7 (ETM+) and 8 (OLI) images of 1986, 2002 and 2016. Image processing was implemented with ERDAS IMAGINE and ENVI software. ERDAS IMAGINE, IDRISI and ArcGIS software are used for evaluation of the spatial and temporal dynamics of Land use/Land cover of the study area. The three sets of Landsat images are classified into seven land use/land cover classes using supervised maximum likelihood algorithm in ERDAS IMAGINE and further LULC analysis was done in IDRISI and ArcGIS software. The computed Overall Classification Accuracy and KAPPA (K^) STATISTIC were 66.7% and 0.60; 70.1% and 064; 74.5% and 0.70 for 1986, 2002 and 2016 respectively. The spatial and temporal analyses indicate that from 1986 to 2016, all LULC classes are significantly altered from their initial state. The forested areas had the heaviest depletion of 29.09%. Mangrove and vegetation also had losses of 1.85% and 2.17% respectively. The high and low density built up areas had gains up to 20% through conversions of forested and arable vegetated cultivated lands to settlements.

Keywords: *Land use/land cover change; remote sensing; GIS; Niger Delta*

I. INTRODUCTION

Land is vital to the survival of all life on earth and it is very important that we quantify and understand the various changes that take place on it. Throughout the world, environmental and anthropogenic drivers are constantly altering the environment. This alteration has always been associated with negative changes to the natural ecosystem most especially the Delta regions of the world. In Nigeria, the Niger Delta is not an exception to this alteration. The Niger delta has a coastline stretching about about 450 kilometres (Boateng, 2010, Ringim et al., 2016). The region has undergone severe environmental alterations since the pre oil boom era of 1975 due to several anthropogenic activities directed at exploring and exploiting the natural resources in the region. This alteration has cause unquantifiable environmental changes to natural land cover, land surface temperature, vegetation health, etc.; and has led to soil and water degradation, air pollution, decreasing biodiversity, increased urban heat, and erosion.

In essence both land use and cover changes are products of prevailing interacting natural and anthropogenic processes by human activities. Orisakwe (2008) observed that land cover and land use patterns are basic data used for physical planning and environmental evaluation. Therefore, periodic land use change patterns are needed for many applications including map revision and updating, natural resources inventory and management, urban planning, agricultural land development, forestry and wide life management and demographic studies.

Also, Land Use Land Cover (LULC) change analysis is very important for environmental management purposes as it helps the decision maker in planning for future changes that may occur in that area and it also helps the decision maker realise the effects of these changes on humans and their environment. Over the years, Land use/Land cover has been a key indicator for the evaluation of environmental impacts. According to Foley et al., (2005); Matthews et al., (2004); and Turner et al., (2007), global and regional assessments on land cover and land use status and changes are fundamentally important for climate and environmental change studies. Thus, the evaluation of the spatial and temporal dynamics of Land use/Land cover (LULC) of a region like Niger Delta that has experienced serious environmental alteration is very essential. For this research, Landsat Satellite imagery with medium spatial resolutions was used for the purpose of change detection both in spatial and temporal extents in the study area. This research

justifies the importance in keeping an eye on resources of the earth using the remote sensing and GIS.

The specific aim of this research is to examine the spatial and temporal dynamics of land use/land cover of the Niger Delta Region of Nigeria from historical multispectral remote sensing dataset from 1986-2016 using remote sensing and GIS techniques. The above stated aim will be accomplished with the following specific objectives: Image preparation and generation/extraction of spatial extent of the study area from Landsat TM, ETM$^+$ and OLI Landsat images; LULC classification and accuracy assessment; evaluation of LULC spatial distribution /magnitude, change trend, gains and losses, net change, and rate of change of each LULC classes.

II. METHODOLOGY

A. Study area

The Niger Delta Region (shown in Figure 1) lies in the southern part of Nigeria where the River Niger divides into numerous tributaries ending at the edge of the Atlantic Ocean. It is bordered to the south by the Atlantic Ocean and to the east by Cameroon.

It lies between longitude 4º 30’ - 9º 50’E and Latitude 4º 10’ - 8º 0’N. The temperature in the region is between 24°C to 32°C throughout the year, rainfall ranges from 3000- 4500mm. The region has two seasons: dry season (starting around December-February) and the rainy season (starting around July-September) (Nwilo & Badejo, 2006). The region covers nine southern states namely: Cross River, Akwa Ibom, Abia, Imo, River, Bayelsa, Delta, Edo and Ondo state with more than 40 ethnic groups and has about 250 different dialects (NDRDMP, 2004). The region is the sole oil producing basin since the discovery of oil in commercial quantity in 1965. The region is the main source of export earnings to Nigeria. Records has it that oil and gas earnings from the region funds 85% of the Nation's yearly budget; and contribute about 95% of Gross Domestic Product (GDP) (NDRDMP, 2004).

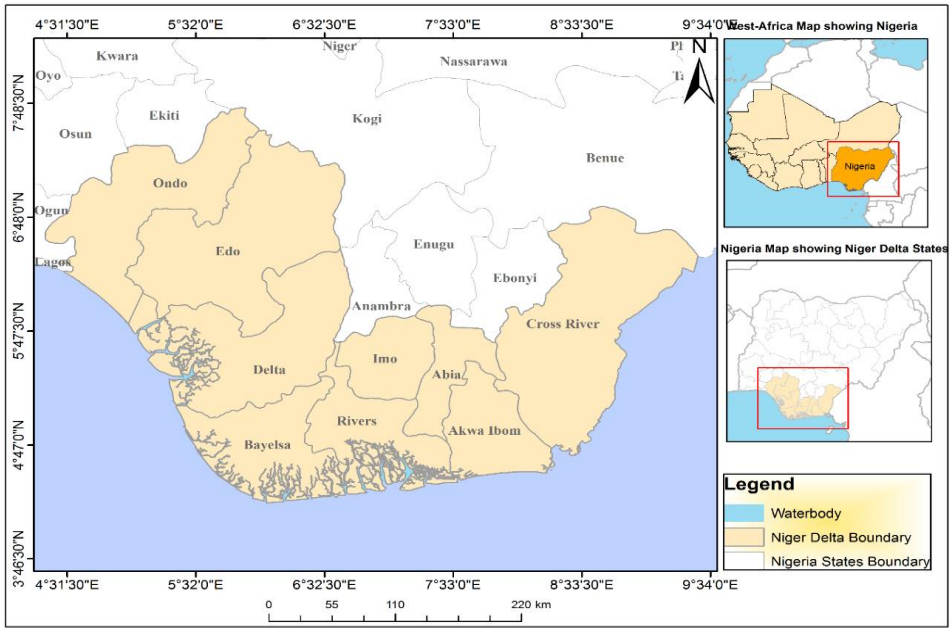

Figure 1: Study Area in Relation to West Africa and Nigeria

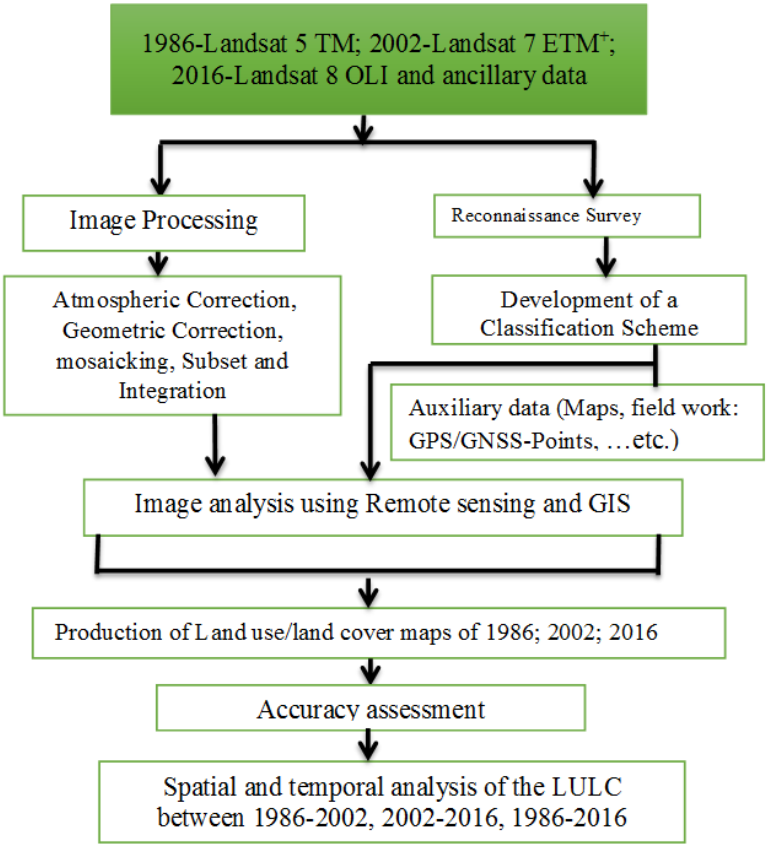

Figure 2: Research Methodology Flow Chart

B. Data

Landsat 5 (TM), Landsat 7 (ETM+) and Landsat 8 (OLI) images of 1986, 2002 and 2016 were used. The eleven Landsat scenes (path 187/row 55, 56 & 57; path 188/row 55, 56 & 57; path 189/row 55, 56 & 57; and path 190/row 55 & 56) that covers the entire study area were obtained from the United State Geological Surveys (USGS) and NASA Earth Observatory website. These datasets were all acquired in the dry season in order to minimise seasonality variations.

C. Image processing and data preparation

For the eleven Landsat scenes of images to be use together for spatial and temporal analysis of LULC change studies, image processing was done using ERDAS IMAGINE and ENVI software. Atmospheric and radiometric correction was carried out; followed by image to image geometric correction. The geometric correction was done by correcting Landsat 5-TM and Landsat 7 ETM+ images using the corrected image of Landsat 8-OLI that was already geometrically registered using ground control points. Thereafter, mosaicking, subseting and integration were done to generate/extract the spatial extent of the study area from eleven scenes of Landsat images. ERDAS IMAGINE, IDRISI and ArcGIS software were used for LULC evaluations. The flow chart of the methodology is presented in Figure 2.

D. Development of image classification scheme and image analysis using remote sensing and GIS

Since Image classification is the process of assigning pixels of continuous raster image to pre-defined land cover classes, there was need to develop a classification scheme. Hence, before the images were classified, field reconnaissance was carried out to identify and developed land use/land cover classes. The land use/land cover classes identified and used for the study were shown in Table 1.

Table1: LULC Classes and Description

LULC CLASS NAME	DESCRIPTION
Waterbody	All the water bodies, ocean, rivers, stream, lagoons, creeks, etc.
High density Built up	City centers, commercial/industrial areas, high density residential settlements
Low Density built up/Exposed Surface	All low density settlements and bare/exposed surfaces
Forest	Primary Evergreen forested areas and forest reserves
Sand Deposit	Sand bars and sediment deposit without any vegetation
Vegetation	Lightly forested areas, cultivated lands and farmlands mixed with light forestation.
Mangrove	Mangrove, swamps/wetlands

Also, substantial number of ground control points belonging to corresponding land use land cover classes was acquired in the field across the study area. In this study image classification was done by performing supervised maximum likelihood classification in ERDAS IMAGINE and further LULC analysis was done in IDRISI and ArcGIS software. Accuracy assessment was also carried out using ground control points acquired during field ground truth along with historical map information of the study area.

III. DATA ANALYSIS AND RESULT DISCUSSION

This section presents and discusses the results of accuracy assessment of LULC classification, LULC spatial distribution /magnitude, change trend, gains and losses, net change, and rate of change of LULC of the study area.

A. Accuracy Assessment

All the three classified LULC images of 1986, 2002, and 2016 were subjected to accuracy assessment. The overall classification accuracy was 66.7% for 1986; 70.10% for 2002 and 74.50% for 2016. KAPPA (K^) statistics was 0.60, 0.64 and 0.70 for 1986, 2002 and 2016 respectively. The high density built-up areas had higher percentages for 1986, 2002, and 2016 user accuracy were 83%, 86% and 90% and producer accuracy were 71%, 86% and 84% respectively; followed by low density built-up areas/exposed a naturally vegetated environment. surfaces. The overall accuracy and kappa statistic were all within acceptable limits.

B. Land Use/Land Cover Distribution/Magnitude

The classified land use/land cover distribution maps of the respective years are presented in Figures 3, 4 and 5. While the magnitude and percentages of LULC are presented in Table 2, 3, and 4. The spatial distribution of land use/land cover types were presented in Figure 3. Figure 3 showed that a large magnitude of forest could be clearly seen in Ondo, Edo, Akwa Ibom, Cross River and the boundary between Delta, Imo and Rivers states. Figure 3 and Table 2 showed the initial distribution of LULC of in 1986 and their spatial extent across the study area. It could be seen that the study area was a healthy eco-environment as over 80% of it environment was still

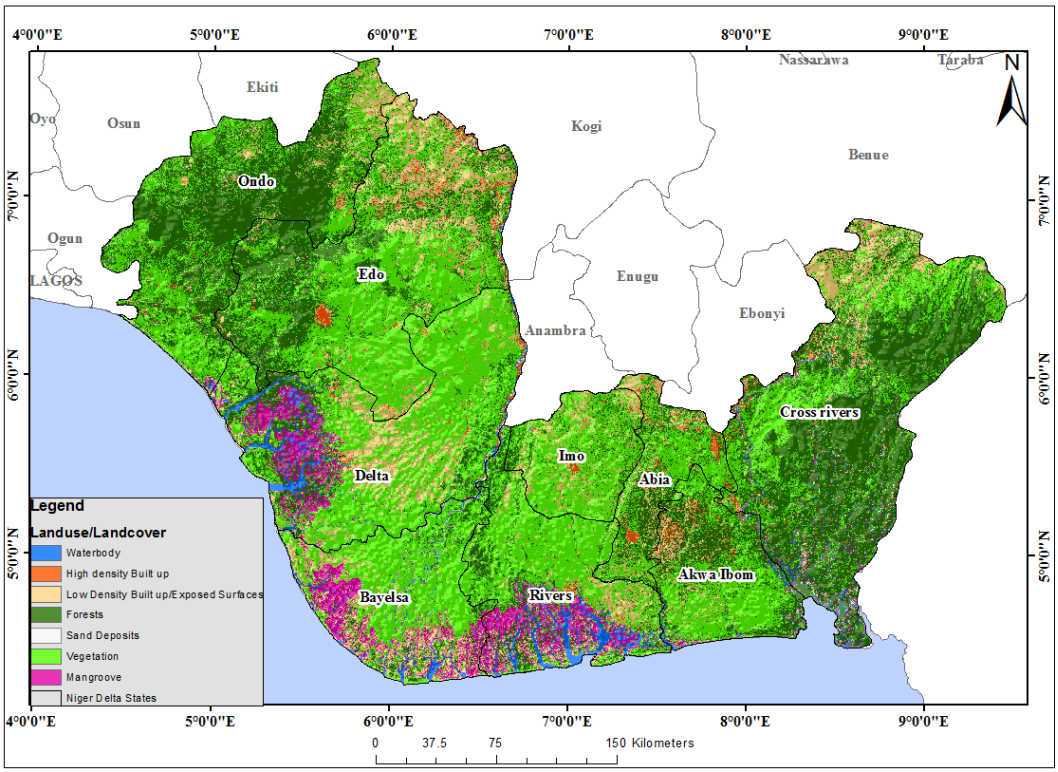

Figure 3: 1986 Land use/Land Cover Map of Niger Delta Region, Nigeria

Table 2: 1986 Percentage and Spatial Extent of LULC of Niger Delta Region, Nigeria

Land use/Land cover	Area (Hectares)	Area (%)
Waterbody	266031.95	2.406
High Density built up	145068.13	1.312
Low Density built up/Exposed Surface	1427240.42	12.908
Forest	3743465.42	33.856
Sand Deposit	23883.17	0.216
Vegetation	4940609.21	44.683
Mangrove	510723.85	4.619

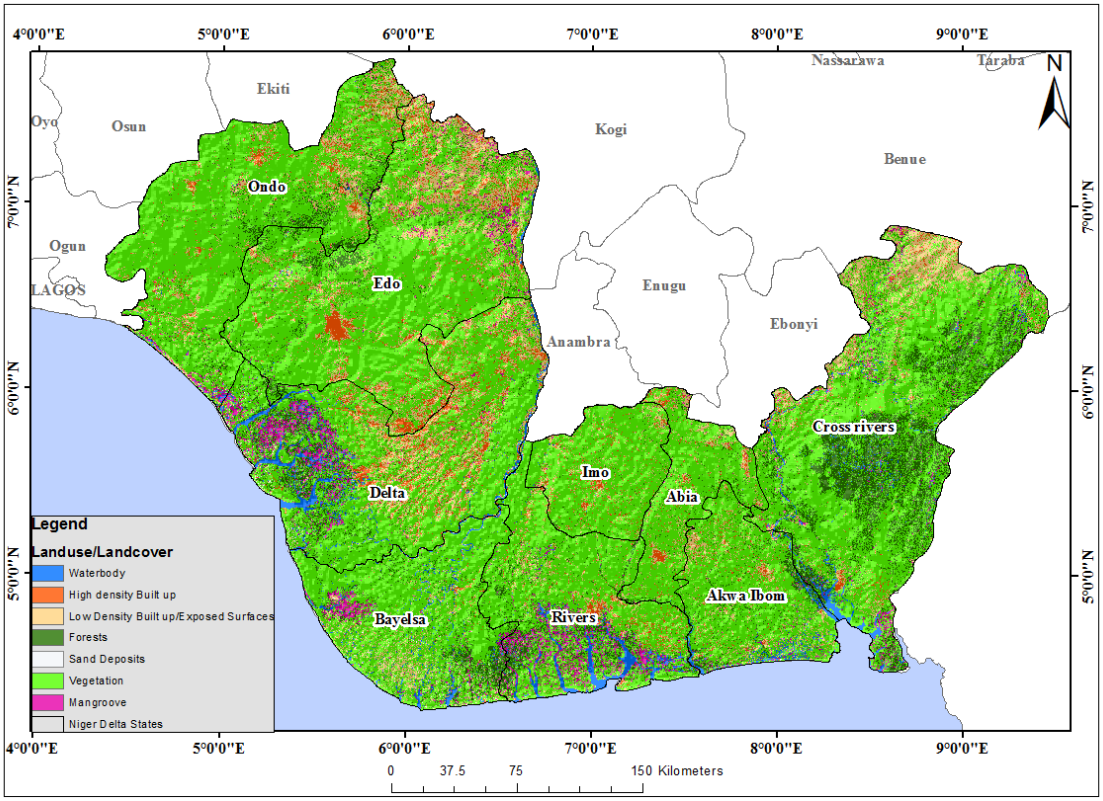

Figure 4: 2002 Land use/Land cover Map of Niger Delta Region, Nigeria

Comparing the 1986 land use/land cover Map of study area shown in 3 and the spatial distribution of land use/land cover for 2002 shown in Figure 4, it could be seen clearly that there has been alteration particularly the forested area and the mangrove. Table 3 depicted the spatial distribution and percentages of LULC for 2002.

Table 3: 2002 percentage and Spatial Extent of LULC of Niger Delta Region, Nigeria

Land use/Land cover	Area (Hectares)	Area (%)
Waterbody	282506.916	2.555
High Density built up	423373.3782	3.829
Low Density Built up/Exposed Surface	1242256.439	11.235
Forest	1026865.647	9.287
Sand Deposit	23219.74652	0.21
Vegetation	7724214.536	69.858
Mangrove	334585.4903	3.026

The results presented in Figure 4 and Table 3 indicated that the spatial extent of high density built up, low density built up/exposed surface, water, sand deposit and vegetation increased whereas, the forested area suffered depletion mostly in Ondo, Edo, Akwa Ibom, Cross River and the boundary between Delta, Imo and Rivers states. The mangrove was depleted mostly in the core oil producing states of Bayelsa, Rivers, Akwa Ibom and Delta States as a result of over two thousand incidents of oil spill that occurred between 1997 and 2002.

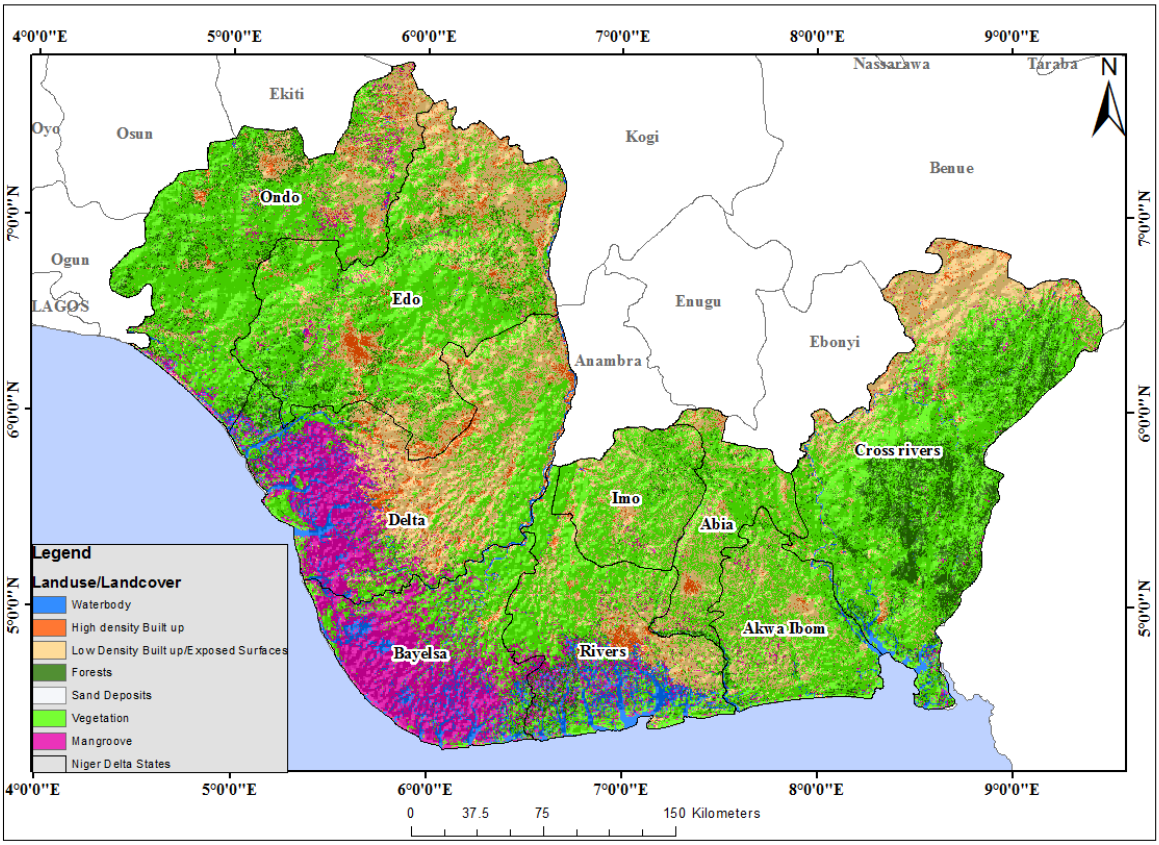

Figure 5: 2016 Land use/Land cover Map of Niger Delta Region, Nigeria

Table 4: 2016 percentage and Spatial Extent of LULC of Niger Delta Region, Nigeria

Land use/Land cover	Area (Hectares)	Area (%)
Waterbody	454111.90	4.107
High Density/Built up	442280.89	4
Low Density built up/Exposed Surface	2684866.12	24.282
Forest	774323.26	7.003
Sand Deposit	4312.24	0.039
Vegetation	5553721.09	50.228
Mangrove	1143406.66	10.341

In 2016, almost similar trend of increase in 2002 occurred. Figure 5 and Table 4 showed that high density built up and low density built up/exposed surface continued to increase and the depletion of the forest continued in virtually all the states. But vegetation magnitude this time was reduced in all the states as a result of settlement sprawl. Mangrove surprisingly increased in all the coastal states probably due to improved strategy of oil spillage amelioration and amnesty intervention that reduced the incident of pipeline vandalism.

C. Land use/land cover percentage trend of LULC magnitude, gains and losses, net change and change rate analysis

The results shown in Figure 6 and Table 6 indicated that all the LULC classes had both gains and losses across the 30years period (1986-2016) confirming the fact that the region has clearly been altered. The result revealed that the forest had insignificant gains of just 2.95% compared to it loss of 29.09% of its extent. Also worthy of note is the high and low density built up/exposed surface that recorded

gains up to 20%. From Figures 6 and 7 and Tables 6 and 7, it was shown that forest suffered heavy depletion all through the 30years period at the rate of about 1% (98.971.41 hectares) per year, while high and low density built up sprawl at the rate of 0.47% (51,827.95 hectares) per year. This revelation makes the LULC change situation in the Niger Delta region of Nigeria so worrisome and calls for proactive measure to ameliorate the trend of incessant destruction of the natural eco-environment of the region.

Table 5: Percentage trend of LULC magnitude

Land use/Land cover	Year 1986	Year 2002	Year 2016
Waterbody	2.41	2.56	4.11
High density Built up	1.31	3.83	4.00
Low Density built up/Exposed Surface	12.91	11.24	24.28
Forest	33.86	9.29	7.00
Sand Deposit	0.22	0.21	0.04
Vegetation	44.68	69.86	50.23
Mangrove	4.62	3.03	10.34

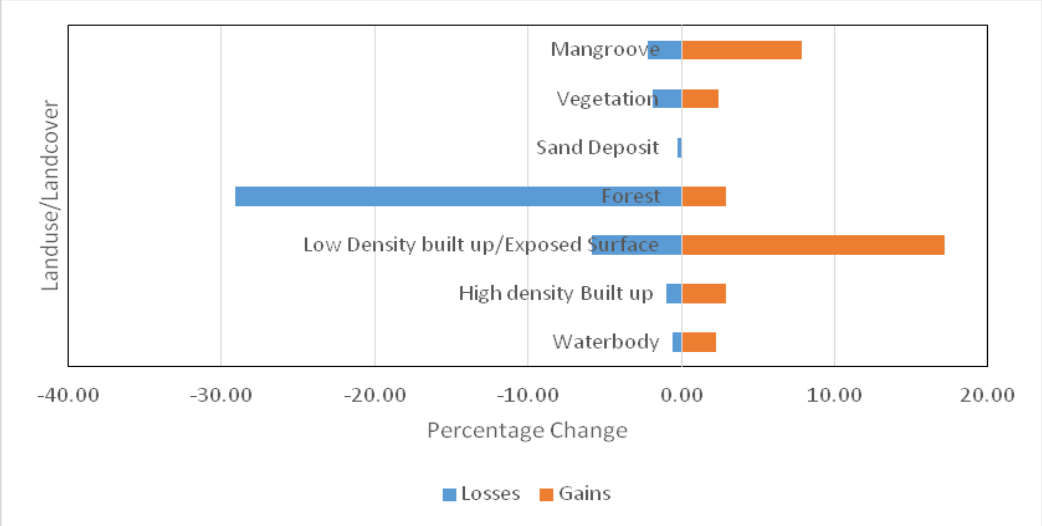

Figure 6: Gains and Losses of LULC of Niger Delta Region, Nigeria (1986-2016)

Table 6: Percentage Gains & Losses and Net change of LULC (1986-2016)

Land use/Land cover	Losses	Gains	Net change
Waterbody	-0.60	2.30	1.70
High density Built up	-0.94	2.91	1.97
Low Density built up/Exposed Surface	-5.82	17.20	11.38
Forest	-29.09	2.95	-26.14
Sand Deposit	-0.21	0.03	-0.18
Vegetation	-1.85	2.40	0.56
Mangrove	-2.17	7.87	5.70

Table 7: Rate of change of LULC of Niger Delta Region, Nigeria (1986-2016)

Land use/Land cover	Rate of Change (Hectares)	Rate of Change (%)
Waterbody	6269.33	0.06
High density Built up	9907.09	0.09
Low Density built up/Exposed Surface	41920.86	0.38
Forest	-98971.41	-0.90
Sand Deposit	-652.36	-0.01
Vegetation	20437.06	0.18
Mangrove	21089.43	0.19

IV. CONCLUSION

This research successfully explored the use of satellite remote sensing and GIS techniques in evaluating the land use/land cover dynamics in the Niger delta region of Nigeria. The spatial and temporal analysis indicated that from 1986 to 2016 all the Land use/land cover classes were significantly altered from its initial state. The result showed that in 2002 the magnitude of high density built up increased from 1.13% in 1986 to 3.83%, vegetation increased from 44.68% to 69.86, forest reduced from 33.86% to 9.26%, and mangrove suffered depletion from 4.62% to 3.03% as a result of several incidents of oil spill that occurred between 1997-2002. In 2016, high density built up further increased to 4.0% and low density built up/exposed surface increased to 24.28%, whereas forest was greatly depleted to 7.0% and vegetation to 50.23%. Surprisingly mangrove increased from 3.03% to 10.34% as a result proactive measures that were put in place to reduce oil spill and pipeline vandalism which destroyed the mangrove within the study area. Most outstandingly, this research revealed that the forest suffered most as it has lost of 29.09% of its extent at the rate of about 1% (98.971.41 hectares) per year while the high and low density built up sprawled at the rate of 0.47% (51,827.95 hectares) per year. The findings presented in this research presented will aid environmental planners, policy makers, stakeholders and the academic community in Nigeria to effectively and efficiently understand land use/land cover change processes, make more precise projections of future planning and management of the eco-environment, and generate plans which will foster the sustainable development of the region.

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