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Research Paper

Change Detection on Land Use and Land Cover Changes in the Wetland Ecosystem of the Niger Delta Region.

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Abstract
LULC changes have been upsetting marine and inland ecosystems, including wetlands, leading to serious destruction of wetlands global. The study examines change detection on land use and land cover changes in the wetland ecosystem of the Niger Delta Region, Nigeria from 1986 - 2016.This study adopted a cross-sectional research design method, both primary and secondary data sources were activated in the studywhile data set includes a notable period of four epoch years landsat images of 1986, 1996, 2006, and 2016, LandSat5Thematic Mapper (TM,) Landsat7Enhanced Thematic Mapper (ETM +), Thermal Infrared Sensor (TIRS) and Landsa8 Operational Land Imager (OLI). The data analysis was carried out through ArcGIS 10.6 environment, descriptive and inferential statistics, Cohen's Kappa statistic were employed in the study. A total area of 25053.93 (km^2) was delineated in the study area and the overall accuracy assessment using kappa statistics shows that from 1986-2016 was 86.06% (0.85 kappa coefficient). The entire results show that land use type has changed over the four epoch years as thus: fallow land covered around 18.317%,13.61%,12.231%, 25.928 %, respectively; built-up areas covered 5.449 %, 14.639 %, 15.795%, and 16.792%, across the study years; natural-vegetation covered around 32.905%, 32.404 %, 30.161%, and 28.156 %; waterbodies covered6.244 %, 6.421 %, 8.051 %, 8.059 %, and wetland covered 37.085%, 33.926%, 33.762 %, and 21.065 %, respectively. These observable trends occur as a result of overall changes in land cover patterns and the conversion of natural land to human-modified landscapes. Conclusively this study will enable planners, conservationist, environmentalist and policymakers to formulate appropriate strategies for the long-term conservation of these vital ecosystems. In furtherance this study demonstrates that GIS and Remote Sensing techniques is a comprehensive and Eco-friendly tool for land monitoring, sustainably capacity building for land inventory and collective understanding of wetland ecosystem and land use and land cover dynamics.

Keywords: *Change Detection, Landuse/ Landcover, Wetland, Ecosystem, Niger Delta.*

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I. INTRODUCTION

Universal sustainability challenges, such as climate change, biodiversity loss, and food insecurity, are often linked to the land use and land cover change (LULCC) taking place. Land use and land cover change can have both undesirable and desirable effects on sustainability challenges, depending on the direction of the change and the components that change (Winkler *et al*.,2021;Agumagu*et al.*, 2025). For instance, rehabilitating degraded agricultural areas to forests can support increased biodiversity, alongside climate change mitigation. However, such changes may not support food security goals (Agumagu*et al.*, 2025).LULC changes have been upsettingmarine and inland ecosystems, including wetlands, leading to serious destruction of wetlands global (Zekarias*et al*.,2021; Wali, 2024). Between 2002 and 2022, most coastal wetlands in northern Africa released blue carbon due to LULC conversion (Aitali *et al*.,2022). In the past few decades, LULC has undergone a major transformation, and the changes in LULC partly reflect the tremendous impact of human beings on natural resources (Minta*et al.*, 2018). LULC changes are closely related to aboveground biomass (AGB) changes in ecosystems (Massetti*et al.,* 2020). Irrational LULC conversion threatens AGB carbon stocks and tropical forest reserves in Africa (Acheampong*et al*., 2022). Analysis of LULC is a necessary condition and a major strategy for effectively managing natural resources and conserving biodiversity (Mallimis*et al*.,2014). In the LULC conversion of reclaimed areas, the conversion from natural wetland to constructed wetland is an important LULC transformation leading to an increase in carbon storage (Li *et al*., 2018). The analysis of the effects of LULC conversion on the aboveground biomass of coastal wetlands in the past is an important way to provide critical information for regulating climate change, managing ecosystems, planning future land use, and making correct policy decisions (Aitali *et al.,* 2022; Wu *et al.* 2023).

Unfortunately, human activities often wieldharmful impacts on wetland ecosystems. The alteration, draining, or filling of wetlands to meet human needs has resulted in the degradation of vital wetland habitats. As a result, the destruction of wetlands means the erosion of the various services they provide (Scanes,2018; Wang & Gu,2021). It is evident that curbing activities that can inflict adverse effects on wetlands is imperative to safeguarding the well-being of these intricate ecosystems (Atesoglu, *et al*.2024)

Wetland monitoring is an important tool for understanding the health of our aquatic ecosystems. Monitoring wetlands can help us assess the health of these sensitive ecosystems, identify changes or disturbances, and develop strategies for protecting them (Xu *et al.,2018*;Ke*et al.,2020* ;). In addition to providing important information about the health of wetlands, wetland monitoring can also help us understand the impacts of climate change (Atesoglu, *et al*.2024; Wali, 2024). Overall, wetland monitoring is an essential tool for understanding and managing its ecosystems (Salimi*et al.,2021;* Wali, 2024).

The popularity of remote sensing-based approaches for monitoring land features is on the rise due to their capacity to furnish detailed information about the land surface across extensive areas (Liu *et al.,2020*;Kafy*et al.,2021*;). Such monitoring methods are commonly utilized to detect changes in land cover/use within wetlands and to assess their overall health (Rapinel*et al.,2019;*Aghsaei*et al*.,2020; Assefa*et al.,2021*; Thamaga*et al*.,2022; Tu and Baykal,2023; Wali, 2024). Incorporations of Remote Sensing (RS) and Geographic Information System (GIS) is a notably efficient means of monitoring alterations in wetland health and tracking changes over time. These incorporation has been employed for landuse/cover monitoring purposes for several years (Atesoglu, *et al*.2024). While remote sensing technology enables the collection of extensive data across large areas, GIS provides the tools necessary for data management, analysis, and visualization. Consequently, these technologies can collaboratively generate intricate wetland maps and facilitate the monitoring of fluctuations in wetland vegetation (Johnston & McIntyre,2019; Orimoloye*et al.,2019;*Bhattacharjee*et al.,2021*). The availability of RS&GIS integrated tools that are freely accessible and designed for the visual interpretation of very high-resolution (VHR) data has significantly expanded in recent times, thereby carrying substantial relevance for land observation and monitoring (Nizeyimana,2020). The utilization of such platforms for land monitoring and evaluation studies has become widespread (Alderson *et al.,*2020;Wali, 2024). Building platforms on diverse cloud-based computing technologies, coupled with their capability to leverage pre-processed satellite image data and graphics, offer significant advantages in this context (Tamiminia*et al.,2020*; Zhao*et al.,*2021;Atesoglu, *et al*.2024).

Change detection modelling in LULCC can guarantee useful information that can better natural resource management and sustainable landuse management practices under changing landscape, guiding environmental assessment, territorial and urban planning, and agricultural production management (Xiang *et al.,*2021;Wali, 2024;Agumagu*et al.*, 2025).

Therefore, this study examines change detection on land use and land cover dynamics in the wetland ecosystem of the Niger Delta Region, Nigeria from 1986 - 2016leaving a gap in knowledge. Consequently, there is need to close this gap by studying the historical patterns of land use change in the following states of the Niger Delta Region, Akwa -Ibom State, Bayelsa State, Cross River State, and Rivers State, from 1986–2016which the background knowledge seeks to focus.

II. METHODOLOGY

2.1 Study Area

From Environmentalistperspectives, Niger Delta region of Nigeria is found along the Gulf of Guinea (Enaruvbe*et al.,* 2014; Wali&Ajake, 2024). It is the world's third largest and Africa's largest Delta. It is also West and Central Africa's most extensive wetland (Akegbejo -Samsons&Omoniyi, 2009;Wali&Ajake, 2024). The region extends from Aboh (5°33′49″ N and 6°31′38″ E) in the North to palm point (4°16′22″ N and 6°05′27″ E) in the South. The East-West limit is between Benin River estuary (5°44′11″ N and 5°3′49″ E) in the West and Imo River estuary (4°27′16″ N and 7°35′27″ E) to the East (Niger Delta Environmental Survey (NDES), 1997). From Niger Delta region, three States were selected for the study which include Rivers, Bayelsa and AkwaIbom State (Fig.1). The area cover of the states in the region is about 28,191 km^2 representing 37.6% of the total land area of the region (NPC, 2006, Elekwachi*et al.,* 2021, Wali&Ajake, 2024;Wali, 2024;Wali&Wosu, 2024).

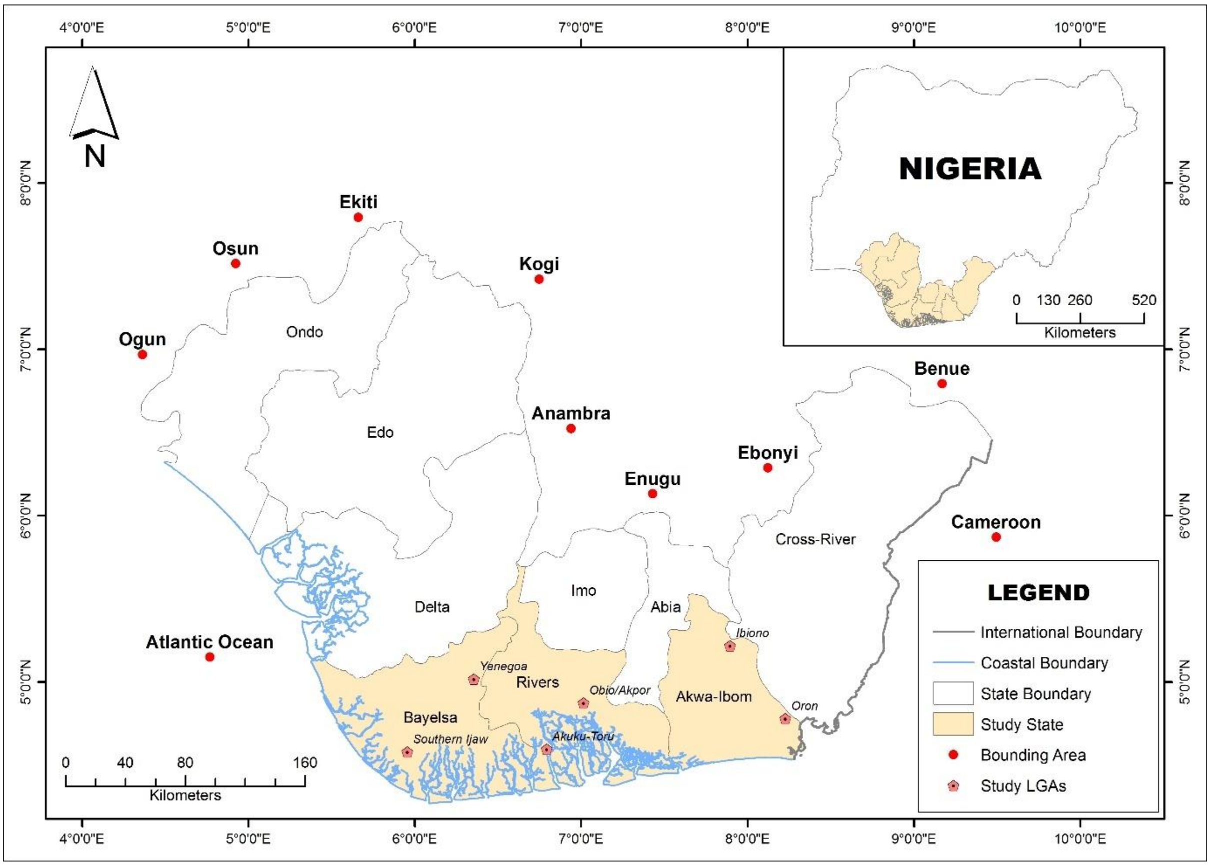

Figure 1: Niger Delta Region Showing Study States and Sampling LGAs.
(Source: Cartography and GIS Unit, Dept. of Geography and Environmental Sustainability UNN, 2025).

2.2 Data Analysis

This study used reconnaissance survey to help the authors familiarize themselves with the study area. GARMIN Etrex hand held Global Positioning System (GPS) was deployed during reconnaissance survey to obtain the coordinates of the following wetlands in the Niger Delta (Fig.2): Upper Orashi Forest in Rivers State, Apoi Creek in Bayelsa State,Akassa Coastal Wetlands in Bayelsa State, Stubbs Creek in Akwa-Ibom State, Kolo Creek Wetlands in Bayelsa State, Eagle’s Island Wetland in Rivers State, Qua Iboe and Itu Wetland in AkwaIbom State.

A cross-sectional and historical research design was adopted in the study. The study population was 2,780,494 but, for the purpose of this study, the population of the study area was carefully and randomly selected, two LGAs in each state of study (Akwa-Ibom State, Bayelsa State and Rivers State), whereas 18 communities in the study area where visited during reconnaissance survey.The maps were projected using Universal Transverse Mercator (UTM) projection system and datum World Geodesy System (WGS) 84 of zone 32.The United States Geological Survey (USGS) satellite data were used to generate high resolution images that are useful for this type of study.The satellite imageries were also employed using GIS and Remote Sensing techniques for our digital map production.

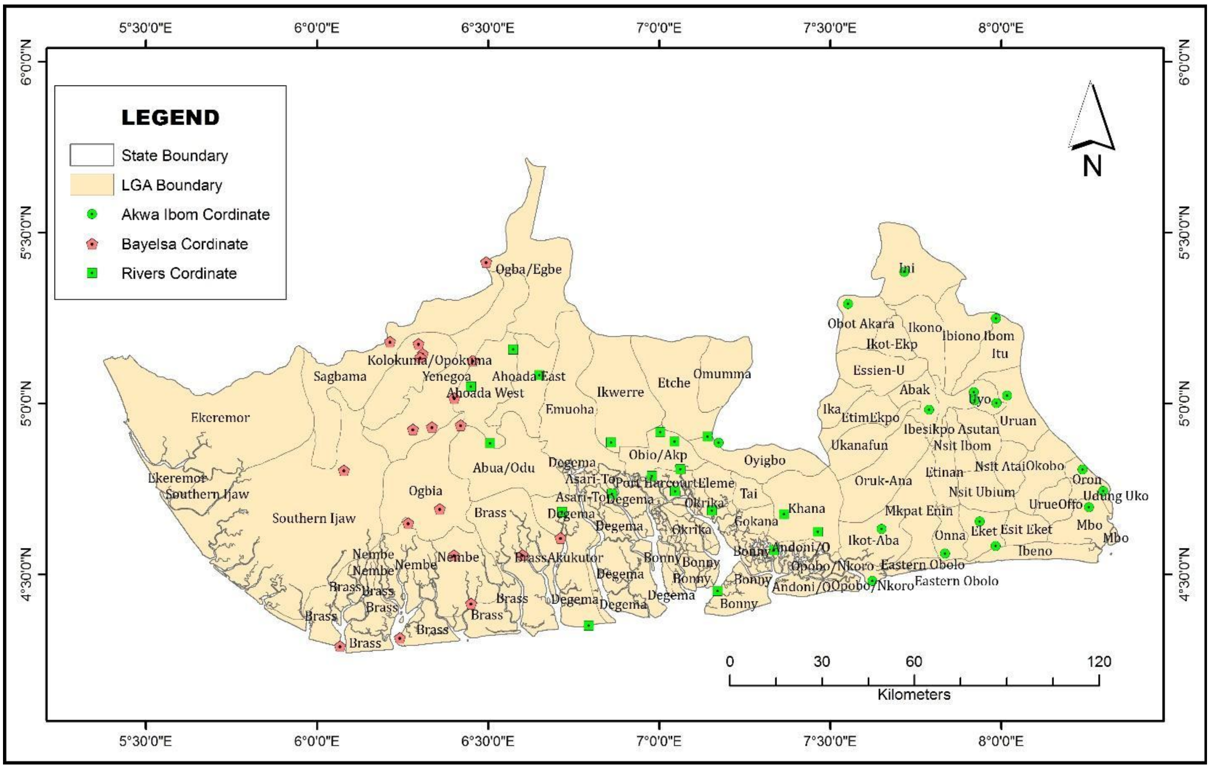

Fig. 2 Study Sampling Locations
(Source: Cartography and GIS Unit, Dept. of Geography and Environmental Sustainability UNN, 2025).

III. RESULTS/DISCUSSION

Change Detection

The changes detected from the comparison of classified Landsat images of 1986, 1996, 2006 and 2016 are presented in Table 1 and 2. The change detection results show that between 1986 and 2016, wetlands were reduced from 36% to 21%, making it a total of 15% change. A severe change was also observed in built up areas, from 5% to 16%, which is a total of 11% increase. This can be attributed to various anthropogenic activities taking place in the area and possible influence of climate change. Water bodies also showed a major increase, from 6% in 1986 to 8 % in 2016.

Table 1: Size and Proportion of Land Cover Classes from 1986-2016 (km^2)

Name	1986 (km^2)	1996 (km^2)	2006 (km^2)	2016 (km^2)
Fallow Land	4589.128	3409.84	3064.346	6495.983
Built Up	1365.189	3667.645	3957.268	4207.056
Natural -Vegetation	8243.995	8118.475	7556.515	7054.184
Water Body	1564.367	1608.713	2017.092	2019.096
Wet Land	9291.249	8499.796	8458.707	5277.61
Total	**25053.93**	**25053.93**	**25053.93**	**25053.93**

Table 2: *Percentage of Land Cover Changes from 1986-2016*

Name	% Cover 1986	% Cover 1996	% Cover 2006	% Cover 2016
Fallow Land	18.317	13.61	12.231	25.928
Built Up	5.449	14.639	15.795	16.792
Natural-Vegetation	32.905	32.404	30.161	28.156
Water Bodies	6.244	6.421	8.051	8.059
Wet Land	37.085	33.926	33.762	21.065
Total	**100**	**100**	**100**	**100**

Land cover maps and land cover changes are shown in Figures 3-6 showsthe visible changes in the LULCC of the study area. The proportions of each land use typehave changed over the study period. For example, fallow land covered around 18.317%,13.61%,12.231%,25.928 %, respectively; built-up areas covered 5.449 %, 14.639%, 15.795%, and 16.792%, across the study years; natural-vegetationcovered around 32.905%, 32.404%, 30.161%, and 28.156%;waterbodies covered6.244 %, 6.421 %, 8.051 %, 8.059 %, and wetland covered 37.085%, 33.926%, 33.762 %,and21.065%, respectively. The study observes overall changes in land coverpatterns and the conversion of natural land cover to human-modified landscapes, as rapiddevelopment took place between 1986–1996 and 2006–2016. The shape increase in waterbodies and fallow land was seasonal flooding and reclaimed land from wetland areas.

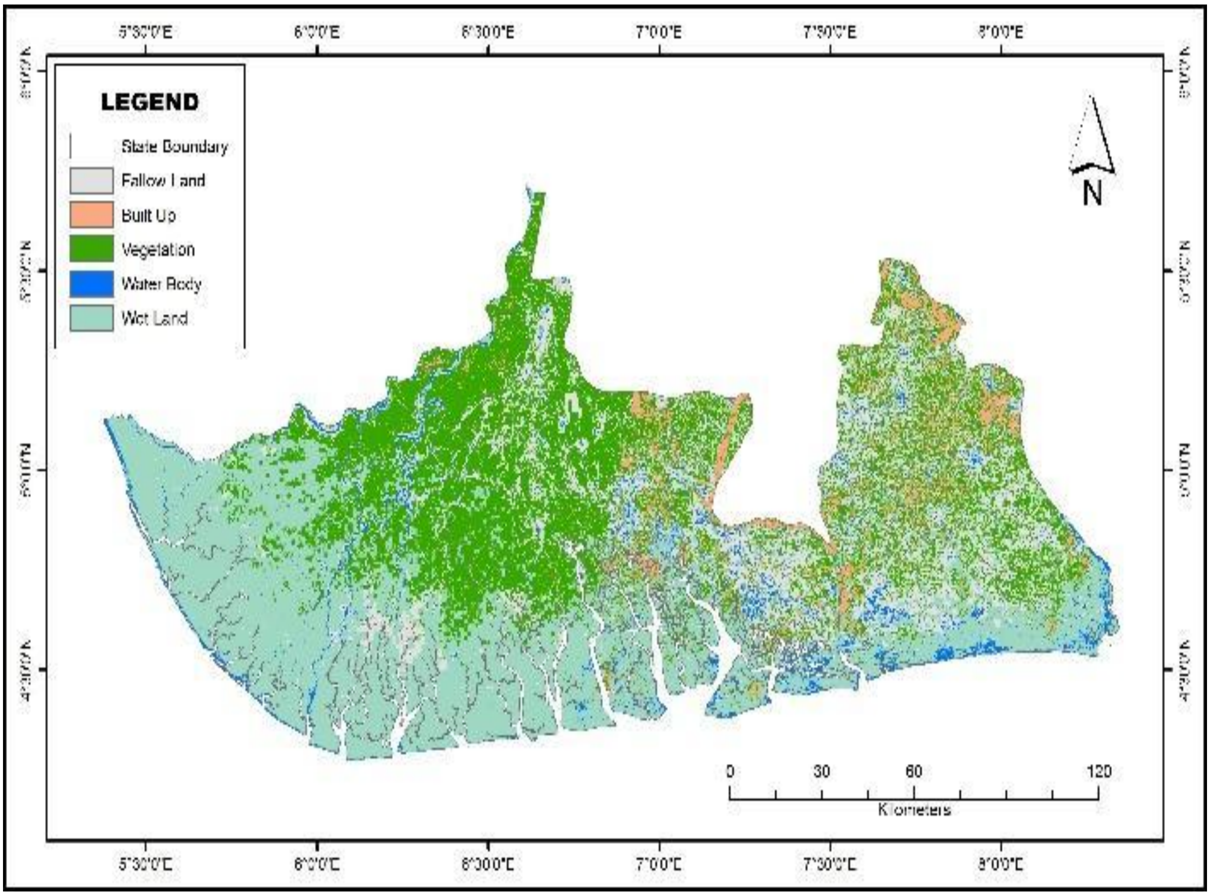

Figure 3: Supervised land-use land-cover classification of Landsat image 1986
Source (Elekwachi*et al.,* 2021).

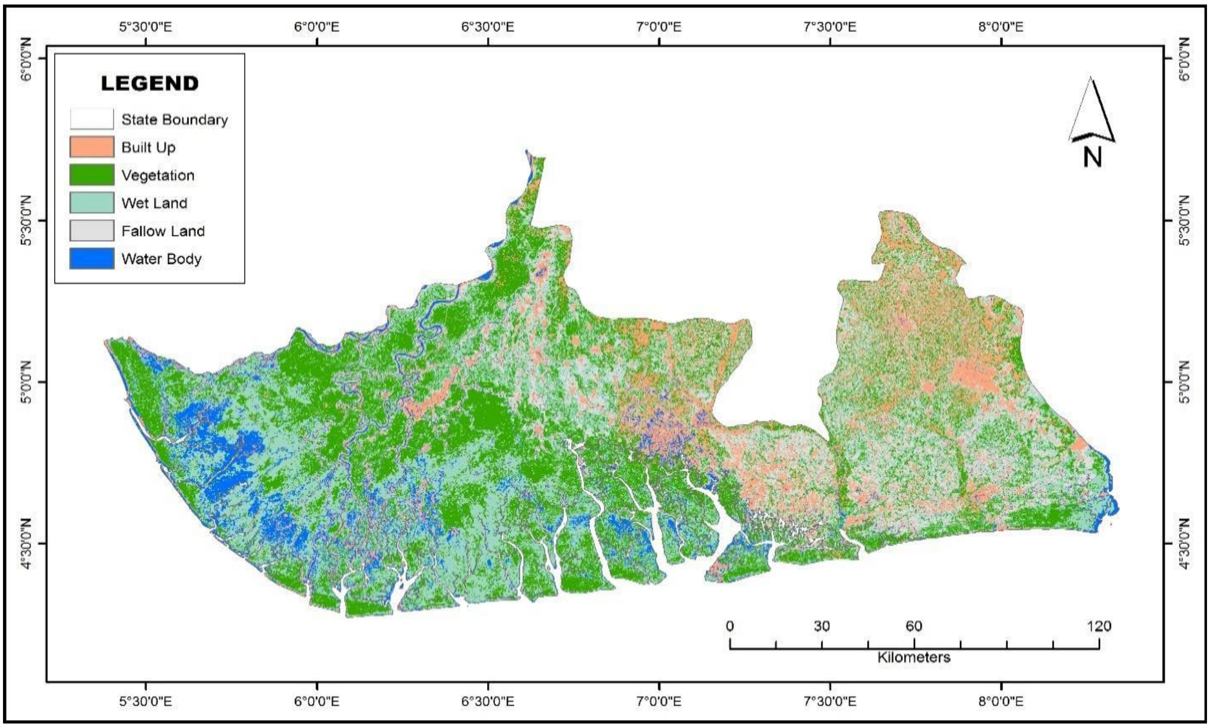

Figure 4: Supervised land-use land-cover classification of Landsat image 1996
Source (Elekwachi*et al*., 2021).

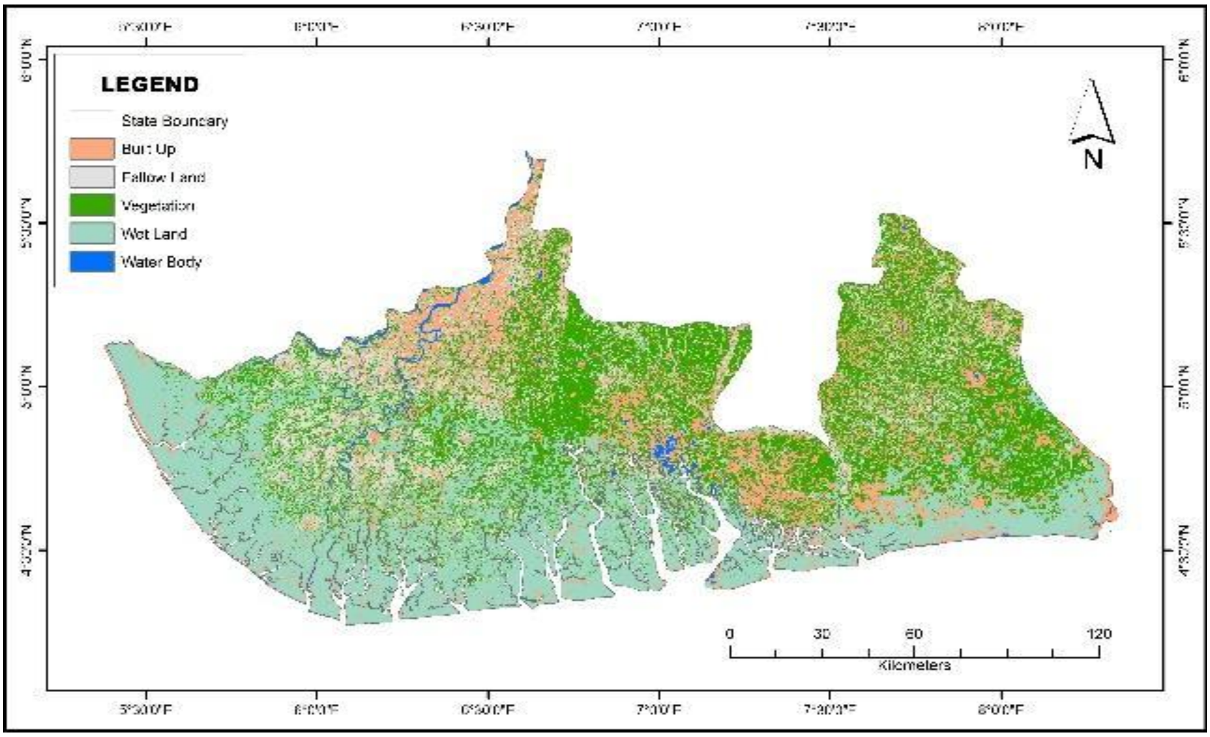

Figure 5: Supervised land-use land-cover classification of Landsat image 2006
Source (Elekwachi*et al*., 2021).

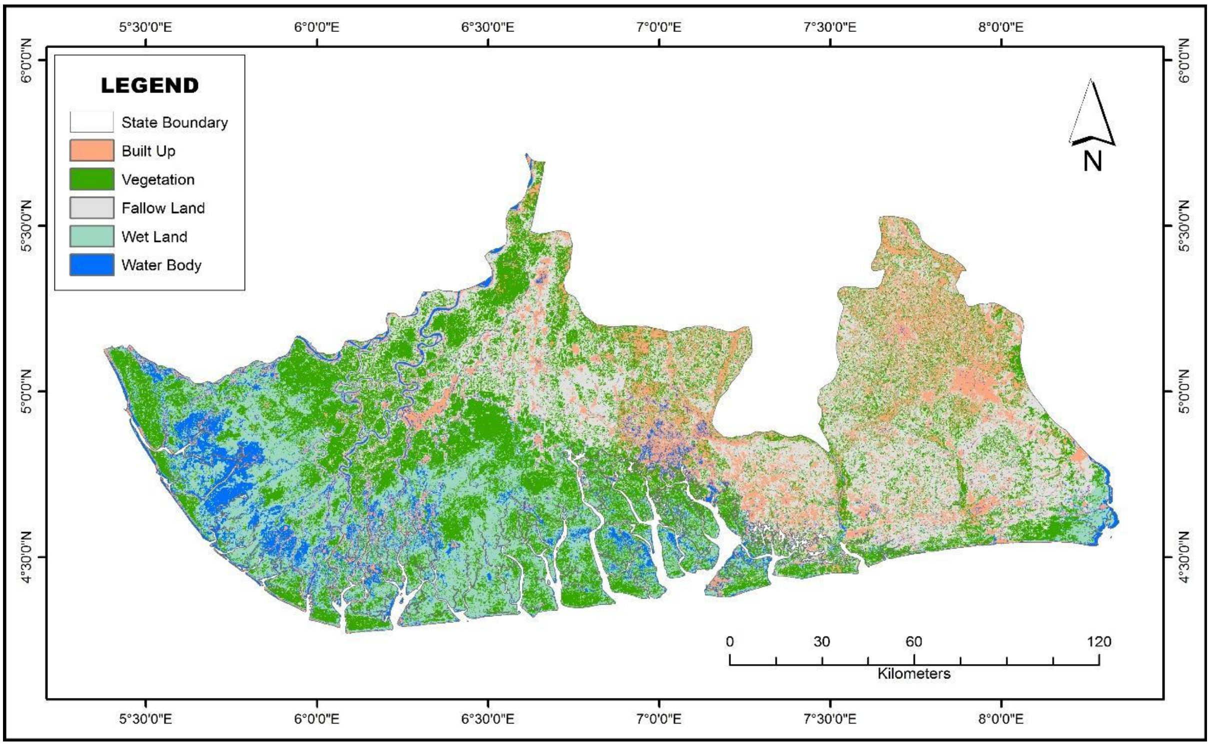

Figure 6: Supervised land-use land-cover classification of Landsat image 2016
Source (Elekwachi*et al.,* 2021).

In Fig. 7, the percentage change in wetland distribution from 1986 to 2016 is clearly depicted. From 37% in 1986 it reduced to 34% in 1996, not much change in 2006 as the percentage change was 33% and in 2006, wetland distribution was in the total of 20%. This establishes that change occurred in the wetland distribution and size as a result of change in land use and land cover. The distributions in area/km and as percentage cover are shown in Tables 1 and 2. Vegetation covers also reduced by 4% from 1986 to 2016 and fallow land increased from 18% to 26%.

The rate of wetland change in the study area is further illustrated with a straightforward distribution trend graph (Fig.8) which shows the distribution of reduction trend of wetlands and their diminishing pattern for the various years understudied.

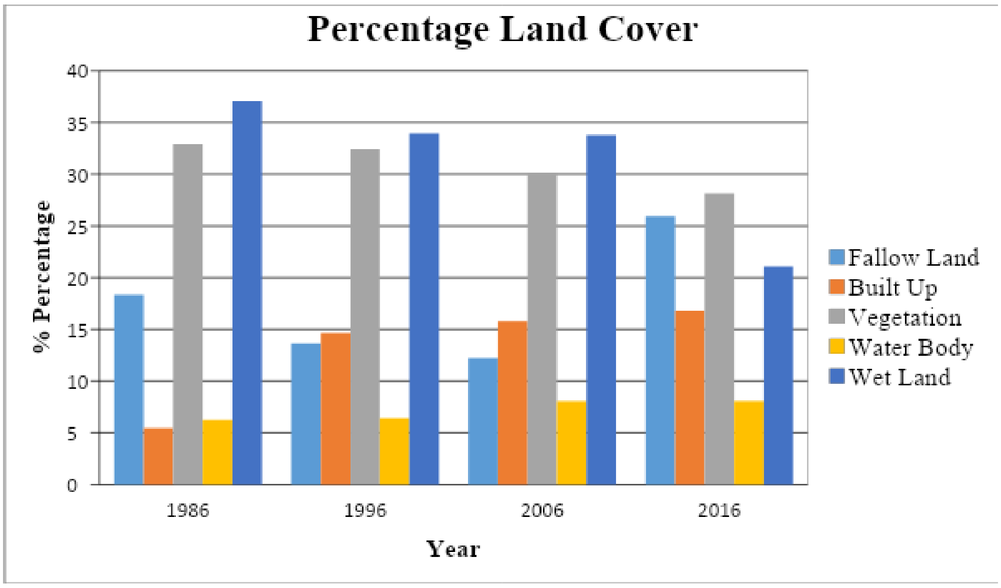

Figure 7: Change detection bar chart for 1986, 1996, 2006 and 2016 Landsat images

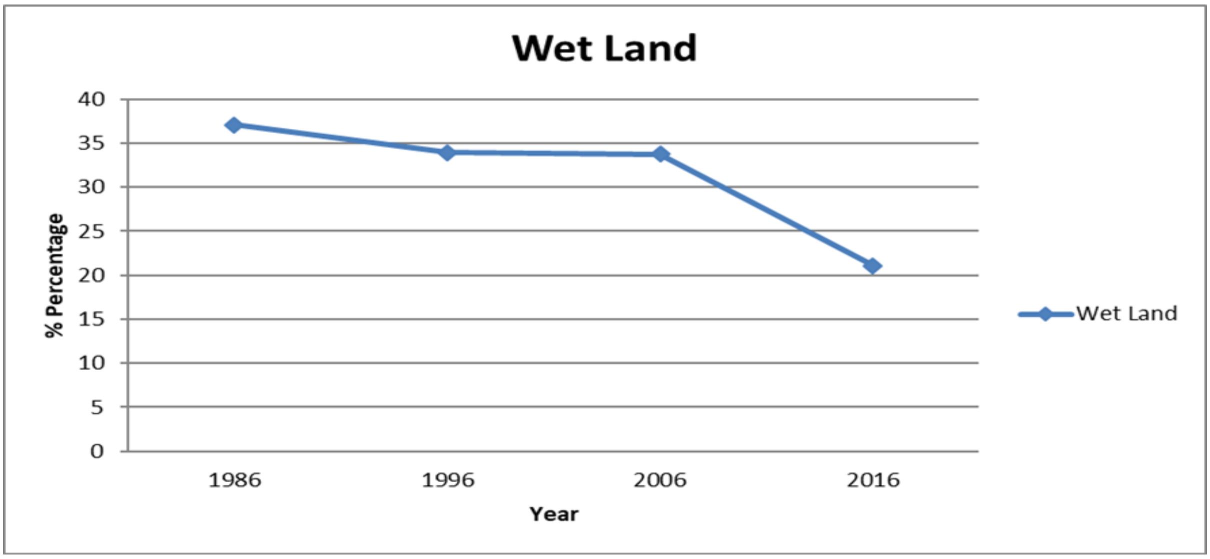

Figure 8: Change detection graph for wetland reduction across the understudied years

The changes in distribution and size in other classes such as waterbody, built up areas, vegetation and fallow land are also shown in graphs below in Fig 9-12 respectively.

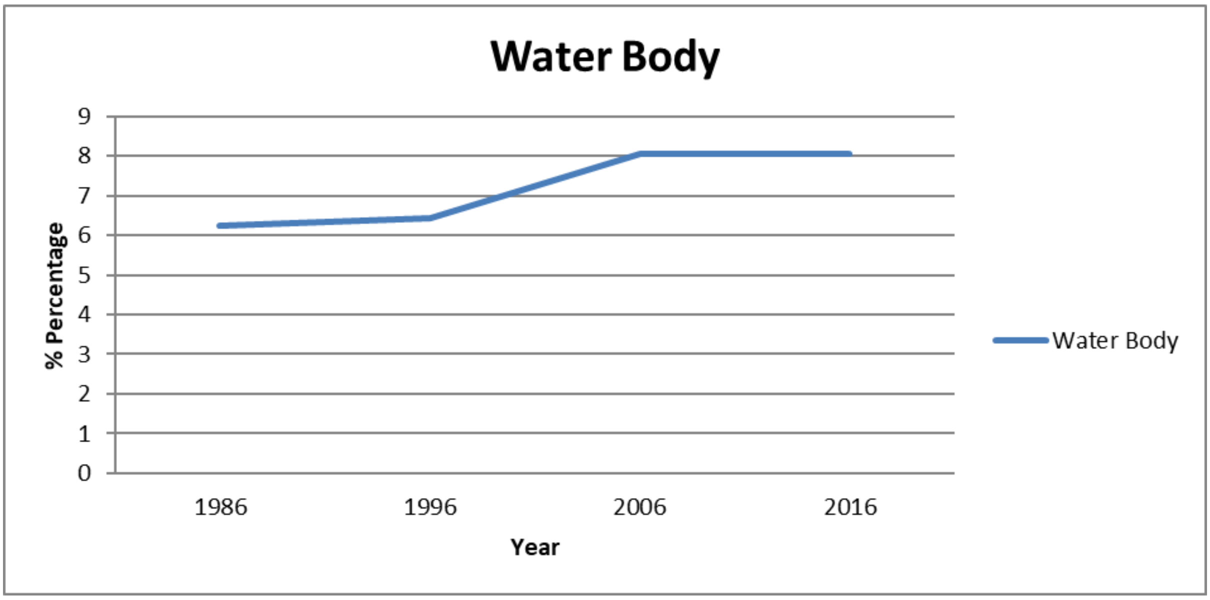

Figure 9: Change detection graph for waterbody across the understudied years

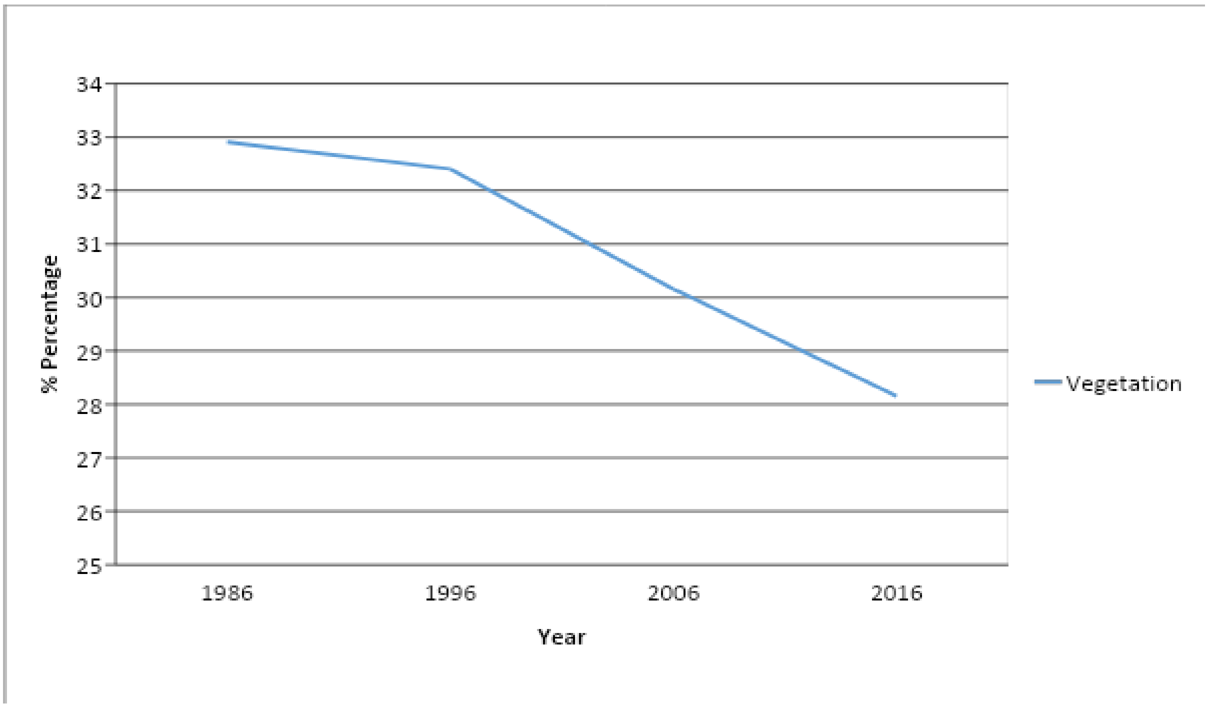

Figure 10: Change detection graph for vegetation reduction across the understudied years

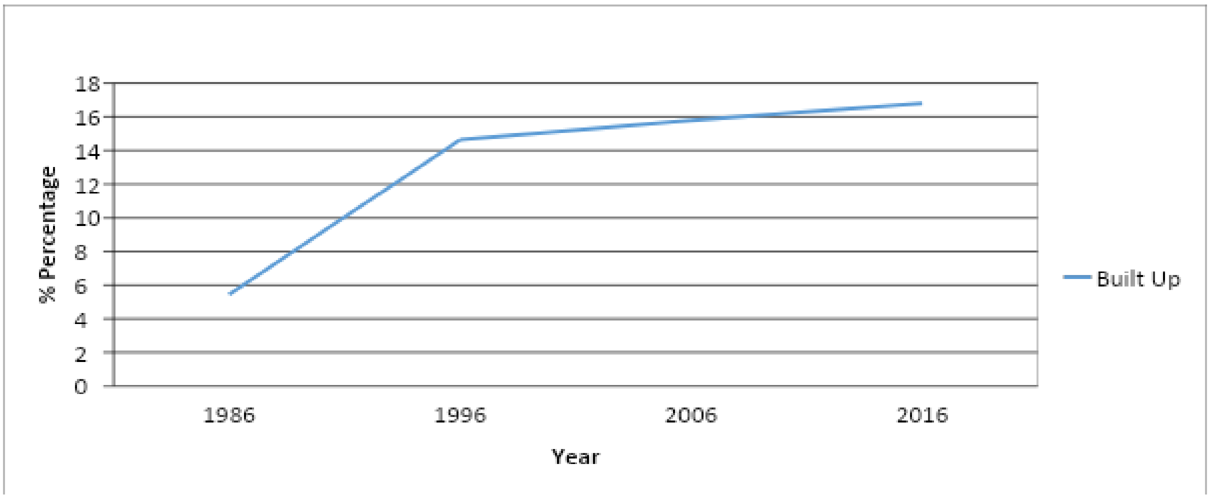

Figure 11: Change detection graph for built up areas across the understudied years

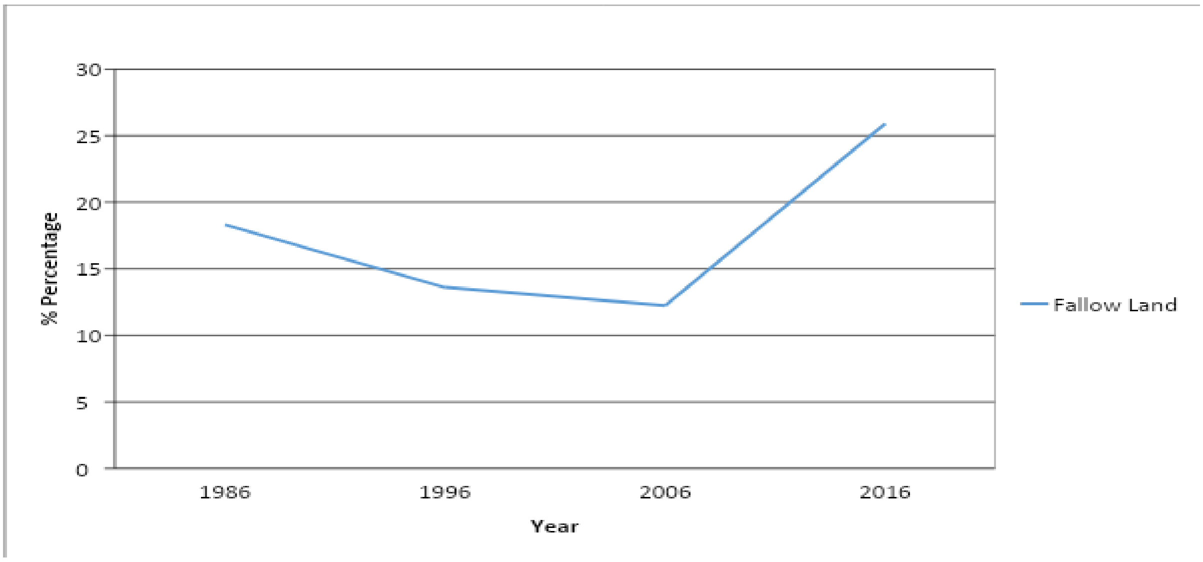

Figure 12: Change detection graph for fallow land across the understudied years

The post-classification matrix (Table 1) shows the individual class percentage and change statistics for 4 cloud-free multi-temporal Landsat images. The percent land cover distribution, percent change in the areal extent of each land cover unit between initial and final state images, and rate of change expressed, and the time rate of change of final and initial state images are clearly presented in the table. In addition, the total land use unit areas, percentage coverage, and corresponding area ratio are indicated in Table 2. The tabular figure is self-explanatory to analyze the change statistics for the 5 major land cover type considered.

From Table 1, it can be observed that the vegetation land use class is continuously increasing with a significantly higher positive rate at the expense of the other land use class (Figure 7). The largest increase of vegetation class in 2016 covered above 7054.184 area in Km (28.7%) of the total study area. However, there was a slight decrease in wetland within 2016. This was mainly due to the significant increase in some major land cover units, such as fallow land. Built-up areas showed a steady increase excepting the year 2006 and 2016, where the spatial extent has increased by 4207.056 area in Km from the current year.

The area of water bodies remained nearly constant with a changing slope significantly less than 6%. The only highest outliers were observed between 1986 (6.2%) and 1996 (6.4%), change, which covered 1564.367 and 1608.713 area Km of the total area. Similarly, in 2006and 2016, there was a substantial increase in the volume of water covering nearly 8.9% of the entire area. This can be attributed to the devastating 2012 floods in the region, resulting from recent sea level rises experienced globally and the gradual changing climate. In the study area, wetlands occupied 21.6% of total land area in 2016. Natural vegetation and fallow land were the dominant wetland types in the study area in 2016. The built-up area and water body had lest distribution which accounted for 16.8% and 8.6% of the total wetland area in respectively.

An accuracy assessment of the reclassified wetland data from 1986 - 2016 was performed with 195 points. When compared with high-resolution aerial imagery, the overall accuracy ranged from 86.6%. In comparison, Anderson et al. (2001) recommended a minimum accuracy for a classification system derived from remotely sensed data of 85%, and the overall accuracy for the NOAA C-CAP (Coastal Change Analysis Program) land cover classification is 82.3% (NOAA 2012). The user's accuracy measures errors of commission, represented by the inclusion of non-wetland reference pixels in the total wetland class. Most errors of commission occurred when other land use classes that cannot be resolved using 30-m resolution Landsat imagery were misclassified with the surrounding wetlands. Water-level differences between Landsat image acquisition and aerial photography acquisition may also contribute to some errors of commission. The Nigersat 1 that were used to ground truth the land-cover classification data were typically acquired during the wet and dry seasons, and were acquired over the study period. The producer's accuracy measures errors of omission, which occur when cells classified as total wetland are represented by other land use class reference pixel.

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LULCC detection techniques were applied extensively to understand changes over thedifferent years of imagery to identify and quantify areas of change in the land cover.LULCC detection was carried out by comparing the classified results of 1986, 1986, 2006 and 2016, determining the extent of change and the degree of expansion or reduction in the landcover resulting from the classification.Image differencing for LULC change detection,image differencing is among the numerous methods that have been developed and used for LULC change detection.About 57 Image difference, the difference in the total number of equivalently classed pixels between 4 images, is computed by subtracting the initial state class totals from the final state class totals. The image difference change detection statistics between 1986, 1996, 2006 and 2016 (Figures 3-6) details the magnitude of land cover charge for the past 30 years.

IV. CONCLUSION

Conclusively, based on the peak outlier the noticeable change was between 1986 (6.2%) and 1996 (6.4%), change, which covered 1564.367 and 1608.713 area km of the total area. Similarly, in 2006and 2016, there was a substantial increase in the volume of water covering nearly 8.9% of the entire area these outlier can be seen as thus : fallow land covered around 18.317%,13.61%,12.231%,25.928 %, respectively; built-up areas covered 5.449 %, 14.639 %, 15.795%, and 16.792%, across the study years; natural-vegetationcovered around 32.905%, 32.404 %, 30.161%, and 28.156 %; waterbodies covered6.244 %, 6.421 %, 8.051 %, 8.059 %, and wetland covered 37.085%, 33.926%, 33.762 %,and 21.065%, respectively.In furtherance this study proven that GIS and Remote Sensing techniques is a comprehensive and Eco-friendly tool for land monitoring, sustainably capacity building for land inventory and collective understanding of wetland ecosystem and land use and land cover dynamics.Therefore, this study will guide planners, conservationist, environmentalist and policymakers to formulate appropriate strategies for the long-term conservation of these vital ecosystems.

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