Spatio-temporal Assessment of Mangrove Cover Change in Niger Delta, Nigeria

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Abstract:- Mangroves are one of the unique ecosystems on earth that provide both ecologic and socio-economic benefits to coastal communities. However, increase in anthropogenic activities has put pressure on the mangrove forests resulting in the decline of mangrove extent. This study assessed the extent and rate of mangrove cover change for the period 1986-2018 in Niger Delta, Nigeria. Mangrove cover extent was estimated using remotely sensed data (Landsat TM images for 1986, 2000, and 2018). Supervised classification was conducted for image classification and mapping changes using a maximum livelihood classifier approach. Changes in the extent of mangrove cover were calculated using the change detection method. An assessment of the Landsat TM images showed a 63.65% (3,206.25 km^2) decrease in mangrove extent and an annual average mangrove loss rate of 1.99% yr $^{-1}$ for the period 1986-2018. The result revealed the dynamics of mangrove cover change, and concludes that the rate of mangrove loss in Niger Delta is consistent with global trend. These findings will provide data for aiding mangrove conservation intervention policies in Niger Delta, Nigeria. The study recommends continuous monitoring and assessment of changes in the mangrove areas which will also help to identify the drivers of these changes.

Keywords:- *Mangrove Cover, Remotely-Sensed Data, Change Detection Method, Mangrove Conservation, Niger Delta.*

I. INTRODUCTION

Mangrove forest is one of the unique ecosystems on earth that provide both ecologic and socio-economic benefits to coastal communities. Mangrove forest is one of the unique ecosystems on earth that provide both ecologic and socio-economic benefits to coastal communities. According to UNEP (2014), mangroves provide a wide range of ecosystem services and products that support the livelihoods of millions of people globally. Mangroves also provide nursery grounds, food, shelter, and habitat for a wide range of aquatic species (Schmitt and Duke, 2015). Furthermore, mangroves store 3–4 times more carbon than tropical forests, thereby mitigating co_2 emissions (Ahmed and Glaser, 2016). Despite their importance, mangroves all over the world are in continuous decline due to degradation and conversion to other land uses. Valiela *et al*. (2001) estimated the global annual rate of loss at 2.07% yr^{-1} over 17 years. The millennium ecosystem assessment (2006) reported 2.1% per year or 2,834 km^2 per annum while Ghosh *et al*. (2015) suggested between 1 to 2% per year. Ahmed and Glaser (2016) estimated that globally, mangrove cover have declined by 30–50% over the last 50 years. In addition, mangroves are now threatened by climate change which could result in a loss of further 10-15% of mangroves globally by 2100. Many factors are behind global mangrove deforestation. Walters, Ronnback, Kovacs, Crona, Hussain, Badola, Primavera, Barbier and Dahdouh-Guebas (2008) reported that aquaculture expansion in coastal areas accounts for 52% of mangrove loss globally, with shrimp farming alone accounting for 38% of mangrove deforestation; Other factors include forest use for industrial lumber and woodchip operations (26%), freshwater diversion (11%), and reclamation of land for other uses (5%). The remaining causes of mangrove deforestation are herbicide impacts, agriculture, salt ponds and other coastal developments. Some of the consequences of mangrove loss include; decline in resource availability to local communities (Walters *et al*., 2008), decrease in fish catch (Satyanarayana, Bhanderi, Debry, Maniatis, Foré, Badgie, Jammeh, Vanwing, Farcy, Koedam, and Dahdouh-Guebas, 2012), effects of cyclone in destroying lives and properties (Feurer, Gritten, and Than, 2018), sea level rise as a result of climate change (Feka and Ajonina, 2011), destruction of nursery habitat for juveniles and adult fish populations (UNEP, 2014), and reduced opportunities to mitigate co_2 emissions and carbon sequestration (Ahmed and Glaser, 2016).

Nigeria has the third largest mangrove forest in the world, and largest in Africa (Adedeji, Ibeh, and Oyebanji, 2011). Nigeria's mangrove has approximately 80% of its vegetation spread within the core Niger Delta (Bayelsa, Delta, and Rivers States) according to James, Adegoke, Osagie, Saba, Nwilo, and Akinyede, 2013. However, Nigeria mangroves have been on the decline over the years. Feka and Ajonina (2011) acknowledged a reduction from 9,990km^2 in 1980 to 7,386km^2 in 2006. Also, Friess and Webb (2013) using trend estimated from data for 1977 and 1994, reported that Nigeria mangrove reduced at 92.09 km^2 per year.

Studies have identified aquaculture, coastal erosion, salt extraction, crude oil exploration and exploitation activities, wetland dredging and reclamation, over-harvesting of mangroves for fuel wood and charcoal, population growth, coastal urbanization, and high incidence of invasive alien species as primary threats to the mangroves and livelihoods of millions of vulnerable coastal households who depend on them for subsistence and income in Niger Delta (Mmom and Arokoyu, 2010; Feka and Ajonina, 2011; Irikana, 2011). Amongst these factors, the unsustainable exploitation of mangrove resources as a means of livelihood has been identified as a major driver of mangrove deforestation in the Niger Delta. Feka and Ajonina (2011) noted that wood harvesting is the most perverse indirect driver of mangrove decline in West-Central Africa region. Irikana (2011) revealed that the increased demand for mangrove wood for building, traps, firewood, charcoal, etc., has resulted in widespread mangrove deforestation in Niger Delta.

Against these threats to both the mangroves and coastal livelihoods, it is necessary to promote conservation solutions that can adequately address these issues, without compromising the sustainable supply of ecosystem services. Several conservation strategies have been employed for the conservation and sustainable use of mangroves through the employment of policy, legislative and response options. Because mangrove ecosystems are dynamic both in space and time, Schmitt and Duke (2015) suggested that an understanding of historical changes in the extent of mangrove forests is therefore important in order to provide information required for management interventions. This can be used to provide spatial and temporal information on mangrove forest area and distribution, as well as on species differentiation. More so, Valiela *et al*. (2001) stated that forest conservation targets rely on an accurate baseline of historical data, and estimates of mangrove cover change are crucial inputs into national, regional and global estimations of change in mangrove cover.

Previous studies have been conducted to assess extent and rate of change in mangrove cover. For example, Cohen and Lara (2003) analysed the temporal changes of mangrove vegetation boundaries in Amazonia, North Brazil using satellite and aerial images covering a 25-year period from 1972 to 1997. The aim of the investigation was to identify and quantify areas with vegetation coverage losses or gains in mangroves and elevated mudflats. Analysis of image time series showed that in 1972, the study area had mangrove vegetation coverage over an area of about 592 km^2, which progressively declined to 585, 583 and 573 km^2 in 1986, 1991 and 1997, respectively. Nguyen, McAlpine, Pullar, Johansen and Duke (2013) used change detection analysis to assess spatial-temporal changes in the extent and width of fringe mangroves, and changes in adjacent land use in Kien Giang Province, Vietnam, for the period 1989-2009. The result showed a significant decrease in mangrove extent for the periods 1989-1992 (-2.7% yr^{-1}) and 2003-2006 (-2.1% yr^{-1}), while a significant increase in mangrove extent was observed during 1992-2003 (0.7% yr^{-1}). In general, the extent of fringe mangroves in study areas increased by 342 ha, with an average rate of increase 9.3% yr^{-1} over 17 years. However, the annual rate of loss in Kien Giang was higher than global annual rate of mangrove loss estimated at 2.07% yr^{-1} by Valiela *et al.* (2001). Dan, Chen, Chiang and Ogawa (2016) used change detection analysis to investigate the spatial and temporal change in mangrove from 1988 to 2014 in West and Central Africa and in the Sundarbans delta. The result shows that in the West and Central Africa, mangrove loss from 1988 to 2014 was approximately 16.9%, and only 2.5% was recovered or newly planted at the same time, while the overall change of mangrove in the Sundarbans delta increased approximately by 900 km^2 of total mangrove area. Ibrahim and Ngigi (2017) employed the post-classification change detection technique to examine the spatio-temporal dynamics of the mangrove forest cover to quantify the extent of degradation in Kilifi County, Kenya. Data obtained from multi-temporal satellite imagery reveals that mangrove area in the years 1990, 2000, 2010 and 2015 were 2134ha, 1984ha, 2082ha and 2083ha respectively. The findings shows that in the epoch 1990-2000, the percent cover change were -8%. In the epoch 2000-2010, the percent cover change was 5% while in the epoch 2010-2015, the percent cover change was 0.04%. The percent mangrove cover change in the epoch 1990-2015 was -2.4%. This suggests an annual rate of loss of 0.095% yr^{-1}. Jayanthi, Thirumurthy, Nagaraj, Muralidhar and Ravichandran (2018) used landsat satellite data, post-classification approach, and ground truth verification in mapping of the mangroves and assessing the changes in protected and unprotected forest regions of India between 1989 and 2013. The results revealed that mangrove extent increased from 3006 km^2 in 1989 to 3406 km^2 in 2013. The annual average rate of increase in mangrove area was 0.55% per yr.

For the Niger Delta area, Ayanlade (2012) used Landsat satellite data, remote sensing change detection and ecological services valuation methodologies to assess the impacts of environment change on the ecological services in Niger Delta. The result shows that mangrove area decreased from 13,396km^2 in 1987 to 12,838km^2 in 2001 and from 12,838km^2 in 2001 to 12,173km^2 in 2011. Wang, Numbere and Camilo (2016) employed the change detection technique to assess long-term changes in mangrove landscape of the Niger River Delta, Nigeria in the period 1984 -2007. The analysis showed that mangrove forest was the major land cover and its average proportion and area are 42.0% and 1444.7 km^2 respectively. The study noted a 4% decrease in mangrove area for the period under investigation. Nababa *et al*. (2020) incorporated image compositing techniques, spectral-temporal metrics, and machine learning classification algorithms into the ‘traditional’ remote sensing mapping method to carry out an assessment of land cover dynamics and estimate the extent of the degraded mangroves in Niger Delta between 1988 and 2013. The study observed that degraded mangrove area reduced from 1800.27km^2 in 1988 to 1169.07km^2 in 2000, and also reduced from 1169.07km^2 in 2000 to1158.61km^2 in 2013. Similar pattern was observed for mangrove area which reduced from 6897.15km^2 in 1988 to 5743.70km^2 in 2000, and also reduced from 5743.70km^2 in 2000 to 5529.72km^2 in 2013.

Despite the important role of analysing historical changes in mangrove cover at regular intervals for use in conservation initiatives, accurate and reliable information regarding the extent and annual rate of mangrove cover change in Niger Delta is very limited. Also, there is a need to identify location-specific annual extent and rate of change

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in order to correctly inform conservation policies designed to reduce such mangrove losses in Niger Delta. Several studies indicated that the original extent of mangrove forests in Niger Delta has declined considerably over time following the global trend. Niger Delta estimates of original mangrove cover lost varies, with the most losses occurring in recent decades due human activities. This paper therefore aims to assess the extent and rate of mangrove cover change in Niger Delta over the period 1986 –2018. This study is very significant in a number of ways. First, it can be used in building up regional, national and global estimates. In addition, the findings can be used as a decision support tool to inform policies on mangrove conservation. More so, it can contribute to climate change adaptation and mitigation efforts through the Land Use and Land Use Change and Forests (LULUCF) option.

II. MATERIALS AND METHODS

The study area

The study area is located along the Gulf of Guinea in the south-south geopolitical region of Nigeria. It lies between latitudes 4° 16′ 22″ and 5° 33′ 49″ N and longitudes 5°3′49″ E and 7° 35′ 27″ E (Fig. 1). The Niger delta mangrove ecosystem is the third largest mangrove in the world, comprising some 36,000 km^2 in area (Wang *et al*., 2016). It is spread across Ondo, Edo, Delta, Bayelsa, Rivers, Akwa-Ibom and Cross Rivers (James *et al*., 2013). However, UNDP (2006) reported that over 70% of Nigeria's mangrove forest is found in Bayelsa (3,533.5km^2), Delta (2,863.1km^2) and Rivers (3,367.3km^2) States. Therefore, this study is focused on these three States (core Niger Delta). According to Ayanlade (2012) Niger Delta has four ecological zones namely the mangrove vegetation, freshwater swamp, rainforest, and derived savannah. The mangrove vegetation in Niger Delta is represented by five plant species and one introduced family of exotic species. The endemic families are *Rhizophoraceae* family (red mangrove), consisting of *Rhizophoraracemosa*, *R. harrisonii* and *R.mangle* species; the *Avicenniaceae* family (white mangrove) made up of *Avicenniaafricana* species; and the *Combretaceae* family consisting of *Lagunculariaracemosa* species. The *Arecaceae (Palmaceae)* is the only introduced family consisting of Nypafrutican exotic species (James *et al.*, 2013).

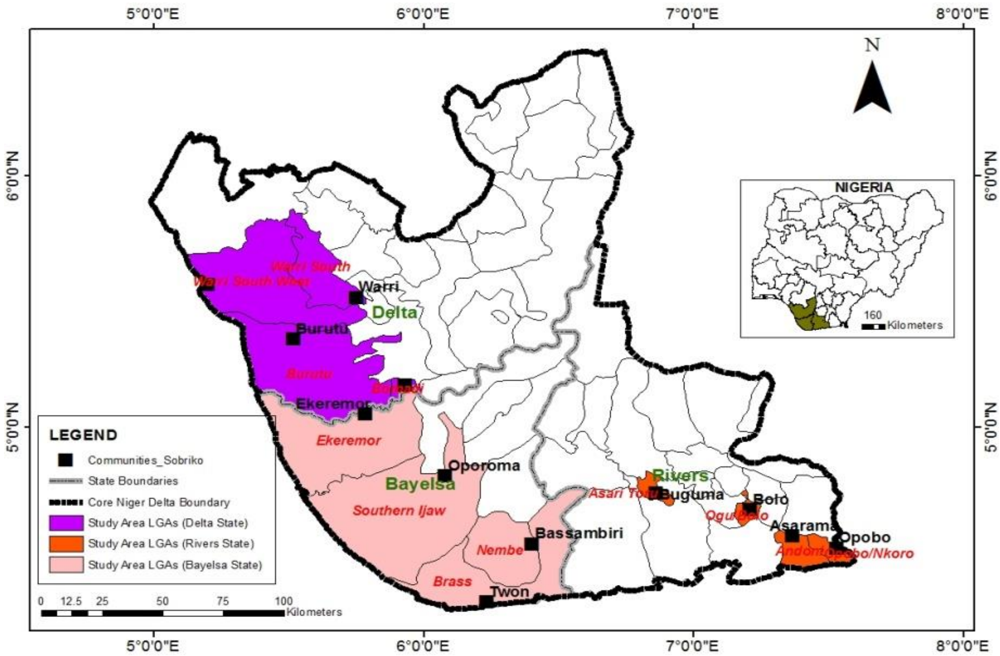

Figure 1: Core Niger Delta

Data acquisition and analysis

Landuse / cover images of different periods in Niger Delta were captured from the Landsat Thematic Mapper (TM) imagery of 30m x 30m for 1986, 2000 and 2018. Each image was geo-referenced in ArcGIS 9.3 to Universal Transverse Mercator, Zone 32N (WGS 84). Composite analysis was carried out for the bands of each image in each period in order to produce a false composite imagery in ArcGIS 9.3.

From the ground-truthing of the land use/cover types in the study area with additional information from the satellite imageries, an image classification analysis was carried out to classify the spectral reflectance into different major landuse types as found during the reconnaissance survey. Six major classes namely floodplain, farmland/cleared land, built-up area/bare land, freshwater swamp, mangrove and water bodies were identified and their descriptions can be found in Table 1. These classes are similar to the landuse / cover categories in the Niger Delta acknowledged by Ayanlade (2012). The landuse/ land cover detected were subjected to accuracy test with the use of Kappa's index. The spatial coverage of each landuse / cover type was determined in squared kilometers using the calculate geometry module of ArcGIS 9.3. These images were used to classify changes in mangrove extent.

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Table 1: Land use /cover classification scheme for Niger Delta

Land use / cover category	Description
Floodplain	swamps and waterlogged areas
Farmland / Cleared Land	An area of farmland, grass plants, scrubs, etc., thinly distributed with in a vegetation
Built Up Area / Bare Land	An area of land used for urban development activities e.g. roads, building, industries, etc.
Freshwater Swamp	An area of rain / fresh swamp and forest land
Mangrove	Area covered by mangrove / tidal marsh
Water bodies	Area of the earth's surface covered by a body of water eg river, streams, lakes, etc.

Change detection analysis

Change detection analysis was performed using land use / cover map in 1986, 2000 and 2018. Change detection refers to the process of identifying differences in the state of land features by observing them at different times (Atubi, Awaritefe and Toyon, 2018). In post-classification change detection, the images from each time period are classified using the same classification scheme into a number of discrete categories (i.e., land cover types) (Nguyen *et al.*, 2013; Ibrahim and Ngigi, 2017). Quantitative analysis of landuse / cover between different dates was conducted to detect the change. The post-classification change detection approach was used to analyse change in landuse and mangrove extent between two-time periods from the three different classified images. The procedure was carried out at three different intervals, for example, the change that occurred during 1986-2000, 2000-2018, and finally from 1986 to 2018. This approach to change detection has been used in several works (Dan *et al.*, 2016).

Annual rate of change in land use / cover

The percentage change in spatial coverage in percentage (%) for each land use type was calculated as a percentage increase or decrease in land use spatial coverage of the previous period for each land use type. The annual rate of change for the different classes of land use was obtained by dividing the observed land use change in area coverage (km^2) by the number of years taken for the change to occur. Valiela *et al.* (2001) estimated the annual mangrove loss rates from the mean number of years between original area and present area. The result obtained from the observed change in each land use / cover category is divided by the number of years between the land use/cover maps (1986–2018) to arrive at the annual rate of change (Enaruvbe and Atafo, 2014).

III. RESULTS AND DISCUSSIONS

Results

Land use / cover change analysis

The land use/cover maps of the study area for 1986, 2000 and 2018 are shown in Figures 2, 3 and 4 respectively. The spatial extent of land use / land cover types for the study area (1986 – 2018) is shown in Table 2. The table indicates that floodplain was 1,560.87km^2 in 1986, 2771.77km^2 in 2000 and 2,979.81km^2 in 2018. This shows an increase of 1418.94km^2 (90.91%) or (2.84% per year) between 1986 and 2018. Farmland / cleared land category was 1320.46km^2 in 1986, 2396.93km^2 in 2000 and 2,075.13km^2 in 2018. This shows an increase of 754.67 km^2 (57.15 %) or (1.79% per year) between 1986 and 2018. Built-up area / bare land category was 2914.22km^2 in 1986, 3795.95km^2 in 2000 and 4329.10km^2 in 2018. This shows an increase of 1414.88 km^2 (48.55%) or (1.51% per year) between 1986 and 2018. Freshwater swamp was 1,910.70km^2 in 1986, 1,710.68km^2 in 2000 and 1,816.46km^2 in 2018. This shows a decrease of 94.24km^2 (4.93%) or (0.15% per year) between 1986 and 2018. Mangrove was 5,037.48km^2 in 1986, 2,090. 84km^2 in 2000 and 1,831.23km^2 in 2018. This shows a decrease of 3206.25km^2 (63.65%) or (1.99% per year) between 1986 and 2018. Water body was 971.91km^2 in 1986, 949.47km^2 in 2000 and 683.91km^2 in 2018. This shows a decrease of 288km^2 (29.63%) or (0.93% per year) between 1986 and 2018.

Table 2: Spatial extent of land use / land cover types for the study area (1986 – 2018)

Land use / cover	**Extent (km^2) 1986**	**Extent (km^2) 2000**	**Extent (km^2) 2018**	**Total change in area**			
				1986–2000 (km^2)	**2000–2018 (km^2)**	**1986–2018 (km^2)**	**1986–2018 (%)**
Floodplain	1560.87	2771.77	2979.81	1210.90	208.04	1418.94	90.91
Farmland/ Cleared Land	1320.46	2396.93	2075.13	1076.47	-321.80	754.67	57.15
Built Up Area / Bare Land	2914.22	3795.95	4329.1	881.73	533.15	1414.88	48.55
Freshwater Swamp	1910.7	1710.68	1816.46	-200.02	105.78	-94.24	-4.93
Mangrove	5037.48	2090.84	1831.23	-2946.64	-259.61	-3206.25	-63.65
Water bodies	971.91	949.47	683.91	-22.44	-265.56	-288.00	-29.63
Total	13,715.64	13,715.64	13,715.64				

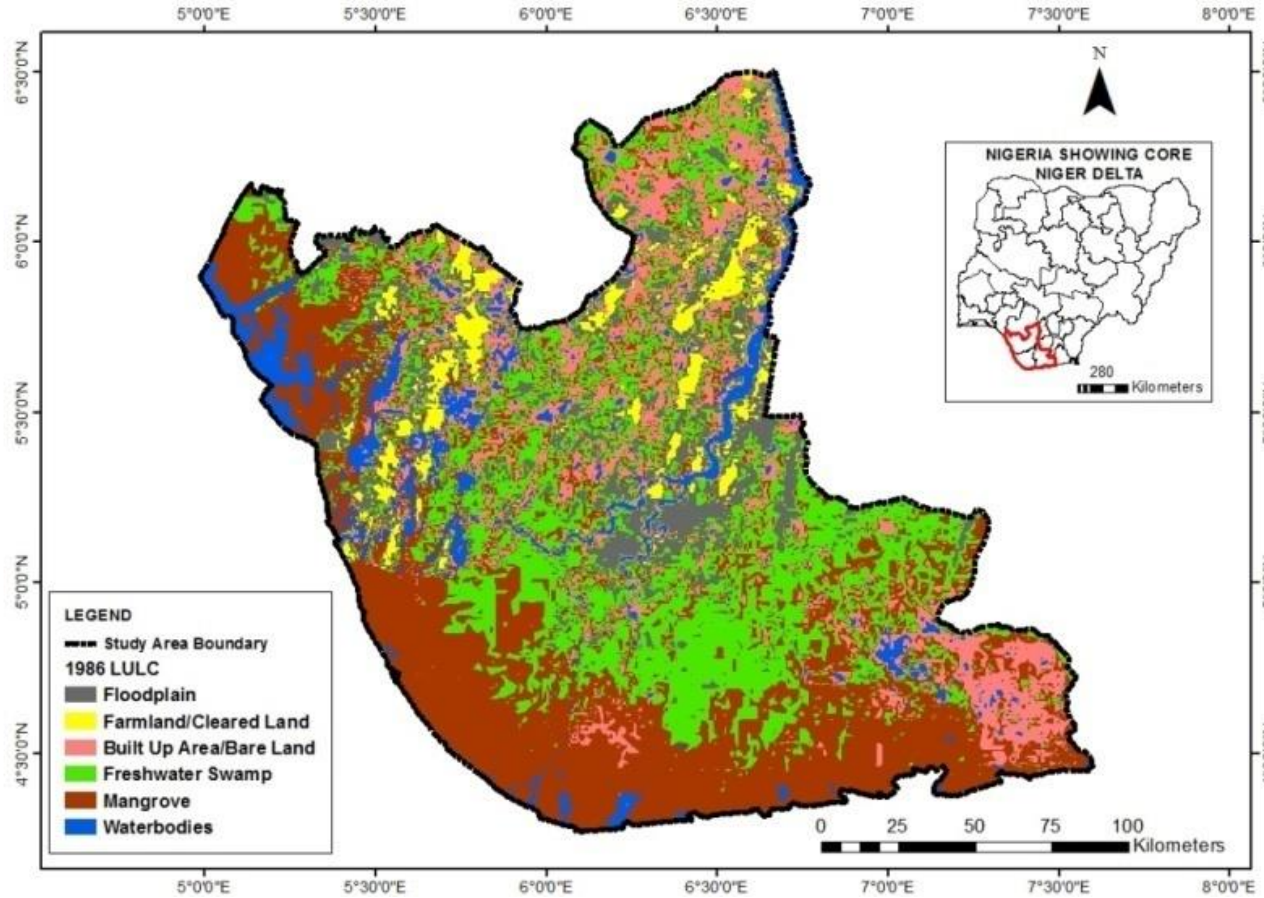

Figure 2: Land use / cover categories (1986)

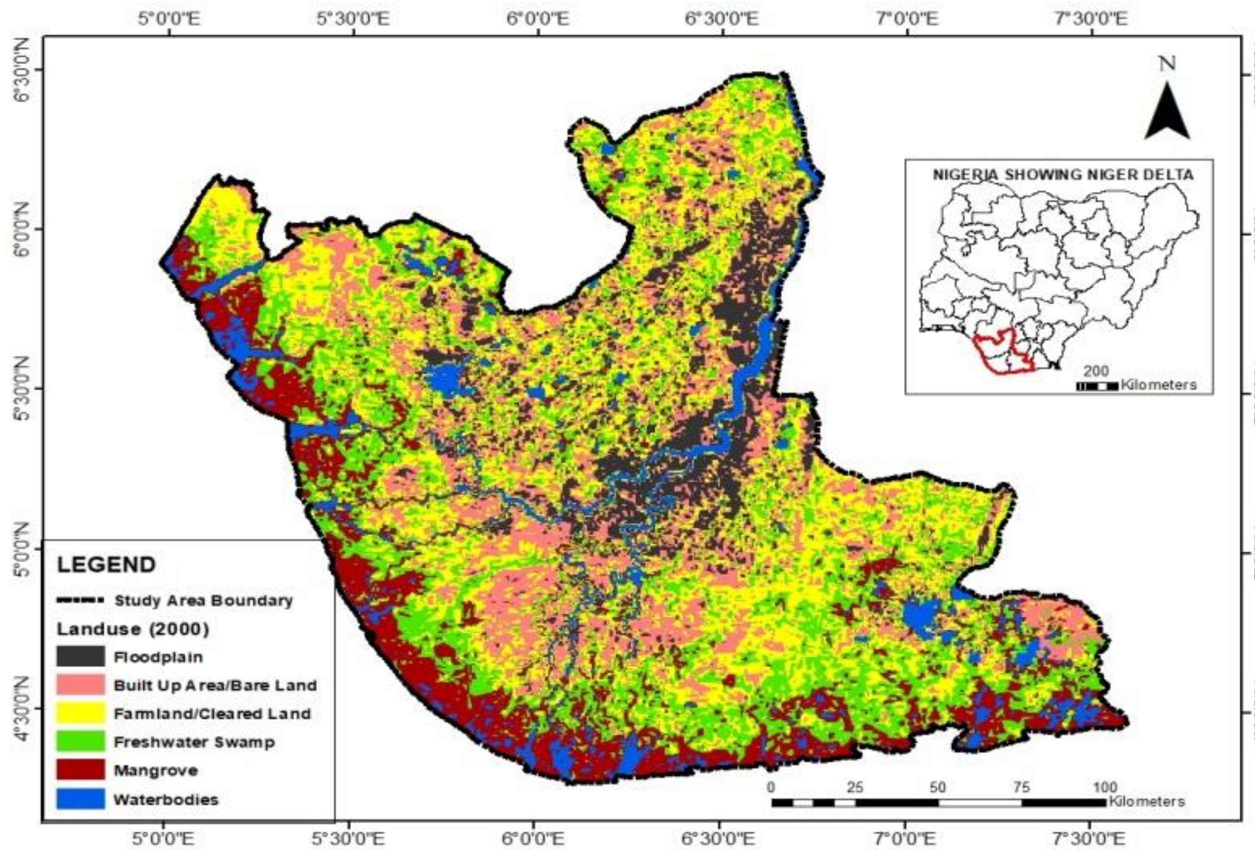

Figure 3: Land use/cover categories (2000)

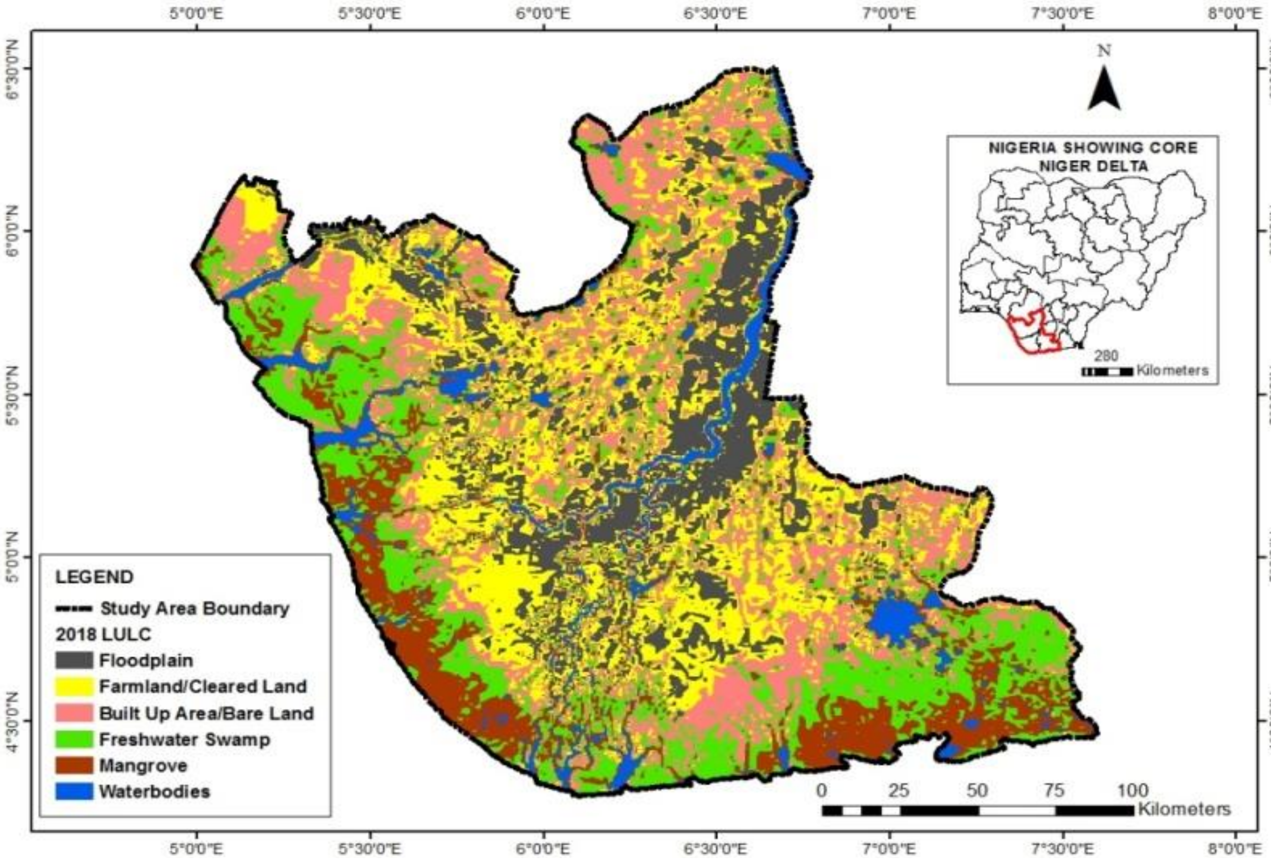

Figure 4: Land use /cover categories (2018)

Changes in extent of mangrove cover

The extent and rate of mangrove cover change (1986–2018) is shown in Table 3. The table reveals that spatial-temporal changes in mangrove extent have been fluctuating over the past 32 years.

The period 1986 – 2000 recorded a loss of 2,946.64km^2 at an annual rate of 210.47km^2 per year.

Percentage of original area lost per year was 4.18% per year. Also, for the period 2000 – 2018, a loss of 259.61km^2 was recorded at an annual rate of 14.42km^2 per year. Percentage of original area lost per year was 0.69% per year. Overall, for the period of 1986-2018, the change analysis indicates that the total mangrove area reduced from 5,037.48 km^2 (36.73%) in 1986 to 1,831.23 km^2 (13.35%) in 2018. This change observed from 1986 to 2018(32 years) resulted in the loss of 3,206.25 km^2 of mangrove forest to other land use/cover types in the study area. This implies that the mangrove forest extent decreased at the rate of 100.19 km^2 per year**.** The annual average rate of mangrove cover decrease was 1.9 % per year.

Table 3: Extent and rate of mangrove cover change (1986–2018)

Period	**Extent of change (km^2)**	**Annual rate of loss (Km^2 per year)**	**Percentage change in area (%)**	**Percentage of original area lost per year (% per year)**
1986–2000	-2946.64	210.47	-58.49	4.18
2000-2018	-259.61	14.42	-12.42	0.69
1986–2018	-3,206.25	100.19	-63.65	1.99

Conversion of mangroves forest in Niger Delta

Several factors contribute to the conversion of mangroves to other land use types. Land use conversion (especially coastal urbanization) is recognized as one of the most significant factors that reduce the extent of mangrove areas in Niger Delta. Based on this study, the Niger Delta has lost 3,206.25 km^2 of the original mangrove area in 1986 to other land use / cover types mainly flood plains, farmland / cleared land, and built up area / bare land.

Discussions

This study observed that the total area of Niger Delta mangrove has decreased from 1986 to 2018 resulting in the loss of 3,206.25 km^2 of mangrove forest to other land use/cover types. This trend is similar to the findings of previous studies which also suggested a general decline in mangrove area in the Niger Delta. Ayanlade (2012) revealed that mangrove area decreased from 13,396 km^2 in 1987 to 12,173 km^2 in 2011. Also, Wang *et al*. (2016) reported a 4% decrease in mangrove landscape from 1984 to 2007. Furthermore, Nababa *et al.* (2020) observed that degraded mangrove area was reducing from 1800.27km^2 in 1988 and 1169.07km^2 in 2000, to1158.61km^2 in 2013. A similar pattern was observed for mangrove area which reduced from 6897.15km^2 in 1988 and 5743.70km^2 in 2000, to 5529.72km^2 in 2013. The finding implies that the mangrove forest extent decreased at the rate of 100.19 km^2 per year**.** The annual average rate of mangrove extent decrease was 1.9% per year. However, the annual rate of loss in Niger Delta is close to the global annual rate of mangrove deforestation. Valiela *et al*. (2001) estimated the global annual rate of loss at 2.07% per year over 17 years. Although this study provides an estimate of spatial-temporal changes in mangrove cover extent in Niger Delta over the last 32 years, earlier findings have shown that there are variability in estimates of mangrove extent as noted by Friess and Webb (2013). Therefore, regular long-term assessment of changes in mangrove cover as provided by this study is required.

IV. CONCLUSION AND RECOMMENDATIONS

Assessing of changes in the extent of mangrove cover at regular intervals helps in understanding their status (decrease or increase) for better implementing conservation initiatives (Vani and Prasad, 2018). This study utilised Landsat data to assess the spatial-temporal dynamics of mangrove cover change in Niger Delta for the period 1986 - 2018. The result reveals that between 1986 and 2018 (32years), the mangrove cover decreased by 63.7% (3,206.25 km^2) at a rate of 100.20km^2/yr or 1.99% yr^{-1}. The findings will provide useful information and understanding of Niger Delta's mangrove extent and the rate of deforestation compared to the global situation. This will support policies and regulations associated with the conservation and rehabilitation of fringe mangroves. Also, it will be useful to conservationists, resource managers and other stakeholders involve in advocating for sustainable utilization of mangrove resources in Niger Delta region.

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