Journal of Agroforestry and Environment

Volume 15, Issue (1), 2022

Journal DOI: https://doi.org/10.55706/jae
Journal homepage: www.jagroforenviron.com

Analysis of Land Use and Land Cover Change in Oil Palm Producing Agro-Ecological Zones of Nigeria

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Received: 06/06/2022

Accepted: 30/06/2022

Available online: 27/07/2022

Abstract: Land-cover change has many environmental, physical, and socioeconomic significances. Therefore, the study investigated the consequence of Land Use/Land Cover (LULC) change on vegetation indices in oil palm producing Agro-Ecological Zones (AEZs) of Nigeria between 1989 and 2019 (30 years). Multistage sampling technique was used to sample 18 communities (six communities per each AEZ) that are known for oil palm production in the study area. Image processing and Geographical Information System (GIS) analysis was carried out. The result revealed that in the freshwater swamp AEZ, there was declining in areas covered by dense vegetation (72%) and wetland receded by 100% in the last 30 years. In the guinea savannah AEZ, the dense vegetation declines by 56.11% while built-up land and agricultural land increase by 169.06% and 17.98% respectively in the last 30 years. In the rainforest AEZ, there was 1689.43% increase in areas covered by sparse vegetation against 50.94% decline in dense vegetation. The study recommends that government and Non-Governmental Organizations should assist in formulating environmental policies that will protect the ecosystem in the study area.

Keywords: Oil palm; Agro-Ecological Zones; Land use cover; Image processing; Geographical Information System; Nigeria.

INTRODUCTION

Land cover change which infers an incessant alteration in some structures of the land such as plants type and soil features. Land-usage alteration involves the difference in the method of usage of some part of land by individual or community collectively (Paul and Rashid 2017). This comprises the modification of the natural landscape due to urban growth to built-up area and agricultural purposes. These changes majorly account for some homegrown and worldwide impacts, comprising biodiversity loss and its associated effects on human well-being, and the damage of environment and ecosystem facilities (Genet 2020). This are mostly caused by urban growth and is very common in both the emerging and developing countries. However, natural phenomenon can lead to land cover alteration over time, nevertheless land-use change needs human associated influences (Ellis 2007). Land-cover alteration has many environmental, physical, and socioeconomic costs. Positively, agricultural development because of the land cover alteration may likely lead to increase in food production for an increasing population. However, the impact on the land because of exploitation is unquantifiable. Hence, there are many negative effects that may not be ascertained immediately (Tang *et al.* 2014). So, transforming natural vegetation, forest or grassland to agricultural uses lead to reduction in biodiversity, decreases the ability of vegetation to capture atmospheric moisture and hold water in the vegetation cover and this leads to global warming effects (Pramit and Raghubanshi 2020).

Therefore, converting the natural vegetation for farming purposes have the likelihood of changing the radiation balance of an area in a particular time. Hence, there is possibility of increase in the reflective power when such vegetation are converted to farmland which leads to increase in solar energy reflecting back to the space. (Parveen *et al.* 2018). Also, there is high likelihood of reduction in the ability of soil to hold water because the vegetations are converted to farmland. This is a serious environmental problem that impact on the soil porosity because of reduction of soil compaction and infiltration capacity of soil. This often leads to incessant soil erosion problem (Huang and Hartemink 2020). In rocky areas, the alteration of the forests to farmlands reduces as does the orphic precipitation as croplands retain minimal atmospheric moisture than multidimensional aboriginal forest or forest of any kind (Holder 2004). Cloud formation over the land unit reduces as the evapotranspiration rate is reducing from grounds than from forests leading evidentially to decreased precipitation (Mölders and Kramm 2007).

Palm oil is very important to individual, families and corporate organizations all over the World (Ogunsina and Akintan 2020). Nigeria is one of major consumer of palm oil in Sub Sahara Africa (SSA), the population of Nigeria is over 190 million people. Nigerians in 2018 consumed about 3 million MT of fats and oil, palm oil consumption was 44.7% (1.34 million). However, in the same year, Nigeria produced 1.02 million MT of palm oil. So, there was 0.32 million MT shortfall, leading to palm oil importation. Nigeria accounted for 43% of palm production in the world in early 1960s, hence, Nigeria was the largest palm oil producing country in the world. Currently, Nigeria is the fifth largest producer of palm oil in the world, producing less than 2% (74.08 million MT) of the total world production. Malaysia and Indonesia palm oil production in 1966 was more than Nigeria palm oil production, so, the two countries became the world largest oil palm producers accounting for 80% of world palm oil production.

Central Bank of Nigeria (CBN) posited that had Nigeria sustained its high market share of palm oil production globally, she should have been earning about $20 billion annually from production and processing of palm oil currently (PricewaterhouseCoopers (PWC) 2019). In Nigeria, the major states producing oil palm are Abia, Akwa Ibom, Anambra, Balyesa, Cross River, Delta, Edo, Imo, Kogi, Ondo, Oyo, and River (National Bureau of Statistics (NBS) 2019). Though, the States are in different Agro-Ecological Zones (AEZs) in Nigeria.

Nigeria is located in the Tropics; climate is seasonally clammy and very humid. The natural vegetative regions that exist in the country are controlled jointly by the impacts of temperature, humidity, rainfall, and mainly, the differences that occur in the rainfall. This led to a significant effect on the type of aboriginal plants that grow efficaciously in different regions of the country (Aminu and Yakubu, 2019). According to Iloeje (2001), Nigeria Agro-Ecological Zones (AEZs) can be categorized into freshwater swamp AEZ, mangrove AEZ, rainforest AEZ, guinea savannah AEZ, sudan savannah AEZ and sahel savannah AEZ. However, oil palm production belt in Nigeria is in freshwater swamp AEZ (Delta and River state), mangrove AEZ (Balyesa state) rainforest AEZ (Abia, Anambra, Akwa Ibom, Cross River, Edo, Imo and Ondo state), guinea savannah AEZ (Kogi and Oyo state). Therefore, the study investigated the consequence of Land Use and Land Cover (LULC) alteration on vegetation indices in oil palm production belt of freshwater swamp, rainforest, and guinea savannah agro-ecological zones of Nigeria between 1989 and 2019 to determine the land cover variations that happened within the period and compare these changes among the three agro-ecological zones.

MATERIALS AND METHODS

Study area, ample techniques and size

The study was carried out in Delta, Kogi and Ondo State in Nigeria. The States were deliberately chosen for the study because the States are among the oil palm producing States in each agro-ecological zone of Nigeria (National Bureau of Statistics (NBS) 2018). The three States are made up of 64 Local Government Areas (LGAs) (i.e., Delta State has 25, Kogi State has 21 and Ondo State has 18 LGAs). The population of the three States is 10,887,365 (i.e., Delta State is 4,112,445, Kogi State is 3,314,043 and Ondo State is 3,460,877). The study used secondary data as shown in Table 1. The information used for the study includes administrative maps and shapefile of each of the selected States. Medium resolution satellite images were obtained from the Landsat Thematic Mapper (LTM) (1989) and the Operational Land Imager (OLI) (2019). These images were used to carry out the vegetation analysis and produce land cover maps of the study area.

Multistage sampling technique was used to select the study area. In the first stage there was purposive selection of three States (Delta, Kogi and Ondo) because the three States are among the oil palm producing States in Nigeria (National Bureau of Statistics (NBS) 2018). The States were also selected because each State represents different Agro-Ecological Zones in the Country that are into oil palm production. Delta State (Freshwater swamp), Kogi State (Guinea savannah) and Ondo State (Rainforest). In the second stage, two Local Government Areas (LGAs) that are known for oil palm production in each State were deliberately chosen for the study. In Delta State, Aniocha South and Ika South LGAs were selected. In Kogi State, Dekina and Olamaboro LGAs were selected. In Ondo State, Idanre and Okitipupa LGAs were selected for the study. The third stage involved purposive selection of three communities in each LGA that are known for oil palm production were used for the study. In Aniocha South LGA, Ejeme Aniogwu/Ejemuno, Nsukwa and Egbudu Akah were selected for the study. In Ika South LGA, Obi Agbor/Obi Anyima, Ekuku Agbor and Agbor Alidinma were selected for the study. In Dekina LGA, Egume 1, Egume 2 and Acharu were selected for the study. In Olamaboro LGA, Okpo, Ofante and Ogugu communities were selected for the study. In Idanre LGA, Ofosu, Onipako/Oniseere farm settlement and Agric. Area communities were selected for the study. In Okitipupa LGA, Okitipupa farm settlement, Igbotako and Ilutitun communities were selected for the study. Figure 1 shows the outline of the Agro-Ecological Zones (AEZs) of Nigeria, with the borderline of the Nigerian guinea savannah shown (adapted from Iloeje 2001).

DOI: https://doi.org/10.55706/jae1508

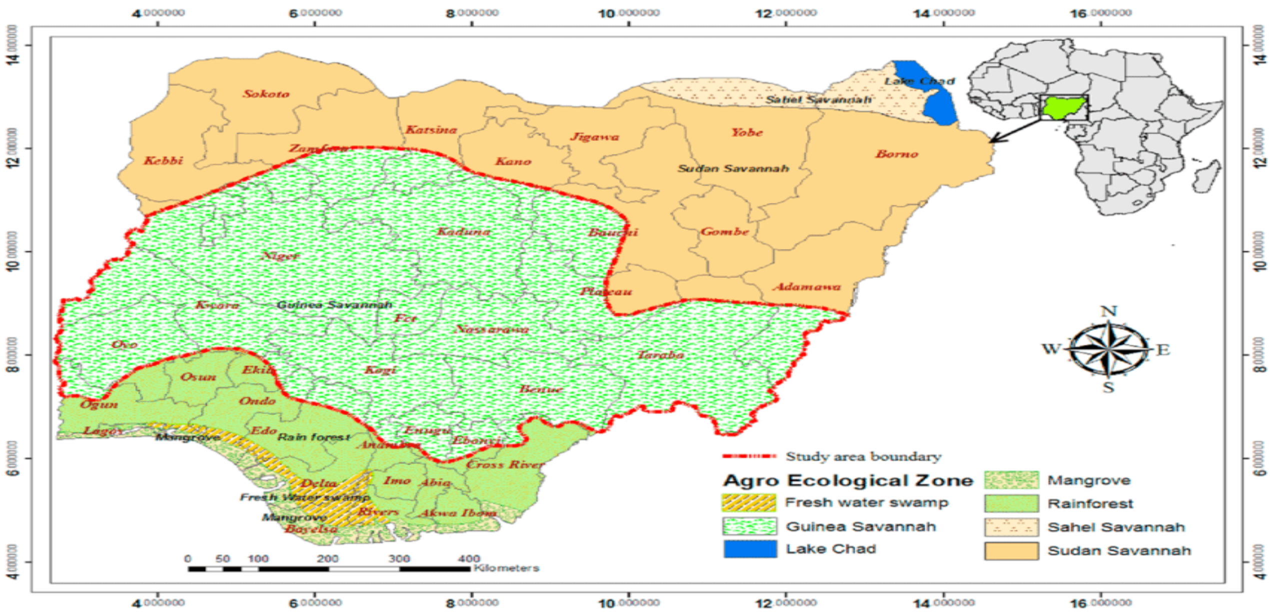

Figure 1. Outline of the agro-ecological zones of Nigeria, with the border of the Nigerian Guinea Savannah shown (Source: Adapted from Iloeje 2001).

Table 1. Data Sources and Description

S/N	Data	Data Format	Sources of the Data	Description
1	GPS coordinates of significant areas in the study location	Numerical	Field Survey	The coordinates were used to find the positions of the significant areas in the study location
2	Topographic map (2014)	Digital Map	SRTM (30m)	The elevation and slope were extracted from it.
3	Landsat TM (1989)	Digital Map	USGS (30m)	Was used to ascertain the LULC and the NDVI analyses.
4	SPOT (2007)	Digital map	Digital Globe (5m)	Was used for ortho-rectification of the Landsat images
5	Landsat 8 (2019)	Digital map	USGS (30m)	Was used to ascertain the Land use/Landcover of study area
6	Shapefile of the study area	Digital Map	Centre for Space Research and Applications (CESRA), Federal University of Technology, Akure, Ondo State, Nigeria.	To delineate the extent of the study location

Methods of data analysis

Image Processing and Geographical Information System (GIS) Analysis

The composites of the satellite imageries for the selected States in this study were clipped out using the shapefile boundary of the States. The process of band composition and masking required more than one landsat scenes for each State, covering the spatial Region of the Interest (ROI) of the study location. The process was done using the ERDAS Imagine 2014 and then later exported to ArcGIS environment for visual interpretation analysis. The downloaded imageries from the satellite were corrected from the manufacturer radiometrically and geometrically to raster image. The imageries coordinate used was the projected coordinate system (WGS 1984) for the satellite imageries of Landsat TM (1989) and OLI (2019) scenes covering each of the State. Geographical information system analysis was carried out to map out the land use/land cover of the study location. Presentation of the results of the mapping showing the distribution and aerial degrees of land use systems and classes was done. This revealed the advantage of the satellite remote sensing and GIS technologies over the conventional land use survey methods. In line with Ayyanna *et al.* (2018), each land use characteristic was identified and mapped using supervised classification method.

Generation of Normalized Difference Vegetation Index (NDVI)

To evaluate the growth and condition and healthiness of the vegetation within the study location, NDVI was used. The (NDVI) is frequently used as a measure of degree of

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land surface greenness based on the postulation that NDVI value is positively proportionate to the amount of green vegetation in an image pixel area (Sadeh *et al*. 2021). In line with Akinola and Akindele (2020), the NDVI was calculated thus:

$$NDVI = \frac{NIR-R}{NIR+R} \quad (1)$$

Where;

NIR = the spectral reflectance measurement acquired in the Near-InfraRed region (band).

R = the spectral reflectance measurement acquired in the Red region (band).

For Landsat Thematic Mapper remote sensing data, the formula is stated thus;

$$NDVI = \frac{TM4-TM3}{TM4+TM3} \quad (2)$$

Where;

TM4 = Near infrared band

TM3 = Red band

Table 2. Description of land use / land cover classes

Land use/land cover class	Description
Built- Up Land	Built-up land is consisting of zone of exhaustive usage mostly encompass with buildings. They include metropolises, townships, communities, highway constructed areas, transport, power and communications amenities located areas, areas occupied by shopping malls, industrial and commercial developments and other developed areas.
Dense Vegetation	Forest lands are zones that consist of tree-crown areal density. These are zones that have trees that can produce timber or other wood products which impact on the climate or water management. Though, the border between it and other types of land may be difficult to define exactly.
Water body	Water is defined as zones in the land mass that are water enclosed perpetually. Waterbodies comprise of streams, canals, ponds, basins, inlets, and creeks.
Agricultural Land	Crop, pasture, irrigated land, and plantation are encompassed in this definition. Diverse agricultural zones and agroforestry zones, Open space with very-little vegetation
Sparse vegetation	The sparse vegetation refers to dispersed vegetation. Vegetation is mostly widely spaced and scrubby. They include areas of soil with less nutrition that may be natural or human induced.

Source: Halmy, (2019).

The principle behind the NDVI is that a positive increase in the value of NDVI reflects an increase in the shades of green on the images. This shows that the quantity reflects high quantity of green vegetation. NDVI values close to zero and negatively reducing in value shows non-vegetated characteristics like desolate or unfertile land that cannot be used for fruitful agricultural purpose. This includes rocks, soil and water (Zhangyan Jiang *et al.* 2006). Positively high value correlation of NDVI with forest stance biomass shows that NDVI can possible be used as suffix for biomass valuation in a likely environmental condition. Therefore, calculating and mapping the thickness of green vegetation transversely the basin, satellite information with discrete wavelengths of discernable and near-infrared sunlight that is absorbed and reflected by the plants were used. Measuring the percentage of the noticeable and near-infrared light reflected up to the sensor ranges between minus one (-1) to plus one (+1). The result of this measurement is termed the Normalized Difference Vegetation Index, or NDVI. So, zero value of NDVI is considered no green vegetation and close to +1 (0.8 – 0.9) shows the maximum likely density of green leaves. Hence, by interpretation, value very close to -1 is link to water, while correspondent value that is close to zero (-0.1 to 0.1) is link to barren areas of rock, sand, or snow. Positively low value shows that the location epitomizes shrub and grassland (approximately 0.2 to 0.4). The tropical rainforest is represented with high values of NDVI (values very close to 1) (Puzachenko *et al.* 2016).

Software Used

Basically, three different types of software were used for this study. These include:

- **ArcGIS** –It was used for the masking of the area of interest, using both the administrative maps. It was also used for maps outputs and visualization.
- **ERDAS Imagine** – This was used for image sampling and image classifications of the Landsat imageries. It was used to produce the accuracy assessment for the analysis.
- **ENVI 5.3** – This was used for satellite Image enhancement and atmospheric correction.

Image Classification

The overseen classification was done making use of the maximum likelihood to categorize various characteristics and a configuration of band 3, 4 and 5 for Landsat TM and Landsat ETM+ and 4, 5 and 7 for Landsat 8 (Cheruto *et al.* 2016). The spectral signature of respective class was gotten from the images make use of the Erdas Imagine and IdrisiSelva, by choosing Region of Interest (ROI) for the respective LULC category. The ROI assisted in creating the map by defining areas in the map based on the training sites and the spectral homogeneity of the pixels of selected location (Pontus Olofsson *et al.* 2014). The categorization made a good outcome after it was subjected to a confusion matrix. The evaluation of the Landsat TM (1986) recorded an overall accuracy range between 78.1 % - 82.5 % and Kappa coefficient ranging between 0.76 – 0.79. The overall accuracy range for the Landsat OLI (2019) recorded 80.2 % - 85.4 %, while the Kappa coefficient range between 0.77 – 0.81 (Table 3).

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Table 3. Accuracy assessment of the image classification

Year	Kappa coefficient	Overall accuracy
1989	0.76 – 0.79	78.1 % - 82.5 %
2019	0.77 – 0.81	80.2 % - 85.4 %

Source: Image Analysis, 2019.

RESULTS AND DISCUSSIONS

NDVI and Land Use/Land Cover Change (LULC) between 1989 and 2019 of the study area;

Freshwater swamp AEZ (Delta state), guinea savannah AEZ (Kogi state) and rainforest AEZ (Ondo state).

NDVI and LULC between 1989 and 2019 in the freshwater swamp AEZ (Delta state)

As shown in Figure 2, the NDVI results showed low values of -0.8 for areas close to the atlantic ocean, it indicates that the areas were waterlogged. The areas away from the ocean including Ika south and Anlocha south local government areas recorded 0.96, suggesting that the areas were forested in 1989 with an healthy vegetation that is high. Therefore, from the Figure, the greener aspect of the Figure reflects a healthy vegetation that is high, the aspect of the Figure that has lighter green shows a vegetation that is low with respect to health. Table 4 and Figure 3 shed more light on this. Table 4 and Figure 3 reflected the prevalence of dense vegetation (45.53%) above other land cover types in 1989. The agricultural land was 22.66%, wetland (23.21%), water body (3.09%), built-up land (3.06%) and sparse vegetation (shrubs) was 2.45%. The changes that had occured in the last 30 years as shown in Figure 2, the NDVI value receded to -0.11 indicating increase in areas covered by water and barren areas of rock. Similar trend was observed to the interior areas with 0.58, suggesting increase in shrubs arising from anthropogenic activities (Halmy 2019). The implication is the reduction of green biomass in the areas previously occupied by rainforest induced by the human-induced activities (Gasparatos *et al.* 2017). The land cover change as shown in Figure 3 and Table 4 revealed the declining in areas covered by dense vegetation (72.03%) in 2019 and increase in shrubs (sparse vegetation) by 1955.64%. The water body also increased in spatial extent by 68.18%, built-up land by 130.66% and agricultural land by 8.88%. This is a critical effect of urbanization, development, and climate change. There is always a tradeoff between retention of dense vegetation and urbanization and development (Chuxiong *et al*. 2021).

The wetland receded by 100% in 2019, this is one of the critical effect of climate change. This will surely distort the ecosystem of the AEZ, it is a threat to ecosystem services in the AEZ and it will surely affect the livelihood of the communities (Adekola and Mitchell 2011). It was observed during the field survey that oil palm and other agricultural crop lands were increasing at the expense of the natural dense vegetation. The oil palm plantation could be regarded as secondary vegetation, which may be seen as not a close replacement for the natural dense vegetation. In fact, oil palm cultivation contributes immensely to the vegetation degradation or deforestation in the freshwater swamp AEZ (Delta state). The rate of deforestation was estimated at 2.40% per annum over 30 years (between 1989 and 2019). Oil palm cultivation and other agricultural crop lands increased at 0.30% per annum, built-up land increased by 4.36% and water body increased by 2.27% per annum as shown in Table 4. Of significance is the tremendous annual increase of 65.19% by sparse vegetation. It is very significant to understand that the trend should not be allowed to continue. According to David *et al*., (2019), farmers should be trained on the best practice on farm management, timber loggings control and quarry activities that are environment friendly to avoid deforestation.

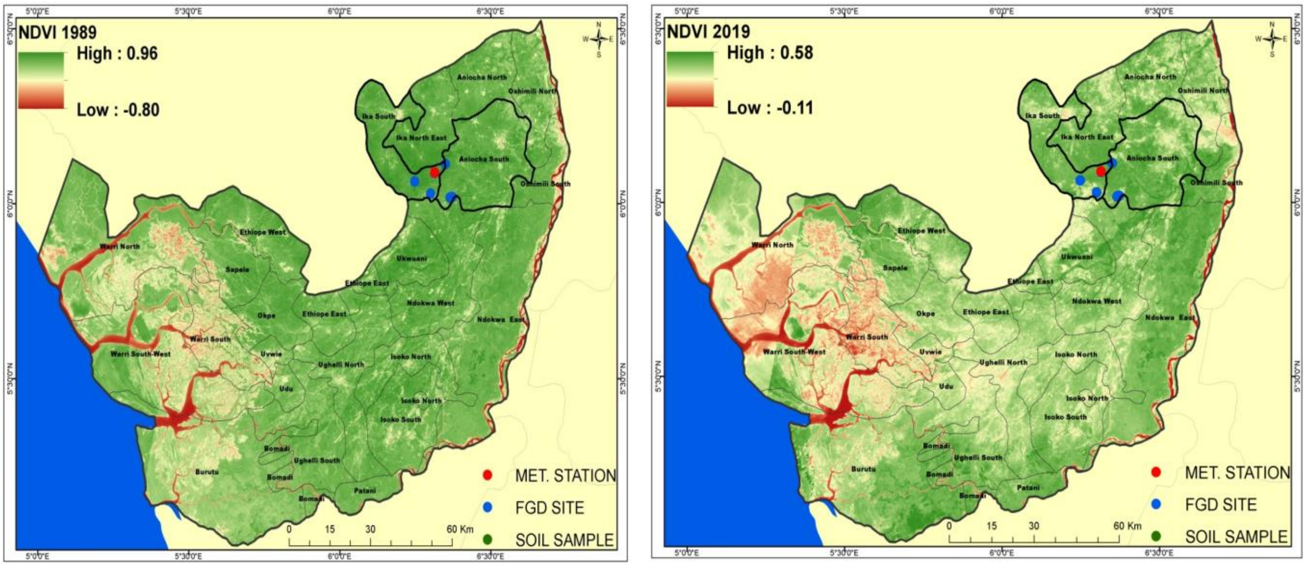

Figure 2. Conditions of Vegetation Biomass in 1989 and 2019 in Freshwater swamp AEZ (Delta State).

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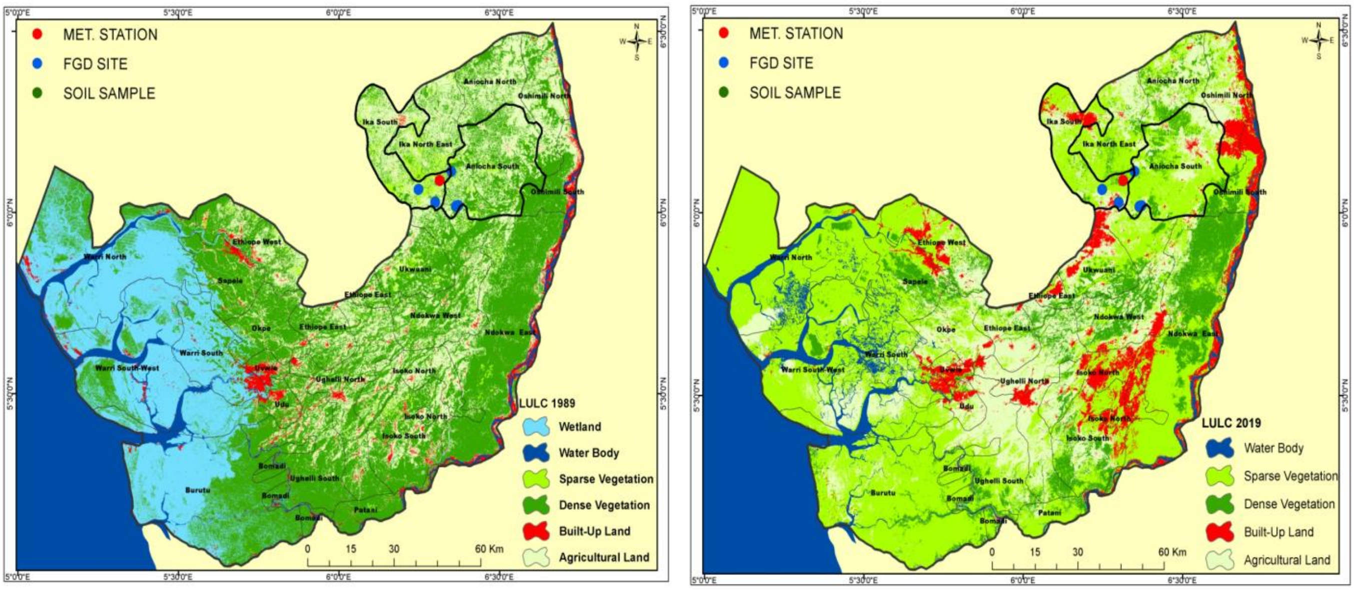

Figure 3. Land Use/Land Cover Change between 1989 and 2019 in Freshwater swamp AEZ (Delta State).

Table 4. Land Use/Land Cover Change between 1989 and 2019 in Freshwater swamp (Delta State).

	1989		2019		Change between 1989 and 2019		Rate of Change per annum	
LULC	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Water Body	547.40	3.09	920.63	5.20	+373.23	+68.18	+12.44	+2.27
Sparse Vegetation	433.30	2.45	8907.08	50.33	+8473.78	+1955.64	+282.46	+65.19
Dense Vegetation	8058.26	45.53	2253.77	12.73	-5804.49	-72.03	-193.48	-2.40
Built-Up Land	541.54	3.06	1249.12	7.06	+707.58	+130.66	+23.59	+4.36
Agricultural Land	4011.21	22.66	4367.39	24.68	+356.18	+8.88	+11.87	+0.30
Wetland	4106.28	23.21	0	0	-4106.28	-100	-136.88	-3.33
Total Area	**17697.99**	**100**	**17697.99**	**100**				

Source: Image Analysis, 2019.

NDVI and LULC Results Between 1989 and 2019 in the guinea savannah AEZ (Kogi State)

Figure 4 shows low (-0.94) and high (0.97) NDVI values for 1989. The low value of -0.94 is an indication that the vegetation is thin and the areas concerned are characterized by barren rock outcrops and sand which is one of the features of the guinea savannah AEZ (Jesse *et al*., 2016). The important means of livelihood of the people of this AEZ is farming in diverse form (Agboma 2017). The agricultural land occupied large areas (6364.55km^2), an equivalence of 21.33% (Table 5). Agricultural activities might have partly responsible for the low vegetation in AEZ. The high value of 0.97 implies high vegetation biomass in some parts of the AEZ. This is evident in the prevalence of dense vegetation above other land cover kinds as reflected in Table 5. Dense vegetation covered an area of 17,158.3km^2, an equivalence of 57.51% of the entire areas of the AEZ.

Tremendous changes were noticed in 2019 as shown in Figure 4. The NDVI values had reduced to -0.16 as low and 0.46 as high. The low value of -0.16 suggests stressed vegetation with increasing sandy land and barren rock outcrops while the high value of 0.46 implies decrease in areas with healthy vegetation. Hence, a high depletion of the dense vegetation in the AEZ. As shown in Table 5, dense vegetation declines by 56.11% while built-up land and agricultural land increase by 169.06% and 17.98% respectively in 2019. Sparse vegetation increased by 120.99% over the last 30 years. It is requisite to be mindful that the rate of deforestation for the period of 30 years is 1.87% per annum, while built-up land increases at 5.64% per annum. Sparse vegetation is increasing at 4.03% per annum, while areas covered by water body increase at 1.18% per annum. Agricultural land increases at 0.60% per annum. Based on these, areas covered by thick vegetation could be seen to be at receiving end. Figure 5 showed Land Use/Land Cover Change in the guinea savannah (Kogi State) between 1989 and 2019.

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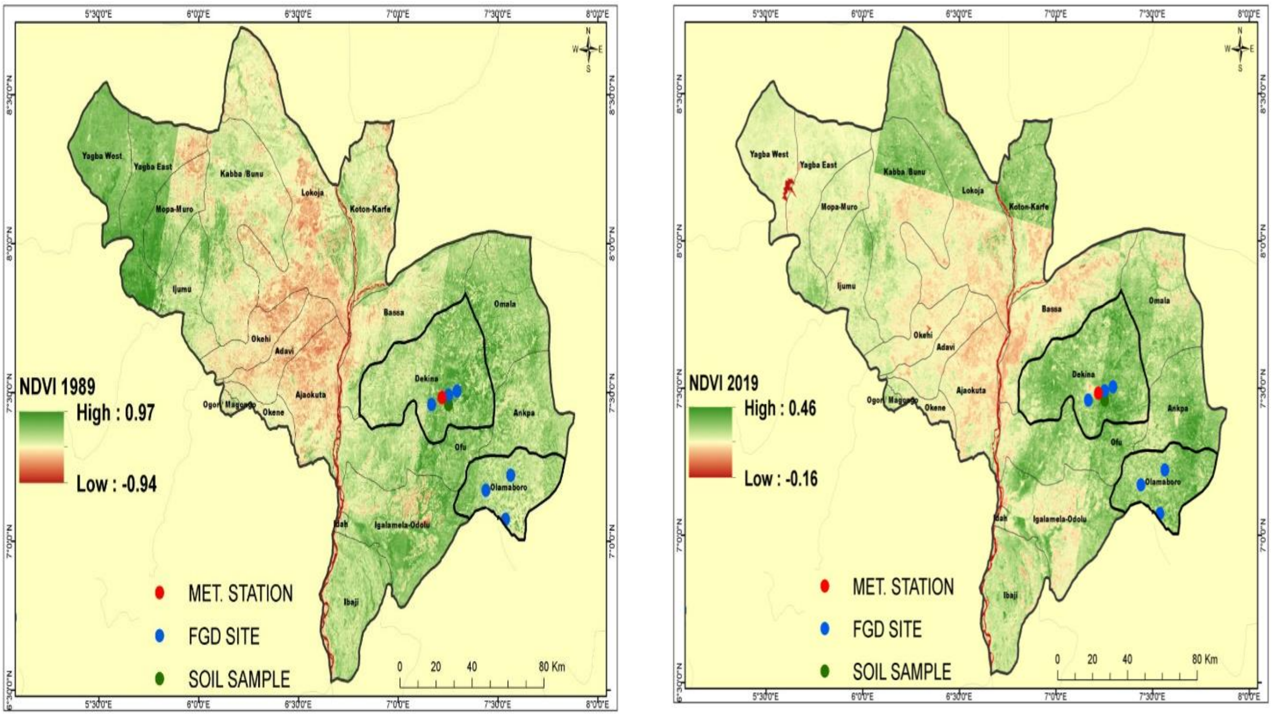

Figure 4. Conditions of Vegetation Biomass between 1989 and 2019 in Guinea savannah (Kogi State).

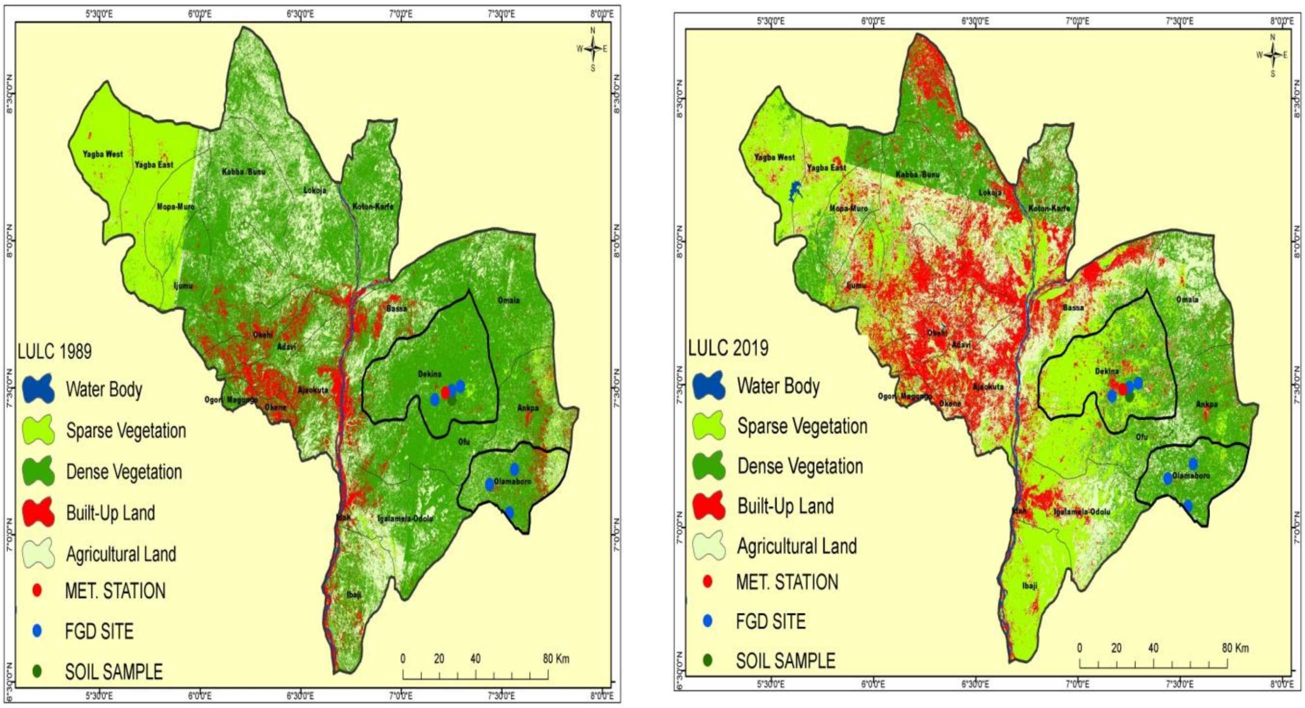

Figure 5. Land Use/Land Cover Change in Guinea savannah (Kogi State) between 1989 and 2019

DOI: https://doi.org/10.55706/jae1508

Table 5. Land Use/Land Cover Change in Guinea Savannah (Kogi State) between 1989 and 2019.

LULC	1989		2019		Change between 1989 & 2019		Rate of Change per annum	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Water Body	190.08	0.64	257.52	0.86	+67.44	+35.48	+2.25	+1.18
Sparse Vegetation	4014.68	13.46	8871.89	2974	+4857.21	+120.99	+161.91	+4.03
Dense Vegetation	17158.3	57.51	7530.11	25.04	-9628.19	-56.11	-320.94	-1.87
Built-Up Land	2105.39	7.06	5664.75	18.99	+3559.36	+169.06	+118.65	+5.64
Agricultural Land	6364.55	21.33	7508.73	25.17	+1144.21	+17.98	+38.14	+0.60
Total Area	**29833.00**	**100**	**29833.00**	**100**				

Source: Image Analysis, 2019.

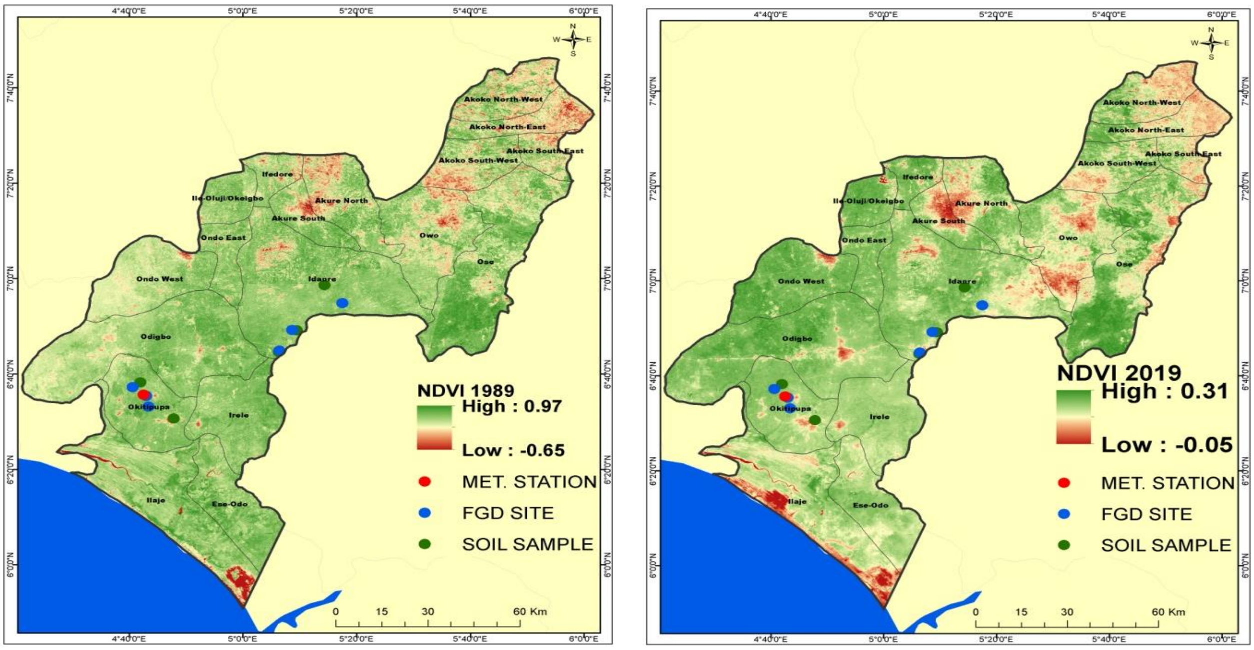

Figure 6. Conditions of Vegetation Biomass in Rainforest (Ondo State) between 1989 and 2019.

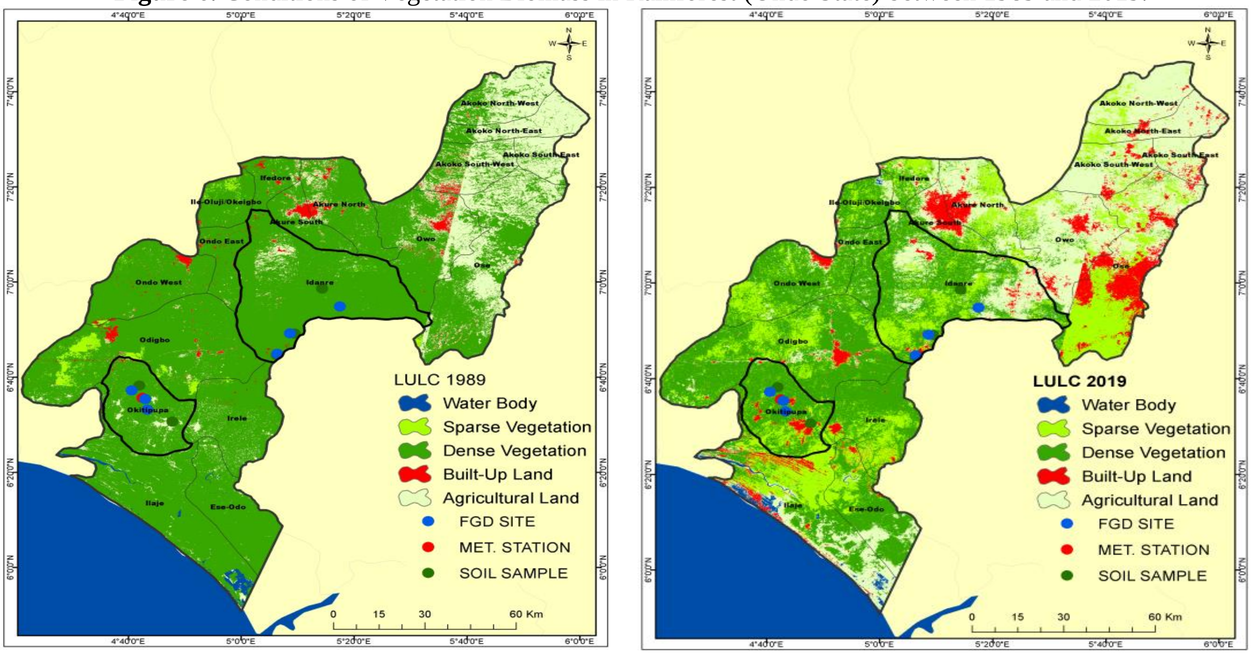

Figure 7. Land Cover Change between 1989 and 2019 in Rainforest (Ondo State).

DOI: https://doi.org/10.55706/jae1508

Table 6. Land Use/Land Cover Change in Rainforest (Ondo State) between 1989 and 2019.

LULC	1989		2019		Change between 1989 & 2019		Rate of Change per annum	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Water Body	80.54	0.52	108.22	0.70	+27.68	+34.37	+0.92	+1.15
Sparse Vegetation	205.44	1.33	3676.2	23.72	+3470.76	+1689.43	+115.69	+56.31
Dense Vegetation	12270.61	79.17	6020.30	38.84	-6250.31	-50.94	-208.34	-1.70
Built-Up Land	273.12	1.76	1101.05	7.10	+827.93	+303.14	+27.60	+10.10
Agricultural Land	2670.29	17.22	4594.24	29.64	+1923.95	+72.05	+64.13	+2.40
Total Area	**15,500.00**	**100.00**	**15500.00**	**100.00**				

Source: Image Analysis, 2019.

NDVI and LULC Results Between 1989 and 2019 in the rainforest AEZ (Ondo State)

Figure 6 shows the conditions of vegetation biomass in the rainforest AEZ (Ondo State) between 1989 and 2019. The NDVI values of -0.65 as reflected in the Figure for 1989 indicate areas occupied by rock outcrops and bare land surface. The vegetation seems to be low in such areas. Contrarily, the NDVI values of 0.97 as depicted by the Figure suggest that such areas were covered by dense forest. It is an indication that the vegetation in the areas are healthy. This is corroborated by Table 6. As shown in Table 6, dense vegetation constituted 79.17% of the entire AEZ in 1989, followed by agricultural land (17.22%), built-up land (1.76%), sparse vegetation (1.33%) and water body (0.52%). Notable changes had been recorded as revealed in the NDVI values of 2019. The NDVI values of -0.05 indicates increase in the exposure of barren areas of rock due to the human-induced processes such as farming, lumbering, road construction, quarry and urban development, and natural process, which include soil erosion, among others. Figure 6 further showed a sharp drop in NDVI values from 0.97 in 1989 to 0.31 in 2019. It implies tremendous increase in shrubs and grasslands in the AEZ. Table 6 showed an increase of 1689.43% in areas covered by sparse vegetation against 50.94% decline in dense vegetation.

Similarly, built-up land increased by 303.14%, agricultural land also increased by 72.05% and water body recorded increase of 34.37%. These tremendous changes have devastating impact on the vegetation of the AEZ. The rate of deforestation over the 30 years was estimated at -1.70% per annum while sparse vegetation was found to be increasing at 56.31% per annum. It is important to note that built-up land and agricultural were increasing at +10.10% and +2.40% respectively per annum. Special attention should be focussed on urban and agricultural development in the AEZ by way of teleguiding development to areas where it is appropriate and introduce better agricultural practices and management to reduce the level of vegetation degradation in the AEZ (Francois, 2016).

Comparative Analysis of Land Use and Land Cover Changes between 1989 and 2019 of the Study Area

As shown in Table 7, the water body in the freshwater swamp AEZ changed by 68.94% between 1989 and 2019 at annual rate of 2.30% compared to 34.37% changed at annual rate of 1.15% in the rainforest AEZ and 35.48% changed at annual rate of 1.18% in the guinea savannah AEZ. This reflects a sumptuous change in the water body in the freshwater swamp AEZ compared to the rainforest AEZ and guinea savannah AEZ. This is expected because according to Iloeje, (2001) freshwater swamp AEZ of Nigeria has more water body compared to other AEZs (Rainforest and guinea savannah). This reflects the consequence of climate change in the AEZ, more rainfall and the incessant flooding in the AEZ may likely account for the increase in the water body. One of the peculiar features of the AEZ compared to rainforest and guinea savannah AEZ is incessant and unpredictable rainfall (Nwabueze and Rob, 2017). This often leads to increase in water body in the freshwater swamp AEZ. There was outstanding increase in the sparse vegetation in both the freshwater swamp AEZ (+1955%) and the rainforest AEZ (+1689%) compared to the guinea savannah AEZ (+120.99%).

The annual rate of change of the sparse vegetation in the freshwater swamp AEZ was +65.19% and for the rainforest AEZ was +56.31%, while for the guinea savannah was +4.03%. This reflects the peculiarity of the both the freshwater swamp AEZ and rainforest AEZ because the two AEZ are known for vast luxuriant vegetation compared to the guinea savannah AEZ (Sowunmi and Akintola 2010). The increase in the sparse vegetation in the freshwater swamp AEZ and rainforest AEZ shows in the growth in the built-up land and agricultural land in the AEZs. The study revealed that there is a positive relationship between the sparse vegetation, built-up land, and agricultural land in all the three AEZs (freshwater swamp AEZ, rainforest AEZ and guinea savannah AEZ). Hence, increase in the sparse vegetation will also lead to rise in the built-up land and agricultural land in all the AEZs under consideration. This in line with the findings of Dingrao *et al*. (2020) that sparse vegetation increases because of urbanization and increase in the use of land for agricultural purposes.

DOI: https://doi.org/10.55706/jae1508

The Table revealed that dense vegetation reduced considerably in the freshwater swamp AEZ (-72.03%) and the guinea savannah AEZ (-56.11%) compared to the rainforest AEZ (-50.94%). This is buttressed by the annual rate of change in dense vegetation in freshwater swamp AEZ of -2.40%, in guinea savannah of -1.87% and rainforest AEZ of -1.70%. This shows that the rate of deforestation in the freshwater swamp AEZ and guinea savannah AEZ is higher compared to rainforest. This could be because the freshwater swamp AEZ of the study area (Delta State) is one of the notable oil producing areas in Nigeria, therefore, the rate of urbanization is very high accounting for increase in the built-up land for development in the AEZ. However, the percentage variation in the built-up land and agricultural land in the rainforest AEZ (+303.14% and +72.05%) is higher compared to freshwater swamp AEZ (+130.66% and +8.88%) and the guinea savannah AEZ (+169.06% and +17.98%). The result revealed that in the rainforest AEZ, there was an increase in the use of land for urbanization and agricultural purpose. This is in line with the findings of Ifeanyi-Obi and Nnadi, (2014) that farmers in the rainforest AEZ of Nigeria are increasing their farmland to ensure food security in the Country. Again, many agricultural policies over the years are encouraging farm expansion of cash crops such as cocoa and oil palm to boost the foreign exchange of the Nigerian government (Eze *et al*. 2010). The rate of urbanization in the rainforest AEZ is alluding to the increase in use of dense vegetation for the purpose of built-up land and.

Wetland is one of the peculiar features of the freshwater swamp AEZ of Nigeria. It is located just after the inland of the mangrove swamp, on a little higher ground. This vegetation belt, on freshwater wetlands, is further inland, far the reach of tidal waters. The lagoons or the rivers that overflow across banks in the wet season provide it with fresh water since the area is low lying. Hence, it is waterlogged with rainwater, and it is rainy most times, eight or nine months of the year in the wetland zone of Nigeria. Part of the country under this agro-ecological zone, are Ogun, Benin, Imo, Delta, and Cross River State (NBS 2018). The increase water flooding enhances the deposit of vast quantities of silt, mud, and sandy materials into this zone. The region is lying very low, with hardly any part rising over 30m above sea level. This is facilitating the growth of freshwater swamps along the zone which is commonly known as Niger Delta Area (NDA) of the country leading to drowned estuaries, lagoons, and creeks. This area comprises of a combination of trees. Important among the vegetation of this area are the various palm and fibre plants such as *Raphia* spp., *Raphia vinifera*, the palm wine, and *Raphia hookeri*, the palm use for roof-mat. They are used in making thatching mats and for rafter, poles, and stiff piassava fiber to make brooms. The better-dry areas of the zone support oil palm trees (*Eleais guineenais*) and big trees like iroko (*Chlorophora exceisa*). Fishing and fiber-making activities are the major products of the fresh-water swamp areas of Nigeria (Sowunmi and Akintola 2010).

From Table 7, the wetland reduced by 100% between 1989 and 2019 at annual rate of 3.33%. This could be because of land reclamation due to human activities of urbanization and advancement. This is in line with the results of Abam *et al*. (2014) that government, corporate organizations, and individual are sand filling the swamp areas in the freshwater swamp AEZ (Delta State) of Nigeria to ensure that there is more land for development.

Table 7. Summary of Comparative Analysis of Change between 1989 and 2019 Among the Agro-Ecological Zones (AEZs).

	Fresh Water Swamp AEZ (Delta State) Change between 1989 and 2019		**Rainforest AEZ (Ondo State) Change between 1989 and 2019**		**Guinea Savannah AEZ (Kogi State) Change between 1989 & 2019**	
LULC	Change between 1989 and 2019 (%)	Rate of Change per annum (%)	Change between 1989 and 2019(%)	Rate of Change per annum (%)	Change between 1989 and 2019(%)	Rate of Change per annum (%)
Water Body	+68.94	+2.30	+34.37	+1.15	+35.48	+1.18
Sparse Vegetation	+1955.64	+65.19	+1689.43	+56.31	+120.99	+4.03
Dense Vegetation	-72.03	-2.40	-50.94	-1.70	-56.11	-1.87
Built-Up Land	+130.66	+4.36	+303.14	+10.10	+169.06	+5.64
Agricultural Land	+8.88	+0.30	+72.05	+2.40	+17.98	+0.60
Wetland	-100	-3.33	…….	………	…….	…

CONCLUSION

From the study, it was discovered that in the freshwater swamp AEZ that changes that had occured within the last 30 years (1989 t0 2019) is unprecedented. The NDVI value receded to -0.11 indicating increase in areas covered by water and barren areas of rock. Similar trend was observed to the interior areas with 0.58, suggesting increase in shrubs arising from anthropogenic activities The implication is the loss of biomass in the areas previously occupied by natural vegetation and this is caused by the anthropogenic activities. In the freshwater swamp AEZ, the wetland receded by 100% in the last 30 years (1989-2019). This will surely distort the ecosystem of the AEZ, it is a threat to ecosystem services in the AEZ and it will surely affect the livelihood of the communities. The study revealed that oil palm and other agricultural crop lands were increasing at the expense of the natural dense vegetation in the AEZ.

DOI: https://doi.org/10.55706/jae1508

In the guinea savannah AEZ, there was high depletion of dense vegetation in the AEZ in the last 30 years. The rate of deforestation within the last 30 years was 1.87% while built-up land increased at 5.64% per annum in the AEZ. In the rainforest AEZ, the NDVI value of -0.05 indicate increase in the exposure of barren areas of rock due to the human-induced activities such as farming, lumbering, road construction, quarry, and urban development. It implies tremendous increase in shrubs and grasslands in the AEZ.

The comparative analysis revealed that freshwater swamp AEZ of Nigeria has more water body compared to other AEZs (Rainforest and guinea savannah) which reflects the effect of climate change in the AEZ, more rainfall and the incessant flooding in the AEZ. This study revealed that there is a positive relationship between the sparse vegetation, built-up land, and agricultural land in all the three AEZs (freshwater swamp AEZ, rainforest AEZ and guinea savannah AEZ). Hence, from the study, the following policy implications can be inferred; farmers should be trained on the best practice on farm management, timber loggings control and quarry activities that are environment friendly to avoid deforestation. Likewise, special attention should be focussed on urban and agricultural development in the three AEZs by way of teleguiding development to areas where it is appropriate and introduce better agricultural practices and management to reduce the level of vegetation degradation.

Furthermore, at all levels of governments in the three AEZ, agricultural and environmental policies that will ensure protection of the ecosystem should formulated. This will ensure that the ecosystem dependent livelihood of the community members is protected, while encouraging farm expansion of tree crops such as oil palm to boost the foreign exchange of the government. Again, the gazetted forest reserves in the three AEZs should be protected against any incursion by the farmers for farming activities and this can be done through advocacy. Also, reafforestation programme should be encouraged in the three AEZs (freshwater swamp, guinea savannah and rainforest AEZ) by the government, national and international non-governmental organizations.

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