Research Article

Mapping and analyzing the land use–land cover of nigeria between 2001 and 2009

Abstract

The study assessed the land use and land cover changes over Nigeria between 2001 and 2009 and predicted what the scenario will be till the year 2020 when Nigeria is planning to be among the top 20 strong economies of the world. The study used Combined Terra and Aqua MODIS land level 3/level 4 yearly tiled products, MCD12Q1–level 3 yearly land cover type at the scale of 250m. This data was accessed from NASA website and processed using ArcGIS 9.3 software to establish the land use–land cover situations for 2001, 2005 and 2009 and subsequently the changes that have taken place between 2001 and 2009. There was continuing decrease in the water bodies from 0.53% coverage in 2001 to 0.47% in 2005 which further decreased to 0.40% in 2009. This poses serious implications for agriculture in terms of food security for those using it for irrigation, water availability for different uses and infrastructural development in term of electricity where it is used for power generation. It also has a serious implication for survival and livelihoods on the communities that depend on aquaculture and irrigational farming. The future prediction could spell a serious calamity due to inundation and loss of small lakes and ponds considering the fact that the loss of the ecosystem constitutes severe degradation and increases the vulnerability of people to disaster especially those whose livelihoods are dependent on the wetlands. Furthermore, the research indicates rapid loss of natural resources especially forest and Savanna which have severe implications for livelihoods and vulnerabilities of communities and also for the environment. General Savanna was being decimated at the rate of 4% while the forest of the study area was being decimated at the rate of about 9% per annum between 2001 and 2009. The loss of forest and gr**assland is an** indication of disturbance and consistent perturbations created by pressure on the existing ecosystems leading to a reduction in soil nutrients, decrease resilience and stability and loss of agricultural lands.

Keywords: land use, land cover, change, projection, nigeria

Volume 3 Issue 3- 2018

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Received: May 10, 2018 | **Published:** June 19, 2018

Introduction

Nigeria is currently undergoing rapid and wide–range changes in its land due to climate change, the practice of slash–and–burn or shifting cultivation and rapid infrastructural development. The study of these changes necessitates the use of remote sensing because it provides data at synoptic scales and facilitates the discerning of large–scale ecosystem patterns. Although remote sensing technology has been used for mapping in Nigeria at various levels for some time now, there has been no attempt to assess the changes for the country as a whole except on two occasions when the country was merely mapped and the changes not analyzed. In view of the above, a qualitative approach that necessitated the use of historical series of MODIS data to produce land cover maps of Nigeria, to evaluate the relative changes in land cover from 2001 to 2009 and also to predict the future scenario is highly necessary. Several studies have been carried out in Nigeria at local or smaller scale such as Land use–land cover change detection in Metropolitan Lagos (Nigeria): 1984–2002 by Adepoju et al.[1] In the study, a post–classification approach was adopted with a maximum likelihood classifier algorithm. The Landsat TM (1984) and Landsat ETM (2000) were merged with SPOT–PAN of2002 to improve classification accuracies and provided more accurate maps for land use/cover change and analysis. It also made it possible to overcome the problem of spectral confusion between some urban land use classes. The land cover change map revealed that forest, low density residential and agricultural land uses are most threatened: most land allocated for these uses have been legally or illegally converted to other land uses within and outside the metropolis. Ifeoluwa et al.,[2] studied Land use– land cover change detection and associated climatic responses in Akure, Nigeria. They used multi–temporal remote sensing data and GIS technique to detect the land use–land cover changes

Hof et al.,[3] also studied integrated land use and land cover assessment in grazing reserves in North–West Nigeria using multi–sensor data for the period 1965 to 2002. They were able to map the natural vegetation lands in 1999 from a land cover classification of Landsat ETM+ data. This land cover information was complemented by ground–based quantitative information on plant productivity of grasslands and croplands. In the study, the author used the visual (manual) method of remote sensing analysis in the interpretation and was able to derive the land use and land cover attributes of the study area. To the best of the author's knowledge, no study has been carried out to assess the changes over the whole of Nigeria in recent years. After searching several kinds of literature, it was discovered that Abbas[4] did an overview of land cover changes in Nigeria, 1975 – 2005 using Landsat data of 1975 and SPOT XS data of 2005. However, the author's work was limited in that he used two dates at such a long period of thirty–five years. Two other studies were done at different times to map the whole study area without looking at the changes over time. These studies, however, are full of deficiencies as explained hereafter and they are not recent studies meaning several events have happened after they were done. The studies are NIRAD (Nigeria Radar) project commissioned in 1976 which was completed in 1978. It was based on imagery acquired through the Side Looking Airborne Radar (SLAR) to produce the first vegetation and land–use maps covering the whole landmass of Nigeria. According to FORMECU (Forestry Management and Coordinating Unit) of 1976, the NIRAD (Nigeria Radar) Project constitutes the first and only nation–wide database on the Nigeria environment as at 1976. The primary thematic purpose of the project was the inventory and mapping of vegetation types in Nigeria as well as the demarcation of forest reserves boundaries.[5] A visual image interpretation method was used and the first national land use/land cover information of any appreciable consistency was produced. However, some shortcomings of the study have been identified by Adeniyi[5] and Formecu.[6] First, the classification scheme developed in the study is largely related to vegetation (a land cover). Thus the vegetation and land use classes as shown on the 1976/78 produced maps do not discriminate between land use and natural vegetation cover. So it was found that many polygons contain inclusions of other classes to varying degrees. Secondly, the NIRAD classification scheme did not include human settlements' as a cover category. Hence the interpreters must have treated the interpretation and delineation of settlement boundaries as residual matters. Also, the scheme is besotted with obvious errors associated with the calculated area of the Country and States and consequent variations among land use, land cover categories. Again, the polygon boundary on the 1976/78 vegetation and land use maps appears to have been derived in part from observations (that is, Fieldwork) despite what the imagery suggested that the boundary classes should be. And lastly, the NIRAD Project may be regarded as suitable for its ad hoc purpose but not suitable for a national land use classification scheme. However, despite the identified shortcomings, the NIRAD Project provided the first national land use/land cover information of any appreciable consistency.[5] The second national database on Nigeria land use and vegetation was provided by the study carried out by Forestry Management and Coordinating Unit (FORMECU) in 1996 and this was part of the national Environmental Management Project (EMP). The objective of the Project was to assess and evaluate the available data; identify data gaps; develop programs for the production of current and reliable information on vegetation changes and degradation over time; develop and implement a GIS database for Nigeria.

To achieve the objectives the Project involved three broad tasks:

a. The establishment of historic statistical record on the status of vegetation and land use (1976/78) which was used as baseline information:
b. The establishment of current information on vegetation and land use (1993/95), and
c. The analysis of trends (extent and intensity of the changes in vegetation and land use) over an 18 years period. These tasks were undertaken using remote sensing data such as Landsat Multispectral (MSS– 1976/78), SPOT Multispectral (1993/1995), Landsat Thematic Mapper (TM–1993), ERS–1 Radar–1994/1995), JERS–1 Radar–1995), and National Oceanic Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR–1978, 1986, 19909, 1995).

Some of the major shortcomings of the FORMECU Project include the fact that the scheme was also more of land cover than land use analysis. Second, the little coverage of the land use aspect was limited to agricultural land use. For instance, urban areas were inputted as point data with associated text. Third, the classification scheme was also limited to the secondary level. Fourth, because of the extent, it was more of a generalized study with the intention of correlating the land use in terms of ecological zones in Nigeria. Fifth, the final map products were at a scale of 1: 250,000, which were too small for meaningful analysis. Sixth, the visual interpretation was utilized. The implication of such is that two individuals may produce different results in addition to being time–consuming and expensive. Finally, the impact of human–induced change on water vegetation and soils was on a qualitative basis and so the FORMECU Project recommended for future quantitative land use/land cover change analysis.

As a result of these obvious shortcomings, this study, therefore, seeks to investigate the recent LULC and changes in Nigeria with a view for effective and efficient management of the land of the country. Thus the need to put in place shortly and long–term disaster preparedness and environmental management strategies which require geospatial data and information gives credence to this study. This is very necessary for the view of the fact that in Nigeria, there is the need for articulate disaster mitigation program.[7] Lastly, understanding land use–land cover change and land management will help the country balance food production and at the same time preserving her natural resources. The ever–growing population of the country places increasing demands on ecosystems. According to the Millennium Ecosystems Assessment report,[8] ecosystems degradation tends to harm rural populations directly more than urban population and has its most direct and severe impact on the poor. This is because the poor rural communities depend entirely on resources which are tied to the land for their livelihoods and are therefore highly vulnerable to LULC changes. These issues mentioned above are fundamental problems that should be of concern to geographers, environmentalists, and policymakers. This is even more disturbing as clashes occurred frequently between nomads and farmers as a result of changes in LULC. The high rate of land degradation and recent studies have suggested strong linkages between land degradation, livelihood, poverty, human well–being, and vulnerability to other hazards.[9,10]

Materials and methods

Types and Sources of data

The type and source of the geospatial data sets used are Combined Terra and Aqua MODIS land level 3/level 4 yearly tiled products, MCD12Q1–level 3 yearly land cover type with a spatial resolution of 250m. This data was accessed from NASA website (www.ladsweb.nascom.nasa.gov/data). The imagery sets were processed using ArcGIS 9.3 software.

Methodology for image interpretation

Aronoff[11] identified measurement, classification and estimation as the three types of analyses that can be carried out on remote sensing data. The last two relates to the objectives of this study. Extraction of information from remote sensor data can be done using digital analysis, manual/visual analysis, and lately, the hybrid system.

Digital process

The analysis used digital classification already embedded in the imagery set. The primary classes of land use– land cover embedded in the imageries are Forest, General savanna, Wetland, Farmland, Barren while the secondary (subtype) land use–land cover classifications are Freshwater, evergreen needle leaf forest, evergreen broadleaf forest, deciduous broadleaf forest, mixed forest, closed scrublands, open scrubland's, woody savannas, savannas, grasslands, wetland, croplands, urban and built up, croplands mosaics, snow/ice, and barren or sparsely vegetated.

Field checks and accuracy assessments

Validating accuracy of classification is vital towards placing a premium on generated data.[12] Validating accuracy of land use classes interpreted from remote sensing imageries requires a validated superior resolution dataset of the same area. For the purpose of this study, field check was the most appropriate. The field check was conducted in company of six local field assistants. The field check was conducted with a handheld Garmin S76 Global Positioning Systems (GPS), digital camera and field note. A total of 185 field checkpoints were established by GPS. Observations of land use land cover characteristics and human imprints were made and recorded. According to Jensen,[12] the ideal number of checkpoints required to be tested in the land use classification map is determined from the binomial probability given in equation i

$$N = 4(p)\ (q\sim)/e^2 \qquad \text{(i)}$$

Where:

N = is the number of points required,

p = is the expected percent accuracy

q~ = the difference between 100 and

e = is the maximum allowable error

For an expected 90% accuracy and allowable error of 5%, the minimum number of points required is 144. This shows that the number of checkpoint (185) established on the field is far higher than the ideal number of checkpoints required. The checkpoints (stored as GPS waypoints) were downloaded using the Easy GPS program. The coordinates (together with descriptions) were imported into Arc GIS and added to the GIS database as an event theme which was converted into a data layer. This theme of field coordinates was then used as a base for assessing accuracy of the interpreted imageries as described by Jensen.[12] The use of handheld GPS as opposed to the traditional method of pixel selection made the field verification exercise very fast (Olorunfemi, 2001). Field observations recorded about the group of pixels around the GPS checkpoints points were matched with what has been interpreted.

Qualitative assessment was made by visual evaluation of remote sensing derived land use/land cover data with data from fieldwork. For quantitative assessment of the tribute accuracy of the map, the GPS checkpoints were analyzed for error matrix using the omission and commission errors computation method used by Jensen.[12] Omission and commission errors were calculated for the different land use land cover classes, accuracy for each class was estimated and the overall accuracy for the map was also determined using equation ii.

$$P = p\sim - (1.645\sqrt{(p\sim)}\,(q\sim)/n + 50/n) \qquad \text{(ii)}$$

Where:

P = map accuracy in percent

p~ = value c/n (number of correct points over total number of points) in percent

q~ = 100– p~. While n = sample size

Land use–land cover change analysis

Change detection for land use and land cover may be carried out using pre–classification or post classification approach. The pre–classification change detection involves matching pixel for pixel to process multi–date imageries of the same area so as to generate changes. In this case, the digital number (DN) of cells in image of time t0 is digitally matched and co–related with the DN value for the image of time t1 using change detection algorithm. The result represents the change area. This is very original because it uses the raw or native DN values of the image which reflects the spectral reflectance of surface features. In this case, subtle changes may easily be captured. However, where different environmental conditions prevail at the time of acquisition of the different images, differences in reflectance which is reflected in DN values may not correspond to changes in surface feature or classes. This may not be recognized by the change algorithm and hence unrealistic results may be generated. The second methodological approach is the post–classification change detection. This involves digital classification of the multi–temporal image of the same area. The classified image data are thereafter overlaid. Change is generated based on the classes rather than on differences in DN values. Much as this is straightforward, any miss–classification error is automatically transmitted into the change generated. So the accuracy of change generated is a function of the accuracy of classified imageries. Therefore, for this study, land use land cover layer for 2001 was overlaid with land use land cover data generated for 2005 and 2009 in the GIS environment. Change analysis was then performed by intersecting the different multi–temporal land use and land cover layers (2001, 2005 and 2009). Change maps were generated and the resulting tables also produced.

Magnitude change, percentage change (trend) and annual change rate

The comparison of the land use land cover statistics assisted in identifying the percentage change, trend and rate of change between 2001 and 2009. In achieving this, the first task was to develop a table showing the magnitude of change (area) and the percentage change for each static year (2001, 2005 and 2009) measured against each land use land cover type. The magnitude change for each LULC class was calculated by subtracting the area coverage of the second year from that of the initial year as shown in equation iii.

$$Magnitude = Magnitude\ of\ the\ new\ year - Magnitude\ of\ the\ previous\ year \qquad \text{(iii)}$$

Percentage change (trend) for each LULC type was then calculated by dividing magnitude change by base year area coverage and multiplied by 100 as shown in equation iv.

$$Trend\ (percentage\ change) = \frac{magnitude\ of\ change}{Base\ year} * 100 \qquad \text{(iv)}$$

Citation: Abbas II, Bello OM, Abdullahi H. Mapping and analyzing the land use–land cover of nigeria between 2001 and 2009. *MOJ Eco Environ Sci.* 2018;3(3):197–205. DOI: 10.15406/mojes.2018.03.00087

In obtaining the annual rate of change for each LULC type, the trend (percentage change) was divided by 100 and multiplied by the number of the study year 2001–2005 (4 years), 2005–2009 (4 years) and 2001–2009 (8 years) as the case may be is as shown in equation v.

$$\textit{The annual rate of change} = \frac{\textit{Trend}\ (\textit{percentage change})}{\textit{No of study years}} * 100 \quad (v)$$

Future projection

Markov Chain Analysis is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe. A Markov process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markov chain analysis describes land use change from one period to another and uses this as the basis to project future changes. This is used to predict the land use – land cover situation in each LULC type for the year 2020 based on the 2001–2009 scenarios

$$\textit{The projection for } 2020 = 2001 - 2009\ \textit{annual rate of change} * 11\ (2020 - 2009) + 2009\ \textit{magnitude}\ (\textit{area coverage}) \quad (vi)$$

Results and discussion

Land Use–Land Cover Statistics for 2001, 2005 And 2009

The static LULC statistics for the study area in 2001, 2005 and 2009 are presented in Table 1 and Figure 1 & 2. It shows both the primary and the secondary classes' area coverage in hectares and their percentages.

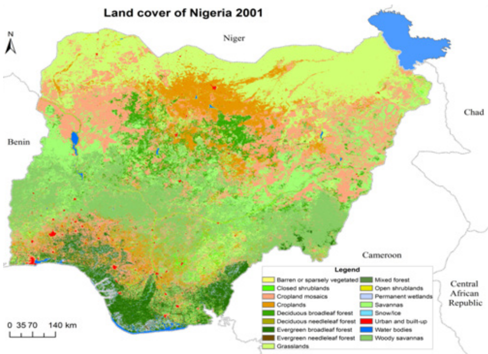

Figure 1 Land use–land cover map for 2001.

Source: GIS Analysis.

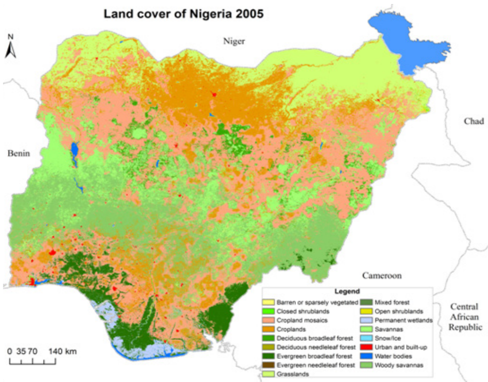

Figure 2 Land Use–Land Cover map for 2005.

Source: GIS Analysis.

Static land use–land covers for 2001, 2005 and 2009

There were five[5] primary LULC categories and 17 secondary LULC categories in all the three dates (2001, 2005 and 2009) as shown in Table 1, Figures 1–3. The water bodies had 0.53% coverage in 2001, decreased to 0.47% in 2005 and further decreased to 0.40% in 2009. The decrease could be associated with land reclamation of the water bodies, siltation and natural shrinkage in the volume of lakes and rivers. The effects are ecosystems and habitat loss, loss of livelihood, economic losses, increased poverty and settlement dislocation. The total forest cover had 10.51% in 2001, decreased to 7.72% in 2005 and further decreased to 6.78% in 2009. This shows that the forest resources have been on the degradation due to effects of climate change, farming, logging activities, woods for domestic uses construction and other anthropogenic factors. The effects might not be immediate but if not curtailed it could be devastating especially if carbon is not sunk through the forest. The total savanna cover was 56% in 2001, decreased to 44% in 2005 as a result of agricultural activities and increased to 47.91% in 2009 due to high gain from forest cover. The loss in savanna could affect agriculture especially if it is lost to barren lands. The wetland area was 1.07% in 2001, increased to 1.54% in 2005 and further increased to 1.65% in 2009. The steady increase was due to gain from the forest ecosystem as a result of an increase in rainfall and human imprint that allowed the water to persist on the forest cover that gradually turned part of the forest cover into the wetland. The farmland of the study area was 31.24% in 2001, increased drastically to 45.72% in 2005 as a result of the need for food security and encouragement by the government for the people to embrace agriculture; and decreased to 42.71% in 2009 probably because of flooding and low return from agriculture. The barren land which comprises of built up and a sparsely vegetated area was 0.64% in 2001, decreased to 0.54% in 2005 and slightly increased to 0.55% in 2009. The decrease was as a result of a loss of the barren cover type especially sparsely vegetated areas to other land covers. The increased barren land could lead to resettlement, loss of agricultural lands, loss of livelihoods, soil impaction, increased poverty and human vulnerability. The pictorial representation of the discussion above is shown in Figure 1 & 2.

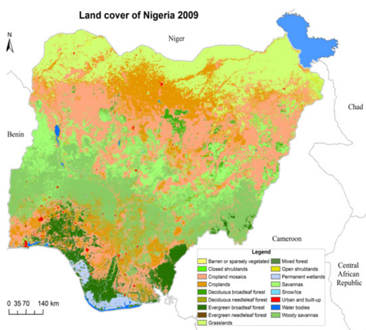

Figure 3 Land Use–Land Cover map for 2009.

Source: GIS Analysis.

Table 1 Land use-land cover statistics for 2001, 2005 and 2009

Primary LULC	Secondary LULC	Class value	2001 Magnitude (Ha)	2001 Percent	2005 Magnitude (Ha	2005 Percent	2009 Magnitude (Ha)	2009 Percent
Water bodies	Fresh water	0	478066.3312	0.527215977	427557.1454	0.47151398	358222.39	0.395051
	Snow/Ice	15	6826.14581	0.007527937	1674.337652	0.001846475	364.91974	0.000402
Sub Total			484892.4771	0.534743914	429231.4831	0.473360455	358587.31	0.395453
Forest	Evergreen needle forest	1	89684.39369	0.09890478	1738.735253	0.001917493	5924.5794	0.006534
	Evergreen broad leaf forest	2	5011872.169	5.527139043	4321594.274	4.765894187	4647510.5	5.125318
	Deciduous needle leaf forest	3	794.2370911	0.000875892	11720.36356	0.012925325	2575.9041	0.002841
	Deciduous broad leaf forest	4	4352183.135	4.799627867	2656615.74	2.929740441	1486726	1.639575
	Mixed forest	5	79015.85763	0.08713942	6568.555402	0.007243864	8479.0176	0.009351
Sub Total			9533549.792	10.513687	6998237.668	7.717721312	6151216	6.783618
Savanna	Closed shrub lands	6	999257.5899	1.101990524	158010.2494	0.174255166	234128.21	0.258199
	Open shrub lands	7	326839.2959	0.360441402	202165.5385	0.222950028	297602.78	0.328199
	Woody savannas	8	19191322.56	21.16436825	17335426.6	19.117669	18221581	20.09493
	Savannas	9	11216409.39	12.36956015	9537027.263	10.51752199	9718843.2	10.71803
	Grasslands	10	19045483.46	21.00353554	12668983.17	13.97147197	14972850	16.5122
Sub Total			50779312.3	55.99989587	39901612.82	44.00386815	43445005	47.91155
Wetland	Wetland	11	971566.6211	1.071452667	1400454.65	1.544434358	1498403.4	1.652453
Sub Total			971566.6211	1.071452667	1400454.65	1.544434358	1498403.4	1.652453
Farmland	Croplands	12	8658042.928	9.548169923	14654447.1	16.16105998	13443364	14.82547
	Cropland mosaics	14	19670462.18	21.69276786	26801294.51	29.5567158	25281275	27.88042
Sub Total			28328505.11	31.24093779	41455741.62	45.71777578	38724639	42.70589
Barren	Urban and built up	13	462074.2601	0.509579773	460528.7176	0.507875335	460528.72	0.507875
	Barren or Sparsely vegetated	16	117611.4871	0.129703037	31705.08604	0.034964663	39132.276	0.043155
Sub Total			579685.7472	0.63928281	492233.8037	0.542839997	499660.99	0.551031
Grand Total			90677512	99.99	90677513	99.99	90677511	100

Source Author's Analysis.

Land use– Land cover changes from 2001 to 2009

The changes in the land use– land cover classes over the three dates are presented by showing the magnitude of change and percentage change of the land use– land cover classes over the years. The annual rate of change of each land use– land cover over the period is also presented.

Magnitude, Trend (percentage change) and Annual rate of change (2001–2009)

The change magnitude, percentage (trend) and annual rate of change from 2001 to 2009 are presented in Table 2. The primary LULC changes between 2001 and 2009 are also pictorially shown in Figures 4–9.

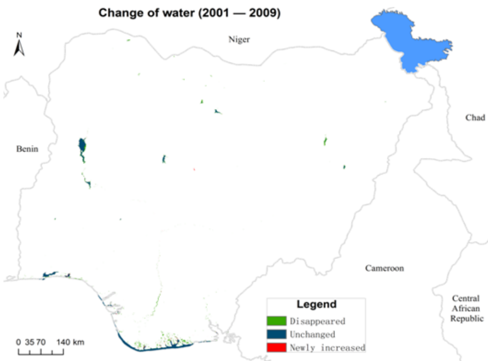

Figure 4 Change in water LULC (2001–2009).

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Table 2 The change (magnitude, trend and annual rate)

LULC-Type	LULC_ Sub type	2001-2005 Magnitude (Ha)	2001-2005 Annual %	2005-2009 Magnitude (Ha)	2005-2009 Annual %	2001-2009 Magnitude (Ha)	2001-2009 Annual %
Water bodies	Fresh water	-50509	-2.64	-69335	-4.05	-119844	-6.27
Water bodies	Snow/Ice	-5152	-18.87	-1309	-19.55	-6461	-23.66
Forest	Evergreen needle leaf forest	-87945	-24.52	4186	60.18	-83759	-23.35
Forest	Evergreen broadleaf forest	-690278	-3.44	325917	1.89	-364361	-1.82
Forest	Deciduous needle leaf forest	10926	344.02	-9144	-19.51	1782	56.11
Forest	Deciduous broadleaf forest	-1695567	-9.74	-1169890	-11.01	-2865457	-16.46
Savanna	Closed shrub lands	-841248	-21.05	76118	12.04	-765130	-19.14
Savanna	Open shrub lands	-124673	-9.54	95437	11.80	-29236	-2.24
Savanna	Woody savannas	-1855896	-2.42	886154	1.28	-969742	-1.26
Savanna	Savannas	-1679382	-3.74	181816	0.48	-1497566	-3.34
Savanna	Grasslands	-6376500	-8.37	2303867	4.55	-4072633	-5.35
Wetland	Permanent wetlands	428888	11.04	97948	1.75	526836	13.56
Farmland	Croplands	5996404	17.31	-1211083	-2.07	4785321	13.82
Farmland	Cropland mosaics	7130833	9.06	-1520020	-1.42	5610813	7.13
Barren	Urban and built-up	-1545	-0.08	0	0.00	-1545	-0.08
Barren	Barren or sparsely vegetated	-85906	-18.26	7427	5.86	-78479	-16.68

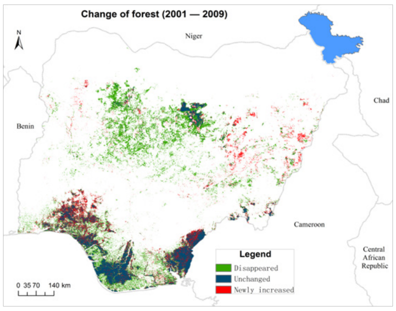


Figure 5 Change in forest LULC (2001–2009).

Source: GIS Analysis.

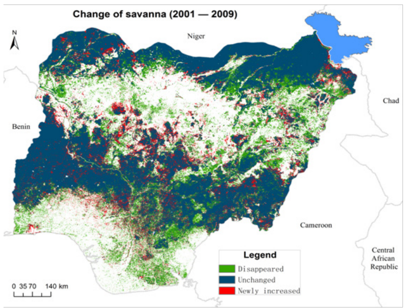


Figure 6 Change in savanna LULC (2001–2009).

Source: GIS Analysis.

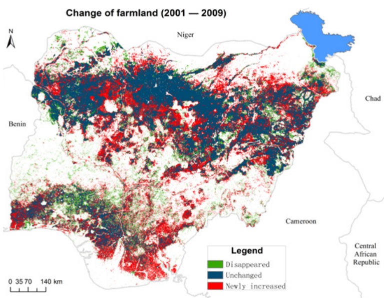


Figure 7 Change in farmland LULC (2001–2009).

Source: GIS Analysis.

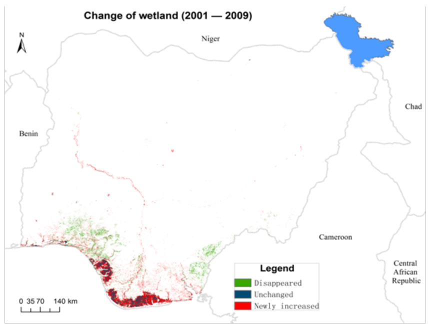


Figure 8 Change in wetland LULC (2001–2009).

Source: GIS Analysis.

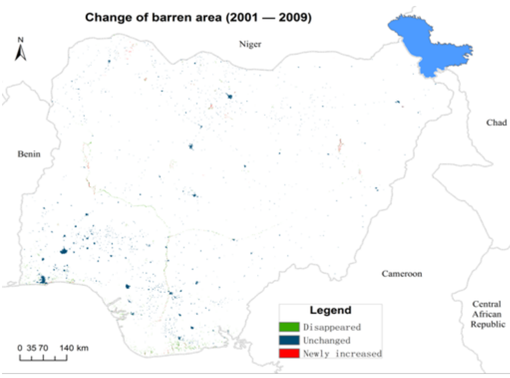


Figure 9 Change in barren LULC (2001–2009).

Source: GIS Analysis.

The magnitude of Change (2001, 2005 and 2009

From table 2, the magnitude changes in the area of water bodies between 2001 and 2005 was –55661ha, the magnitude change between 2005 and 2009 was –70644ha and between 2001 and 2009 it was –126305ha. This shows that the water body has been on the decrease over the years. The magnitude change in the forest cover was –2462865ha meaning a decrease in the magnitude between 2001 and 2005, it decreased again (–848932ha) between 2005 and 2009 while it was also a decrease (–3311797ha) between 2001 and 2009. The magnitude changes in the savanna primary class between 2001 and 2005 was –10877699ha which means a decrease in the magnitude, it was 3543392ha between 2005 and 2009 which means there was an increase in the magnitude of the savanna while the overall magnitude change between 2001 and 2009 was a reduction in coverage (–7334307ha). Between 2001 and 2005, the wetland increased in magnitude by 428888ha, it also increased between 2005 and 2009 by 97948ha while between 2001 and 2009 it increased by 526836ha. The magnitude changes in farmland coverage between 2001 and 2009 was an increase in the size of 10396134ha, it also increased by 13127237ha between 2001 and 2005 while there was a decrease (–2731103ha) between 2005 and 2009. For barren lands, the magnitude changes between 2001 and 2005 was a decrease (–87452ha), it increased by 7427ha between 2005 and 2009 but also decreased (–80025ha) between 2001 and 2009.

The trend between the years (2001, 2005 and 2009)

From table 3, the trend follows the pattern of the magnitude change with water bodies having –11.48, –16.46 and –26.05 between 2001 and 2005, 2005 and 2009 and from 2001 to 2009 respectively. It was a decreasing trend over the years. The same decreasing trend continued for forest resource at –26.05, –12.14 and –35.03 for 2001–2005, 2005–2009 and 2001–2009 respectively. The trend for savanna cover was –21.42 between 2001 and 2005, 8.88 between 2005 and 2009; and –14.44 between 2001 and 2009. It was a decreasing trend. The Wetland trend between 2001 and 2005 was 44.14; it was 6.99 between 2005 and 2009 and 54.23 from 2001 to 2009. It was an increasing trend. The trend between 2001 and 2005 for farmland LULC was 46.34 while the trend was a decreasing one (–6.59) between 2005 and 2009 but it increased in trend (36.70) between 2001 and 2009. For the barren cover, it was a decreasing trend. The 2001–2005 trends were –15.09; the trend was 1.51 between 2005 and 2009 while it was –13.80 between 2001 and 2009.

Annual change (2001, 2005 and 2009)

From Table 3, it can be observed that some LULC classes continued to decline in their annual rate area coverage from 2001 to 2009. These LULC classes are water bodies (–2.87, –4.11, –6.51) and forest (–6.51, –3.04, –8.76). Some LULC classes had fluctuating area coverage based on their annual rate of change; such LULC classes include grassland (–5.36, 2.22, –3.61), wetlands fluctuated but it increased all through (11.04, 1.75, 13.56), farmlands (11.58, –1.65, 9.17) and barren lands (–3.77, 0.38, –3.45).

Land Use–Land Cover Transformation

The transformation of land use–land covers from one particular type to another was generated from the GIS analysis to know which particular class has lost or gained from the other. This is achieved by developing a transition probability matrix of land use change from the time one to time two, which shows the nature of change.

Contingency matrix of change

Tables 3, 4 and 5 show the contingency matrices of LULC changes of 2001–2005, 2005–2009 and 2001–2009. The diagonal figures on the tables represent the static land cover while other figures represent the matrices of change from one land cover class to another. The record (row) totals indicate the areal extent of each LULC class in initial period (t1) and the field (column) totals represent the area of each LULC class in present period (t2). In other words, reading down each row of the table indicates the transition (loss) of the row header class into other LULC classes in year t2; and reading down each column indicates the transition (again) from each LULC class to the column header class in year t2. In simple term, the column represents gains from other LULC classes to the column header, while the row represents the loss of row headers to other LULC classes. The frequency of land transformation from the contingency matrices (Table 3–5) shows that the study area experienced rapid LULC transformations within the period under investigation.

Land Use – Land Cover Projection

The LULC projection for the future was done using Markov chain model incorporated in the Arc GIS software. The change between 2001 and 2009 was used as the basis for the prediction. The result generated is shown in Table 6 and also represented in Figure 10A–10F. From Table 6 and Figures 10A –10F, it can be observed that using the 2001–2009 change scenario as the basis in Markov chain analysis model, all the primary LULC types would decrease in area coverage from 2010 to 2020 except the farmland that would increase in area coverage. This sends a very alarming danger to the planners and environmentalists that a lot of work needs to be done fast to stem the impending implications for the study area and its inhabitants.

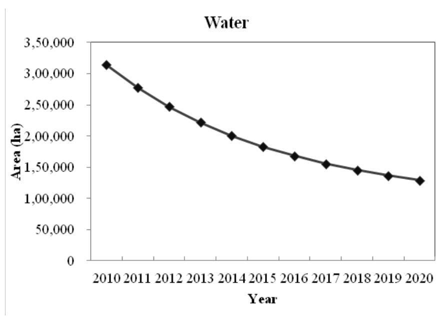


Figure 10A Water bodies LULC prediction (2010–2020).

Citation: Abbas II, Bello OM, Abdullahi H. Mapping and analyzing the land use–land cover of nigeria between 2001 and 2009. *MOJ Eco Environ Sci.* 2018;3(3):197–205. DOI: 10.15406/mojes.2018.03.00087

Table 6 Land use –land cover prediction (2010 to 2020)

LULC_ Type	2010 Magnitude (Ha)	2011 Magnitude (Ha)	2012 Magnitude (Ha)	2013 Magnitude (Ha)	2014 Magnitude (Ha)	2015 Magnitude (Ha)	2016 Magnitude (Ha)	2017 Magnitude (Ha)
Water bodies	314425	277697	247133	221686	200483	182794	168011	155632
Forest	5670395	5462483	5366038	5316847	5288888	5271278	5259236	5250505
Savanna	40694340	39208914	38413665	37993679	37776796	37669090	37619463	37600221
Wetland	40694340	1465253	1430404	1401057	1378047	1360332	1346647	1335944
Farmland	40694340	43836960	44826228	45379377	45694776	45879188	45990572	46060638
Barren	40694340	426204	394043	364864	338521	314828	293580	274569

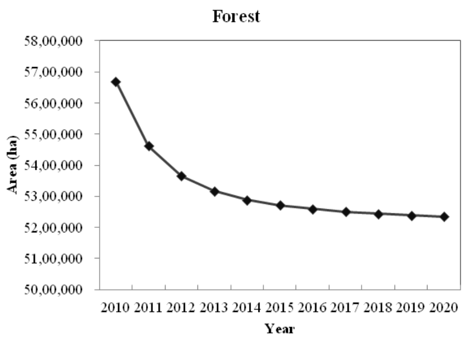


Figure 10B Forest LULC prediction (2010–2020).

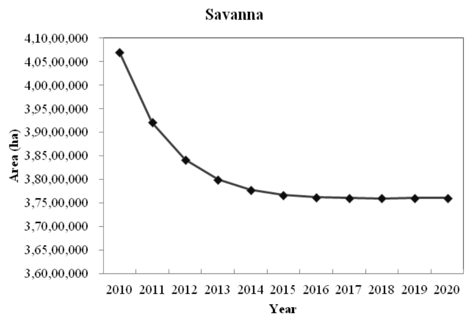


Figure 10C Savanna LULC prediction (2010–2020).

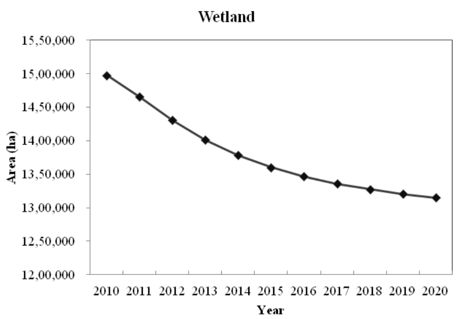


Figure 10D Wetland LULC prediction (2010–2020).

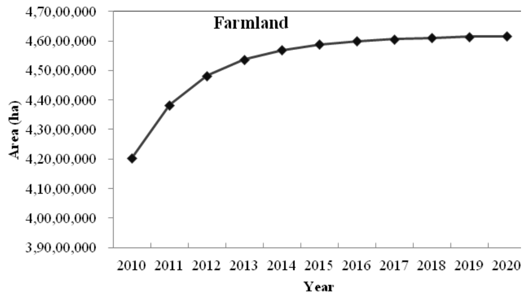
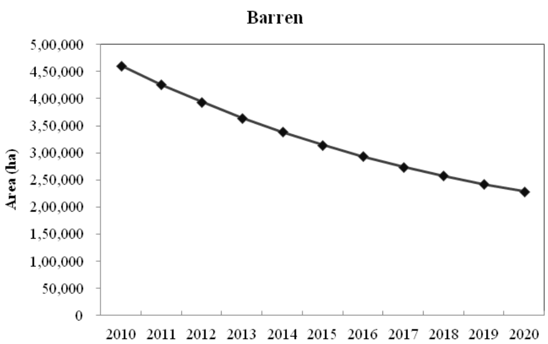


Figure 10E Farmland LULC prediction (2010–2020).

Figure 10F Barren LULC prediction (2010–2020).



Conclusion

The research has demonstrated the link between various LULCs in such a way that what happened to one LULC type invariably was happening to another or sets of LULC types and that the impact in an area could spin off in several other areas. For example, the loss of fishing pond or lake leads to a forced shift in occupation and sources of livelihood and opening of new lands for other livelihood sources including farming and logging. In addition, the movement of people from a degraded LULC also leads to the establishment of settlements together with the transfer of human activities to another LULC probably still fertile or yet to be degraded. From the above, therefore, this means that a holistic approach to the investigation of LULC and LULCC that incorporates all the basic connectives is better and this can only be achieved through investigations that utilize the trans–disciplinary approach to researchers which is key to sustainable science. Based on the strength of the findings of this study, the following recommendations to entrenching sustainable environment, natural resources and disaster management in the study area are proposed: there is the need for ecosystems restoration for areas that have suffered terrible degradation, there is urgent need for the governments through appropriate MDAs to embark on data gathering on critical environmental variables through in–situ and field measurements. Remote sensing and GIS with the view to developing an integrated comprehensive databank and information systems for environmental monitoring and natural resource management. A synergy of efforts by all relevant MDAs is recommended to eliminate waste of resources, time and man–hour, and legislations compelling environmental protection; restoration and remediation need to be enforced.

Acknowledgements

None.

Conflict of interest

The author declares there is no conflict of interest.

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Citation: Abbas II, Bello OM, Abdullahi H. Mapping and analyzing the land use–land cover of nigeria between 2001 and 2009. *MOJ Eco Environ Sci.* 2018;3(3):197–205. DOI: 10.15406/mojes.2018.03.00087