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Original Article

Spatiotemporal analysis of land-use and land-cover changes in Kainji Lake National Park, Nigeria

Nijerya Kainji Gölü Milli Parkında arazi kullanımı ve arazi örtüsü değişikliklerinin mekansal analizi

Adesoji Akinwumi Adeyemi, Taofiq Maijindadi Ibrahim

Department of Forest Resources Management, Faculty of Agriculture, University of Ilorin, Ilorin, Nigeria

ABSTRACT

There is paucity of information on the rates at which most protected areas in Nigeria are being depleted as population soars. In order to formulate realistic management policies, reliable data on land use/land cover are indispensable. We evaluated the changes in the forest covers of Kainji Lake National Park (KLNP) using multi-temporal remote-sensing data. Landsat TM, ETM+, and OLI/TC images of five age-series were analyzed using ArcGIS 10.5. A Normalized Difference Vegetation Index analysis was performed, and vegetation covers were distinguished. The rates of change were x-rayed and future projections made. Five land-use and land-cover classes (forest, savannah, swamp/water body, bare land, and built-up area) were distinguished. The results revealed that the area experienced considerable changes in vegetation covers. It was evident that from 1988 to 2018, the Borgu sector increased in forest and bare land by 10,728.18 ha (2.4%) and 19,540.83 ha (4.3%) at 0.08% and 0.14% per annum, respectively, whereas savannah and swamp/water body decreased by 27,134.28 ha (6.0%) and 3,104.73 ha (0.7%) at annual rates of 0.20% and 0.02%, respectively. In the Zugurma sector, forest and bare land increased by 7,242.21 ha (5.3%) and 44,341.74 ha (32.5%) at 0.18% and 1.08% per annum, respectively, whereas swamp decreased by 51,583.95 ha (37.8%) at 1.26% per annum. These changes were due to increases in anthropogenic activities in these parks, which negatively impacted the swamps and grassland. There were depletions along borders shared between the park and surrounding communities, and this poses degradation threats if not stemmed. A stricter protection measure is advocated. The park management must explore possible alternatives for area management.

Keywords: Land use, land-cover changes, classification, projection, conservation

ÖZ

Nüfus artışı ile Nijerya'da korunan alanlardaki azalma oranları hakkında yeterli bilgi bulunmamaktadır. Gerçekçi yönetim politikalarının oluşturulabilmesi için, arazi kullanımı / arazi örtüsü ile ilgili güvenilir bilgilerin elde edilmesi gerekmektedir. Kainji Gölü Milli Parkı (KLNP) orman alanlarındaki değişiklikler çok yönlü uzaktan algılama verileri kullanılarak değerlendirilmiştir. Belirlenen beş yaş sınıfında Landsat TM, ETM + ve OLI/TC görüntüleri ArcGIS 10.5 yazılımı kullanılarak analiz edilmiştir. Normalleştirilmiş Bitki Örtüsü Farklılığı İndeksi analizi yapılarak ve bitki örtüsü değişiklikleri belirlenmiştir. Değişim oranları belirlenerek geleceğe yönelik tahminler yapılmıştır. Arazi kullanımı ve arazi örtüsü sınıfları orman, mera, bataklık/sulak alan, çıplak arazi ve yerleşim alanı olarak belirlenmiştir. Elde edilen sonuçlara göre, bölgenin arazi örtüsü sınıflarında önemli değişiklikler oluşturduğunu ortaya koymaktadır. 1988-2018 yılları arasında, Borgu bölgesinde orman alanlarının yıllık %0,08 oranında (19740,18 ha - %2,4), çıplak arazilerin ise %0,14 oranında (19540,83 ha - %4,3) arttığı görülmektedir. Yine aynı bölgede mera alanlarının yıllık %0,20 (27134,28 ha - %6,0) ve bataklık ve sulak alanlar ise yıllık %0,02 oranında (3104,73 ha - %0,7) azaldığı tespit edilmiştir. 1988-2018 yılları arasında, Zugurma bölgesinde orman alanlarının ve çıplak arazilerin yıllık %0,18 (7242,21 ha - %5,3) ve %1,08 oranında (44341,74 ha - %32,5) arttığı, bataklık alanların ise yıllık %1,26 oranında (51583,95 ha - %37,8) azaldığı görülmektedir. Bu değişikliklerin bataklık ve otlakları olumsuz etkileyen bu parklardaki antropojenik aktivitelerdeki artıştan kaynaklandığı tespit edilmiştir. Milli park sınıları çevresindeki sınırlar boyunca bazı değişikliklerin bulunduğu görülmekle birlikte, milli park sınırları boyunca daha sıkı koruma tedbirlerinin alınması önerilmektedir. Milli Park yönetimi için daha farklı olası alternatiflerin araştırılması gerekmektedir.

Anahtar Kelimeler: Arazi kullanımı, arazi örtüsü değişiklikleri, sınıflandırma, planlama, koruma

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Corresponding author:
Adesoji Akinwumi Adeyemi
e-mail:
adeyemi.aa@unilorin.edu.ng;
adeyemiadesoji@yahoo.com

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INTRODUCTION

The national parks in Nigeria are some of the very few remaining natural ecosystems that are capable of enhancing ecological processes and life support systems. It is a form of protected area approach to conservation in the tropics, which is well adopted all over west African countries due to peculiar situations in perspectives toward natural resource exploitation. In the subcontinent, a layman prefers consumption to conservation, not minding sustainability of the resources in question. In Nigeria, it was hardly believed that natural resources can be exhausted if over-exploited. The views of rural and urban dwellers regarding this matter did not vary. Consequently, the level of exploitation, especially through, but not limited to, illegal grazing and other illegal activities carried out in these natural ecosystems are worrisome, and are fast depleting the resource base of the country. For instance, Nigeria had the highest rate of deforestation in the world at 5% with 410,000 hayr^{-1} of net forest loss between 2010 and 2015. Within the period of 1976 to 1995, agricultural land use increased by 64.4% with a corresponding loss of 16.6% in natural forest extent (FAO, 2014; Oyebo et al., 2010). From 1990 to 2010, Nigeria lost 52.5% of her forest cover mainly due to high deforestation rate, contributing to the desertification of the country (Akinbami, 2003).

According to FAO (2001; 2003; 2005), deforestation increased at a rate of 2.4% a year in 2000 to 3.1% in 2005. It is wisely said that a nation with sustainable utilization of its environment in mind must have adequate information on complex interrelated aspects of its activities in order to make good decisions. In this dynamic situation, accurate and meaningful data on land use are essential (Ikusemoran, 2009). The utilization of reliable land use data is enormous; land-use and land-cover data are needed for water resource inventory, flood control, water supply planning, and wastewater treatment. One of the prime prerequisites for better land use is information on existing land-use patterns and temporal changes in land use.

There have been severe threats to forests, with forest reserves and national parks being the major victims, due to rapid population growth. However, little is known about the rates at which these protected areas are being depleted. The baseline information about land-use and land-cover changes of the protected areas is yet to be explicitly analyzed. It will be difficult to develop a high-quality management plan to monitor and address issues concerning Kainji Lake Park without having adequate knowledge of the changes in sizes and structures over the years, although studies have shown that the protected areas have been encroached by humans due to lack of law enforcement, which has led to rise in illegal grazing, deforestation, and forest degradation. Therefore, there is a need to provide relevant information and evaluate changes that may have occurred over time to support a subsequent management plan.

With the current depletion of forested areas around the world, it is important that the trends in protected natural ecosystems are managed in a justifiable manner. In order to formulate and implement efficient management policies, it is important to have reliable information about the current land use and land cover (LULC) of Kainji Lake National Park (KLNP). In this dynamic situation, accurate and meaningful data on land use are essential for change detection. It is necessary to understand the dynamic nature of emerging LULC types of an area, which may have been impacted over time. Understanding the dynamics of these changes is necessary for generating valuable information for better decision-making (König et al., 2013; Li et al., 2017; Lu et al., 2003). Mapping LULC at local and regional scales is essential for planning and better understanding of the rates of forest disappearance, as well as the drivers of the observed changes, particularly in the tropics (Liu et al., 2010; Martínez et al., 2012; Poongothai et al., 2014; Reis, 2008; Tendaupenyu et al., 2017). Moreover, remotely-sensed data provide a historical vehicle for determining and evaluating long-term trends in biophysical landscapes. The objective of this study is to evaluate the changes in forest covers of KLNP over a 30-year period using multitemporal remote-sensing data and GIS-based techniques, and to assess factors responsible for land-cover changes in the parks with a view to suggest appropriate sustainable management strategies.

MATERIALS AND METHODS

KLNP was established in 1979 by the merger of two former game reserves, Borgu Game Reserve (in the Niger and Kwara states) and Zurguma Game reserve (located in the Niger State). The two sectors were gazetted in 1962 and 1971, respectively, as game reserves by the then Northern Regional Government. KLNP is located in the northwest and central part of Nigeria between the Niger and Kwara states. It has a total area of 534,082 ha (Marguba, 2002, Ogunjobi et al., 2012). The Borgu sector is currently located between latitudes 9°35′N and 10°25′N, and longitudes 3°30′E and 4°30′E, covering 397,002 ha of land, while the Zugurma sector occupied a relatively smaller area of 137,080 ha and situated between latitudes 9°40′N and 10°0′ N and longitudes 4°40′E and 5°20′E (Figure 1).

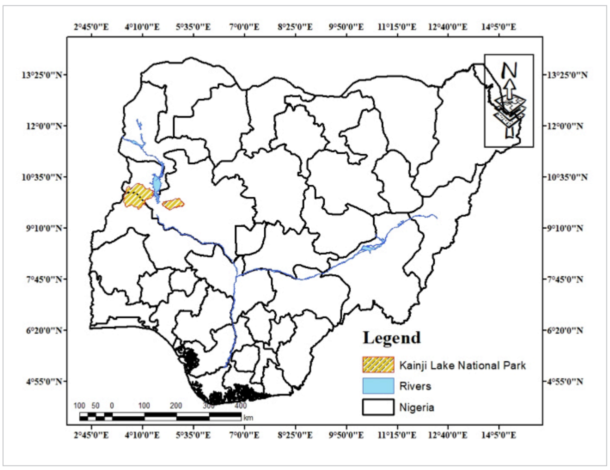

Figure 1. Map of the study area

Table 1. Characteristics of the satellite data used for the study

S/N	Borgu	Zugurma
1	Landsat 5 (TM), 21/02/1988	Landsat 5 (TM), 03/02/1988
2	Landsat 5 (TM), 11/02/1999	Landsat 5 (TM), 16/11/1998
3	Landsat 7 (ETM+), 26/11/2002	Landsat 7 (ETM+), 20/02/2002
4	Landsat 8 (OLI/TC) 18/12/2013	Landsat 8 (OLI/TC) 09/11/2013
5	Landsat 8 (OLI/TC) 03/03/2018	Landsat 8 (OLI/TC) 25/12/2018

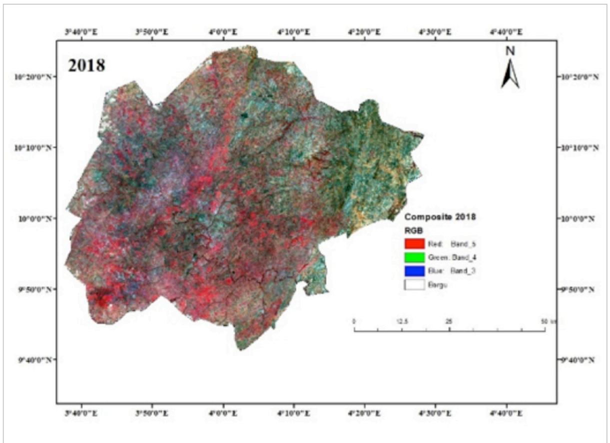

Figure 2. Composite image of Borgu sector of KLNP in 2018

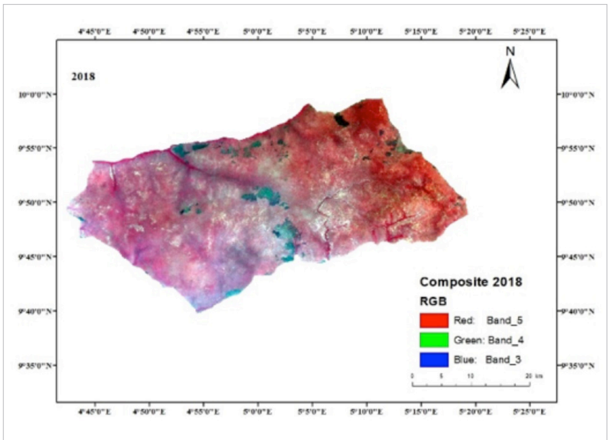

Figure 3. Composite image of Zugurma sector of KLNP in 2018

Kanji Lake National Park has a savannah climate. Night temperature can be as low as 7°C near *Oli* River. There is a distinct rainy season from May to October with maximum rains in August and September (Adesalu, 2010). The mean annual rainfall varies from 1100 mm in the eastern part to 1150 mm in the western part (Meduna et al., 2009).

The type of vegetation of the Borgu sector is transitional between Sudan and northern guinea savannah types, while that of the Zugurma sector is typically northern guinea savannah woodland (DRB, 2004). The vegetation of the Borgu sector is differentiable by hydrological, as well as soil factors, into six major types (Adesalu, 2010). The Borgu sector is drained by the *Oli*, *Timor,* and *Doro* Rivers, as well as their tributaries. The Zugurma sector is drained by the *Maingyara* and *Nuwa Tinzururu* Rivers. The *Oli* River takes its source from the Niger River (Meduna et al., 2009).

In this study, time series were defined to analyze LULC changes. Landsat TM, ETM+ and OLI/TC satellite images of five age-series for the study areas with their corresponding paths and rows were acquired from the United States Geological Survey Earth Explorer data portal (http://earthexplorer.usgs.gov/). The acquisition dates of the multitemporal data from different sensors (TM and ETM Scenes) in the change detection process fall within acceptable anniversary windows of equivalent seasons. Landsat images were downloaded for free from Earth Explorer. Among all available satellite data, the following scenes were chosen for their quality, clarity and minimal cloud covers (Table 1).

Image Processing

Landsat 8 composite images and a Global Positioning System (GPS) receiver were used to aid the location of ground control points (GCPs) on the field during ground-truthing or verification of the actual LULC classes on the field (Figures 2 and 3). The essence of GCPs was to determine the accuracy of classes in classified images, to determine what the class corresponds to the GCP point in the classified image, or to perform fine geo-referencing. The GCPs were randomly generated on the pre-classified Landsat image for different land-cover classes, which were stored in the GPS, and used for ground verification of different land-cover classes on the field. The geographic coordinates of the study sites from the GPS readings were then recorded, and the locations were indicated on the images for final verification of appropriate classes as pre-defined. The main aim of image classification was to automatically categorize all pixels in an image into land-cover classes. The images were level-1 products, implying that they were already corrected for radiometric, atmospheric (including cloud patching), and noise errors by the data provider. However, to maximize the use of all spectral information contained in the satellite images, all forms of atmospheric effects caused by scattering and absorption from the earth surface radiation at the time of acquisition were removed in the course of image pre-processing using ArcGIS 10.5. For Landsat 8 OLI/TC of 2013 and 2018, Bands 5 (NIR): 0.85–0.88 µm, 4 (red): 0.64–0.67 µm, and 3 (green): 0.53–0.59 µm were combined (stacked) together to form a single multi-spectral image dataset using the following steps in ArcGIS 10.5 or other versions: Arctool Box ► Data Management Tools ► Raster ► Raster Processing ► Composite Bands ► Band Selection in this order ► 5,4,3 ► OK ► Done. The pre-processing operations performed consist of atmospheric correction, radiometric corrections, and extraction of region of interest (i.e., the study area to be analyzed) or sub-setting, as follows: Spatial Analyst Tools ► Extraction ► Extraction by Mask ► Input raster file ► (i.e., the composite image) ► Input feature mask (select the vector or enveloped file, as the case may be) ► OK. For Landsat 7 images, however, gap filling was done for each of the bands before band combination to remove scanline errors as follows: ArcTool Box ▶ Landsat Toolbox ▶ Fix Landsat 7 Scanline Errors ▶ OK ▶ Done. These procedures were repeated for Landsat 7 ETM+ image of 2002 using band combination 4,5,3 and 4,3,2 for Landsat 5 TM of the 1988 and 1999 images.

The image analysis or land-use/land-cover type classification was pixel-based and unsupervised, followed by image reclassification into about five land-cover types, as follows: Spatial Analyst Tools ▶ Reclass ▶ Reclassify ▶ Specify the land-cover/land-use classes ▶ OK ▶ Done. Prior to image classification, ground-truthing of relevant land-cover and land-use types in the study area was done using ArcMap 10.5. For the image analysis and classification, the following steps were followed: ArcTool Box ▶ Spatial Analyst Tools ▶ Multivariate ▶ Iso Cluster Unsupervised Classification ▶ Input composite image (the extracted image) ▶ Specified number of classes ▶ OK ▶ Done. Unsupervised Classification was used with 20 classes, which were later re-classified, and three to five classes were determined. Using the Landsat image bands, false color composites, a preliminary land-cover map was obtained and land-cover classes were distinguished. In this technique, the images of different dates were classified and labeled individually. A hand-held GPS receiver was used to collect up to 50 spatial locations within each of the land-cover/land-use categories. A total of 450 GCPs were used.

Change Detection

The first step in change detection was raster to vector conversion, as follows: Arctool Box ▶ Conversion Tools ▶ From Raster ▶ Raster to Polygon ▶ Input Raster (include class in the attribute table of the raster data) ▶ Select the class created in the raster ▶ OK ▶ Done. The second step was dissolution of the vector data (polygon). This was done through following the steps: Geoprocessing ▶ Dissolve (the 1988, 1999, 2002, 2013, and 2018 images done separately) ▶ Input feature class (select the vector file to be dissolved) ▶ OK ▶ Done. The third step was unification or to unify the three images or datasets (1988, 1999, 2002, 2013, and 2018 images) as follows: Geoprocessing ▶ Union ▶ Input feature class (select the three dissolved vector files for 1988, 1999, 2002, 2013, and 2018) ▶ OK ▶ Done. Then, open the attribute table of the unified vector (shapefile) ▶ Add another field (Area) ▶ right-click on the field ▶ Calculate Geometry ▶ Yes ▶ Change the unit to hectare ▶ OK ▶ Yes ▶ Export the attribute table ▶ Table Options ▶ Export ▶ Change the file extension to dBASE Table ▶ Save ▶ OK ▶ No ▶ Done. The exported file was then opened in Microsoft Excel. The next thing was to make a pivot table for the three years, and the differences in land use/land cover over the period was then determined using appropriate statistics.

Accuracy Assessment

The overall accuracy of land use/land cover classification was done by creating a confusion matrix in ArcMap 10.5 using ground reference points obtained during ground-truthing, and following these steps: Spatial Analyst Tools ▶ Extraction ▶ Extract Multi Values to Points ▶ Input point features (input the Ground-truth GPS points collected on the field) ▶ Input raster (input the classified raster) ▶ OK ▶ Done. The attribute table was then exported (in dBASE format) for further analysis of the confusion matrix to determine classification accuracy and the Kappa Coefficient. A total of 450 ground-truthed points (locations) were used for the accuracy assessment of the land-use/land-cover classification. A total of 450 points were also created in the classified images of the study area to generate the cell array for the confusion matrix table. It was computed by dividing the total correctly classified pixels by the total number of pixels in the confusion matrix as adopted from Liu et al. (2007), Enaruvbe and Atedhor (2015), and Rwanga and Ndambuki (2017). The overall classification accuracy was determined by:

$$Y = \frac{\sum_{i=1}^{n} x_i}{\sum_{j=1}^{N} X_j} \times 100 \quad \ldots\ldots 1$$

Where Y = overall accuracy, $\sum_{i=1}^{n} x_i$ = sum of the correct points, and $X_j = \sum_{i=1}^{n} x_i$ = total number of all points.

Other statistics that were used for accuracy assessment included sensitivity (Producer's accuracy), specificity, commission error, omission error, users' accuracy, and Kappa's coefficient (K) as given in the subsequent lines.

$$Producer's\ Accuracy = \frac{w}{w+x} \quad \ldots\ldots 2$$

$$User's\ Accuracy = \frac{y}{y+z} \quad \ldots\ldots 3$$

$$Specificity = \frac{z}{x+z} \quad \ldots\ldots 4$$

$$Commission\ \ Error = 1 - Specificity \ldots\ldots 5$$

$$Ommission\ \ Error = 1 - Producer's\ accuracy \ldots\ldots 6$$

Where w = number of times a classification agreed with the observed value, x = number of times a point was wrongly classified, y = number of times a point was correctly classified, and z = number of times a point was not classified as 'a' when it was not observed to be 'a'.

Kappa's coefficient measures perfect agreement between prediction and reality or classification results and the real observation, as is the case in this study. It was computed as:

$$K = \frac{N\sum_{ij=1}^{r} x_{ij} - \sum_{ij=1}^{r}(x_{ij} + Xx_{+1})}{N^2 - \sum_{ij=1}^{r}(x_{ij}Xx_{+1})} \quad \ldots\ldots 7$$

Where r = number of rows and columns in error matrix, N = total number of observations (pixels), x_{ij} = observations in the ith row and jth column, x_{+i} = marginal total of the ith row, and x_{+j} = marginal total of the jth column.

Table 2. Land-cover description of the study areas	
LULC	Description
Bare land	An area of land covered with pebbles, gravel and sand, and includes hills and weathered rocks.
Built-up area	An area loosely covered by houses, road or other buildings as well as other infrastructural facilities and increasing in intensity over a period of time.
Forest	This comprises of tall dense, canopy covered vegetation, secondary forest, and riparian.
Savannah	These are sparsely scattered trees of all ages with underbrush and tall grasses. They are also characterized by small shrubs and are dominated by grasses.
Swamp/water body	Areas of marsh, fen, peat land, wetland, or water, whether natural or artificial, permanent or temporal, with water that is static or flowing,
LULC: land-use/land-cover	

The Kappa Coefficient ranges between 0 and 1. A Kappa Coefficient of 1 implies perfect agreement, while any value nearing zero means that the agreement between prediction and reality or between classification and real observation is no better than that due to chance. The LULC classification of each year was done and further analyzed in the attribute tables, and the data were then exported to statistical software for trend analysis as follows:

Trend

$$\Delta LULC = L_2 - L_1 \quad (8)$$

Where; L_2 (ha) = land use/land cover (Final year) and L_1 (ha) = land use/land cover (Initial year).

Rate of change

$$R_t = (L_2 - L_1) \times \frac{1}{t} \quad (9)$$

Where; L_2 (ha) = land use/land cover (Final year), L_1 (ha) = land use/land cover (Initial year), and t (year) = periodic interval.

LULC Prediction

$$A_2 = (R_t t \times {}^{L_1}\!/_{100} + L_1) \quad (10)$$

$$P_r = A_2 - A_i \quad (11)$$

Where; P_r = predicted area increase, A_2 = predicted year's trend, L_1 = land use/land cover of base year (1988), R_t = rate of change of LULC in 30 years, R_i = incremental ratio, and t = years of projection.

Normalized difference vegetation index was used to assess the extent and intensity of the live green vegetation, and it was analyzed as follows:

$$NDVI = \frac{\text{NIR - Red}}{\text{NIR + Red}} \quad (12)$$

Where; NIR = near infrared band and red = red band of the electromagnetic spectrum.

RESULTS

Land Use/Land Cover of the Two National Parks

Table 2 presents the description of the land-use/land-cover types in the study areas, as defined for this study.

Table 3 presents the spatial extents of LULC of the Borgu sector between 1988 and 2018. Majority of the LULC changes took place within forest and savannah, while built-up/bare land and swamp/water body had slight changes over the 30-year period under study. Figure 4 presents LULC changes for the Borgu sector over the years.

Table 4 presents the spatial extents of LULC proportions of the Zugurma sector between 1988 and 2018. Majority of the LULC changes took place within forest and swamp. Bare land made slight changes over the 30-year period under study. Figure 5 shows the LULC changes for the Zugurma sector within the period.

LULC Trends for the Borgu sector of KLNP between 1988 and 2018.

The results of the trend analysis for the Borgu sector revealed that LULC classes changed over the 30-year period (Table 5). Generally, there was a net increase in forest size, while built-up area/bare land declined. From 1988 to 1999, forest and swamp/water body increased by 59,678.9 ha (13.2%), while savannah and built-up area/bare land shrank by 56,239.10 ha (12.4%). From 1999 to 2002, savannah and swamp/water body areas increased by 46,887.70 ha (10.4%) and 12,452.94 ha (2.8%), respectively, while that of forest and built-up/bare land were negatively impacted, and reduced by 58,152.10 ha (12.8%) and 1,188.63 ha (0.3%), respectively. From 2002 to 2013, forest and swamp/water body experienced improved by 8,894.70 ha (2.0%) and 37,406.34 ha (8.3%), respectively, while savannah and built-up area/bare land contrasted by 42,642.80 (9.4%) and 3,658.23 (0.8%), respectively. Between 2013 and 2018, forest, savannah and built-up/bare land increased by 306.8 ha (0.1%), 24,860.20 (5.5%) and 28,430.19 ha (6.3%), respectively, while swamp/water body declined by 53,597.16 (11.8%).

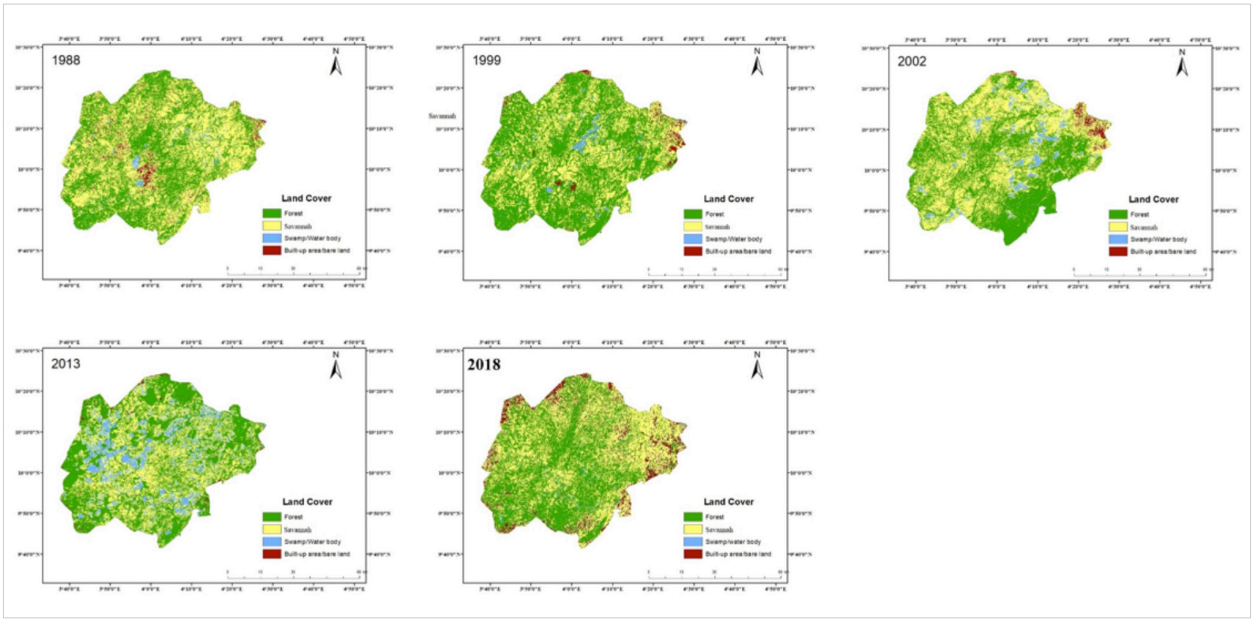

Figure 4. LULC classes of the Borgu sector of KLNP between 1988 and 2018

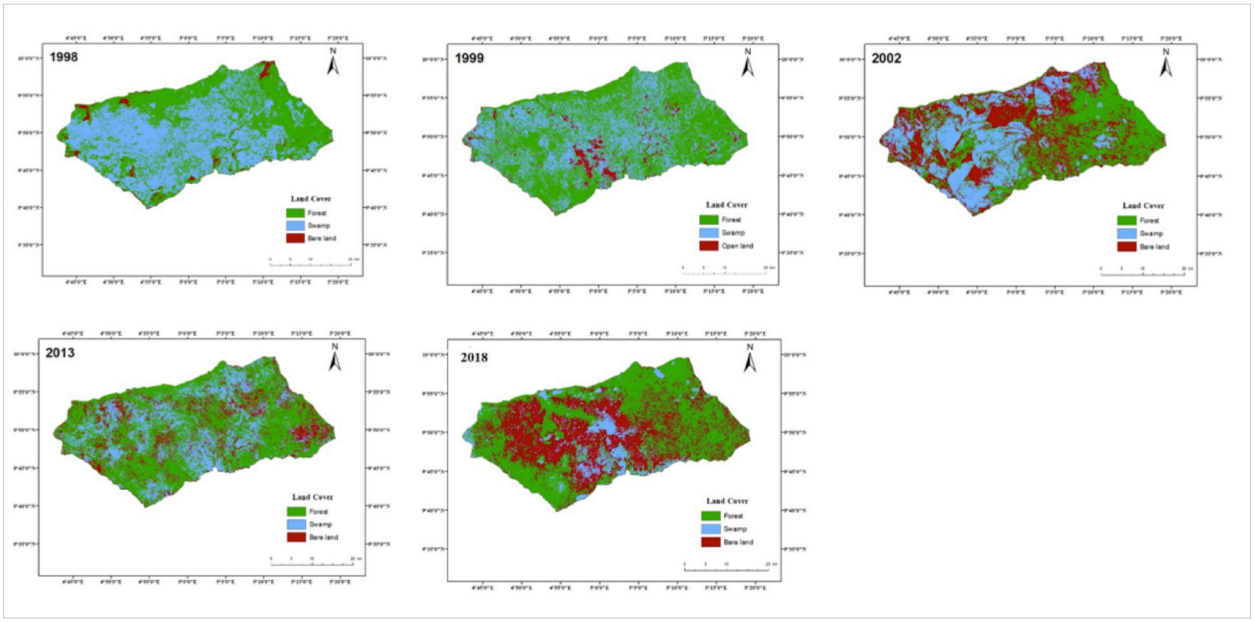

Figure 5. LULC classes of the Zugurma sector of KLNP between 1988 and 2018

The results showed that forest and swamp/water body increased by 2.0% and 8.3%, respectively, between 1988 and 2018 at 0.07% and 0.28% per year, respectively, while savannah and built-up area/bare land decreased by 9.4% and 0.8%, respectively, at 0.31% and 0.03% per annum, respectively.

There were changes in the sizes of the four LULC classes in the Zugurma sector over the 30-year period (Table 6). From 1988 to 1998, forest and bare land increased by 13,701.87 ha (10.0%) and 3,320.28 ha (2.4%) in area, respectively, while swamp contrasted by a decrease of 17,022.15 ha (2.4%). From 1998 to 2002, bare land increased by 24.9%, while forest and swamp decreased by 18.0% and 6.3%, respectively. From 2002 to 2014, forest increased by 22,815.90 ha, while swamp and bare land deceased by 4,164.93 ha and 18,650.97 ha, respectively. From 2014 to 2018, forest and swamp decreased by 4.0% and 16.0%, respectively, while bare land increased by 5.4%. Between 1988 and 2018, forest and bare land increased by 5.3% and 32.5%, respectively, at 0.18% and 1.08% per annum, respectively. Swamp, however, decreased by 37.8% at 1.26% per year.

Table 3. LULC changes within Borgu sector in KLNP

	1988		1999		2002		2013		2018	
LULC	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	205,437	45.3	265,115.9	58.5	206,963.8	45.6	215,858.5	47.6	216,165.3	47.7
Savannah	226,524	49.9	170,284.9	37.5	217,172.6	47.8	174,529.8	38.5	199,390	44.0
Swamp/water body	9,045.09	2.0	9,678.24	2.1	22,131.18	4.8	59,537.52	13.1	5,940.4	1.3
Built-up/bare land	12,577.90	2.8	8,505.36	1.9	7,316.73	1.6	3,658.5	0.8	32,088.7	7.1

LULC: land-use/land-cover; KLNP: Kainji Lake National Park

Table 4. LULC changes within the Zugurma sector (KLNP)

	1988		1999		2002		2013		2018	
LULC	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	65413.62	47.9	79115.49	58.0	54578.34	40.0	77394.24	56.7	72655.83	53.2
Swamp	67945.59	49.8	50923.44	37.3	42306.84	31.0	38141.91	27.9	16361.64	12.0
Bare Land	3152.34	2.3	6472.62	4.7	39626.37	29.0	20975.40	15.4	47494.08	34.8

LULC: land-use/land-cover; KLNP: Kainji Lake National Park

Table 5. LULC trends for the Borgu sector of KLNP between1988 and 2018

	Extent				LULC change		
	1988		2018		1988-2018		Rate
LULC	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	%	%year^{-1}
Forest	205,437	45.3	216,165.30	47.7	8,894.70	2.0	0.07
Savannah	226,524	49.9	199,390	44.0	-42,642.80	-9.4	-0.31
Swamp/water body	9,045.09	2.0	5,940.36	1.3	37,406.34	8.3	-0.28
Built-up/bare land	12,577.90	2.8	32,088.69	7.1	-3,658.23	-0.8	0.03

LULC: land-use/land-cover; KLNP: Kainji Lake National Park

Table 6. LULC trends for the Zugurma sector of KLNP between 1988 and 2018

	Area extent				LULC change		
	1988		2018		1988-2018		Rate
LULC	Area	%	Area	%	Area	%	%yr^{-1}
Forest	65413.62	47.9	72655.83	53.2	7242.21	5.3	0.18
Swamp	67945.59	49.8	16361.64	12.0	-51583.95	-37.8	-1.26
Bare land	3152.34	2.3	47494.08	34.8	44341.74	32.5	1.08

LULC: land-use/land-cover; KLNP: Kainji Lake National Park

The results of the accuracy assessments obtained from random sampling of the images in the two sectors of the park showed overall accuracy values of 87.6% and 89.2% for the Borgu and Zugurma sectors, respectively (Table 7). For the Borgu sector, User's accuracy ranged between 0.698 and 0.881, while Producer's accuracy values were between 0.852 and 0.901. With regards to the Zugurma sector of the park, User's accuracies were between 0.738 and 0.915, while Producer's accuracy ranged between 0.892 and 0.927. The narrow range of accuracy indicates a less severe confusion of built-up area with other LULC classes. Besides, the high Producer's accuracy values reflect the accuracy of prediction of each of the LULC classes. The User's accuracy reflects the reliability of the classification to the user, and is a more relevant measure of the classification's actual utility in

Table 7. Classification accuracy assessment results

LULC classification	Category-wise accuracy statistics					
	Specificity	CE	OE	UA	PA	Kappa coefficient
Borgu Sector	Overall accuracy = 87.6%					
Forest	0.8875	0.113	0.078	0.872	0.923	0.871
Savannah	0.9254	0.075	0.071	0.805	0.929	0.852
Swamp/water body	0.9028	0.097	0.084	0.881	0.916	0.859
Built-up area	0.9137	0.086	0.092	0.698	0.908	0.713
Zugurma Sector	Overall accuracy = 89.2%					
Forest	0.8938	0.106	0.083	0.892	0.917	0.883
Savannah	0.9172	0.083	0.096	0.915	0.904	0.874
Swamp/water body	0.9406	0.059	0.073	0.864	0.927	0.896
Built-up area	0.8791	0.121	0.108	0.738	0.892	0.925

CE: commission error; OE: omission error; UA: user's accuracy; PA: producer's accuracy

Table 8. Future projeciton for the Borgu sector of KLNP

	2018		2030		2040		2050	
LULC	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	216,165.3	47.7	216319.07	47.7	218910.01	48.3	221500.94	48.8
Savannah	199,390	44	207552.68	45.8	203035.65	44.8	198518.61	43.8
Swamp/water body	5,940.36	1.3	8958.41	2.0	8937.77	2.0	8917.14	2.0
Built-up/bare land	32,088.69	7.1	20754.17	4.6	22700.91	5.0	24647.66	5.4

Table 9. Futue projeciton for the Zugurma sector of KLNP

	2018		2030		2040		2050	
LULC	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	72655.83	53.2	83290.50	61.0	96985.84	64.1	91605.33	67.1
Swamp	16361.64	12.0	-3281.18	-2.4	-19845.54	-14.5	-36409.90	-26.7
Bare land	47494.08	34.8	56502.22	42.0	127306.84	50.5	81316.12	59.6

LULC: land-use/land-cover; KLNP: Kainji Lake National Park

the field. The commission error reflects the points, which were included in the category, while they really do not belong to that category. The overall Kappa coefficients for the Borgu and Zugurma sectors were 0.824 and 0.895, respectively.

Land-use/Land-cover projection

Table 8 presents future projections for the Borgu sector in 2050. The results revealed that forest, savannah, swamp/water body, and built-up area/bare land will be 48.8%, 43.8%, 2.0%, and 5.4% in year 2050, respectively. The results showed that LULC of the Zugurma sector will be 67.1%, −26.7%, and 59.6% for forest, swamp, and bare land in year 2050 if the current trends persist (Table 9).

Normalized Difference Vegetation Index (NDVI)

Table 10 presents the NDVI results for the Borgu and Zugurma sectors of KLNP. The maximum NDVI (0.45) was found in 2018, which indicates increase in vegetation and corresponds to the increase in forest and savannah in that year. Also, the lowest NDVI value (−0.44) was found in 2002, which indicates the presence of swamp/water body. This value is close to the lowest figure of −1 NDVI (for no vegetation). The NDVI value of 0–1 indicates the terrestrial vegetation with increase in their maximum proportion. Figures 6 and 7 show the NDVIs values between 1988 and 2018 for the Borgu and Zugurma sectors of the park. For the Zugurma sector, the highest value of NDVI (0.53) was in 2013, which indicates the increase in vegetation, and corresponds to the increase in forest in that year. The lowest NDVI

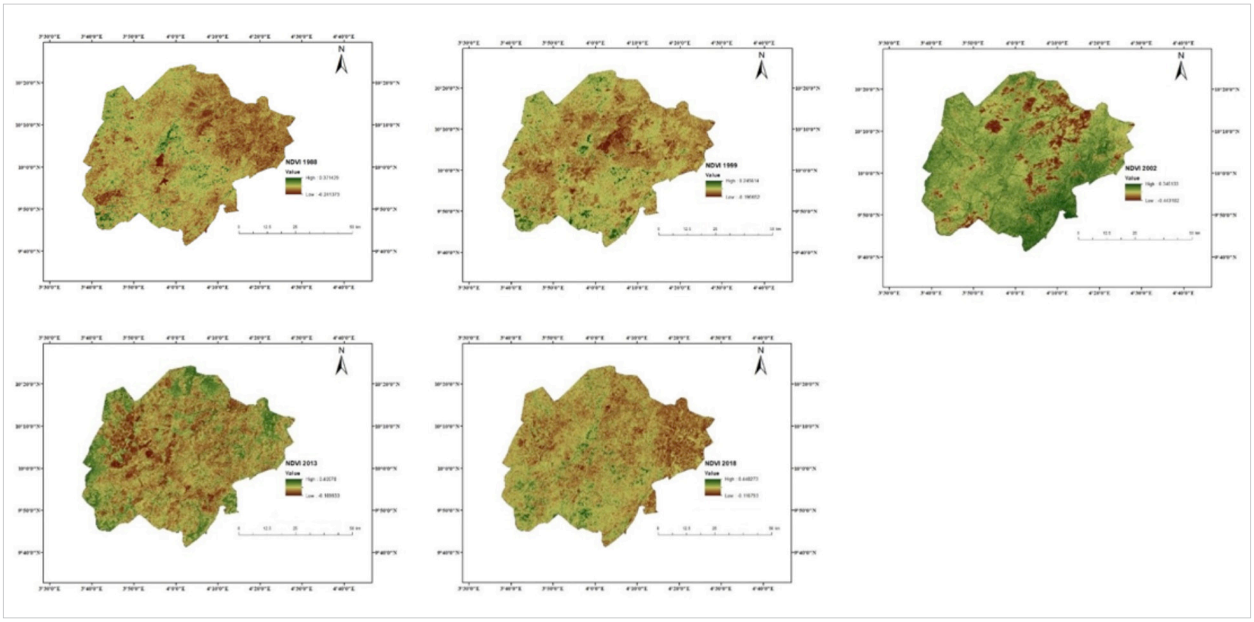

Figure 6. NDVI of the Borgu sector of KLNP

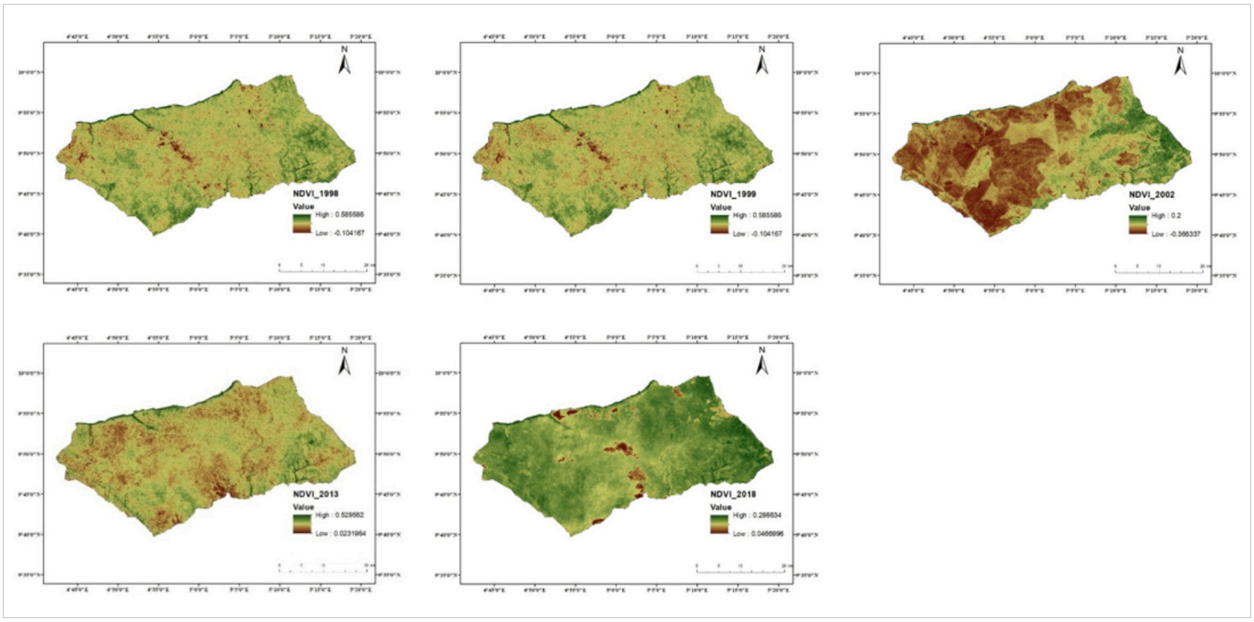

Figure 7. NDVI of the Zugurma sector of KLNP

value (−0.37) was in 2002. The swamp in this year decreased in area in great proportion.

DISCUSSION

The results showed that forest extents in Kainji Lake increased considerably between 1988 and 2018. This considerable increase in forests may be due to intensive patrol and other effective monitoring strategies adopted in the areas by the park management, especially foot patrols to prevent encroachments and illegal exploitations. As noted by Bi et al. (2019), foot patrols are the most straightforward means among other conservation mechanisms. This increase in forest cover recorded over the period did not, however, reflect the projections by Mohammed et al. (2013), who forecasted depletions in vegetal covers for KLNP in five years. Their projections may have been informed by the prevailing corruption and the scenarios at the time, which did not give any indication that things can better be managed without failure. In Nigeria, it is believed that public properties are to be exploited, used, and destroyed, while privately owned properties survive several seasons of hardships. For instance, most of the state-owned forest reserves now exist on paper with no

Table 10. NDVI results for the two sectors of KLNP

	NDVI			
	Borgu Sector		Zugurma Sector	
Year	Minimum	Maximum	Minimum	Maximum
1988	-0.24	0.37	-0.12	0.37
1999	-0.20	0.25	-0.10	0.59
2002	-0.44	0.35	-0.37	0.20
2013	-0.19	0.41	-0.02	0.53
2018	-0.12	0.45	-0.05	0.29

NDVI: normalized difference vegetation index

trees on site, rather they are currently replaced by plantain, cocoa, and oil palm plantation in most states of Southern Nigeria, while such areas have become grazing ground in the savannah ecosystems of the northern part.

The decline in savannah, which was derived through savannization processes, may have resulted from the suppression of disturbances within the savannah ecosystem, which have now grown to the original status as forests, and have become parts of forest covers. This corroborates the findings of Reis et al. (2015), who noted serious improvement to the savannah ecosystems due to the suppression in wildfire and related forms of disturbances. The management had also stepped actions up against uncontrolled bush fire, which drastically reduced losses in forest extent. Within the period, overgrazing, however, negatively impacted the savannah ecosystem, as there were compactions of soils that may have prevented easy growth of grasses. This is in line with Adetoro et al. (2011), who noted that nomadic cattle farmers and poachers were the parks' major enemies for consistent depletion of savannah ecosystems through overgrazing. The findings in this study are also consistent with the observation of Akhmadov et al. (2006), who reported that the negative effects of overgrazing include loss of important biodiversity and, subsequently, soil erosion.

The bare land of the park has increased significantly in the last 30 years as a negative consequence of losses in savannah. Signs of soil erosion were noticed in some parts due to use-pressure or severe damages from anthropogenic activities, especially overgrazing. This corroborates the report by Boakye et al. (2008), who observed that vegetation changes are often the result of anthropogenic pressure, which comes majorly in the form of farming that fragments landscape and denudes the forested areas of the needed covers. The effect of anthropogenic pressure on forest and savannah resources are well noted by Osborne and Shapiro-Garza (2018), who observed that fragmentation through farming, as well as overgrazing, is sufficient enough to completely degrade a diverse ecosystem through persistent utilization, causing soil compaction among several other dangerous precursors to dire consequences. The researchers believe that if the pattern of grazing in the area is unchecked, it will increase the susceptibility of the savannah ecosystem to gully erosion and consistent destruction of the less fire-resistant species in the drier part of the year. It is almost certain that if wildfire and grazing are controlled in the ecosystem, there are better chances that the rare species in the area will thrive and propagate themselves beyond the constricted extent that they presently occupy.

CONCLUSION

The main LULC types identified in the park were forest, savannah, swamp/water body, built-up area, and bare land. The study has shown that the areas had changed significantly both in composition and configuration over the past 30 years. The negative impact on the park can be attributed mainly to anthropogenic factors, which are either internal or external. Nevertheless, there were improvements in forest extents in the park, except in some parts of the Borgu sector, where some encroachments were noticed to affect the savannah ecosystem. It can be said that the park still stands commendable in terms of management ability to maintain the integrity of the forest, considering the happenings in most protected areas in Nigeria where national parks and forest reserves were not spared of heavy illegal exploitations. Nevertheless, the forest extent of the KLNP, though increased at the core, is being tremendously invaded at the buffers. The rate at which built-up/bare land increased is alarming and needs urgent attention.

The management is thus recommended to enforce laws protecting the park and take proper measures on whoever violates the laws. The government is also advised to support the management of the national parks financially and provide them with basic amenities and incentives. Considering the fact that part of KLNP has been encroached, proper monitoring and appropriate management practices must be carried out by the management of the park to tackle illegal operations within and around the park. The management of the parks is recommended to employ committed professionals, train their staff properly, utilize the funds allocated, and establish proper approaches to curb intruders. Finally, there is a need to create special park–community partnerships for joint management.

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