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Analysing the rate of land use and land-cover changes in Gambari Forest Reserve, Nigeria

Analiziranje sprememb rabe in pokrovnosti tal na območju gozdnega rezervata Gambari v Nigeriji

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Abstract in English

This research work discusses the phenomenon of land use and land cover, which has undergone constant changes over the past few decades due to major variations in the environment caused by anthropogenic and natural factors. This study is supported by a long time series of land use and land-cover satellite data of the Gambari Forest Reserve boundary map for 1984, 2004, and 2020. A maximum likelihood classification scheme was employed to classify the satellite imageries using ArcGIS 10.1 software to derive the spatial patterns and temporal variation of the land-use and land-cover change (LULC) classes: dense forest (DF), light forest (LF) and non-forest (NF). Data on deforestation of the study area showed that the area of DF increased from 31.7 km^2 (23.4%) to 72.8 km^2 (54.4%) within a 36-year time series, with a percentage change of 31.0%. The area of LF decreased from 79.2 km^2 (65.4%) to 51.2 km^2 (41.5%), with a percentage change of −23.9%, and that of NF decreased from 14.7 km^2 (11.2%) to 2.6 km^2 (4.1%), with a percentage change of −7.1%. This indicates that it would be reasonable to anticipate an increase in deforestation in the future.

Keywords: geospatial technique, LULC, change detection, deforestation, mapping

Abstract in Povzetek

Raziskava se osredotoča na pojave rabe in pokrovnosti tal, ki se je v zadnjih nekaj desetletjih stalno spreminjala zaradi večjih okoljskih sprememb, povzročenih z antropogenimi in naravnimi dejavniki. Raziskava je osnovana na dolgoletnih satelitskih podatkih iz leta 1984, 2004 in 2020 o rabi in pokrovnosti tal na območju gozdnega rezervata Gambari. Za razdelitev satelitskih posnetkov v razrede rabe in pokrovnosti tal – LULC (gosti gozd, redek gozd, negozd) je bila uporabljena klasifikacija maksimalne verjetnosti s pomočjo programske opreme ArcGIS 10.1. Rezultati posnetkov na raziskovanem območju v obdobju 36 let so pokazali, da se je gosti gozd povečal iz 31.7 km^2 (23.4%) na 72.8 km^2 (54.4%) s spremembo 31.0%. Redki gozd se je zmanjšal iz 79.2 km^2 (65.4%) na 51.2 km^2 (41.5%) s spremembo −23.9%. Negozd se je zmanjšal iz 14.7 km^2 (11.2%) na 2.6 km^2 (4.1%) s spremembo −7.1%. To dokazuje da je verjetnost za krčenje gozdov v prihodnosti visoka.

Ključne besede: geoprostorske tehnike, LULC, zaznavanje sprememb, krčenje gozdov, kartiranje

Introduction

As an important part of worldwide sustainable development, land -use and land-cover change (LULC) and deforestation in Nigeria have attracted great attention. LULC has been considered as an important research topic for global environmental change and sustainable development [1]. Land cover refers to the biophysical attributes of the Earth's surface, while land use refers to the human purpose or intent applied to these attributes [1]. Deforestation is an important process of LULC [2], and it is also a factor that provides feedback for the drivers of land-use change [3]. However, examining the process and trends of LULC via quantitative analysis is a prerequisite for gaining a deeper understanding of LULC and help policy makers set improvement targets in specific areas and adopt appropriate practices while also keeping in line with other fields of sustainability [2,4, 5,6]. The acceleration of urbanisation and industrialisation has led to serious ecological destruction, such as a decrease in ecological carrying capacity, vast coverage and intensity of water and soil loss, desertification, soil erosion, vegetation degradation, biodiversity losses, invasion of alien species, environmental pollution, natural hazards, geological hazards, and forest hazards [7].

LULC is the conversion of different land-use types and is the result of complex interactions between humans and the physical environment [8]. Therefore, accurate and up-to-date land-cover change information is necessary for understanding and assessing LULC changes. Remote sensing (RS) and geographic information systems (GIS) are essential tools that are used to obtain accurate and timely spatial data of land use and land cover, as well as to analyse the changes in a study area [9,10]. RS images can effectively record land-use situations and provide an excellent source of data from which updated LULC information and changes can be extracted, analysed, and simulated efficiently through certain means [11,12]. Therefore, RS is widely used in the detection and monitoring of land use at different scales [13–15]. GIS provides a flexible environment for collecting, storing, displaying, and analysing digital data necessary for change detection [9,16,17]. The present study aims to assess the changes that occurred in Gambari Forest Reserve, Nigeria, within the period of the 32 years from 1984 to 2016. The objective of this study is to examine the LULC changes in the study area between 1984 and 2016.

Study Area

Gambari Forest Reserve is located between latitude 7°10′51″N and longitude 3°52′34″E. Figure 1 shows the natural forest reserve plot at 6.5 km from the Cocoa Research Institute of Nigeria (CRIN), on the Idi-Ayunre-Ijebu-Ode Road, Oyo State.

Gambari Forest Reserve has one of the most complex vegetation types with the highest number of plant species per unit area. This vegetation is dominated by woody trees to the exclusion of grasses; grasses are shade-intolerant and cease to grow under such tall vegetation, which has a heavy total canopy [19]. The topography of the study area is generally undulating with the presence of lianas, climbers, twiners, stranglers, scramblers, and epiphytes, which makes movement almost impossible. The valuable indigenous species are *Terminalia spp* K. Shum (Afara), *Triplochiton scleroxylon* K. Shum (Arere, Obeche), *Irvingia garbonensis* (Oro) and *Treculia africana*, among others. Exotic species such as *Gmelina arborea* (Gmelina) and *Tectona grandis* (teak) are found in the study area. The study area lies at an altitude between 90 m and 147 m above sea level [20]. The study area is bounded by two rivers (rivers Ona and Awon).

The major dry season occurs between December and March. Temperatures are high throughout the year, with a mean annual value of about 27°C and an annual range of 30°C [18,21].

Materials and Methods

In this study, the sources of data collected are the Landsat satellite RS images for 1984, 2004, and 2020 with a resolution of 30 m. This study will also show how the data are collected and the methods of analysis used.

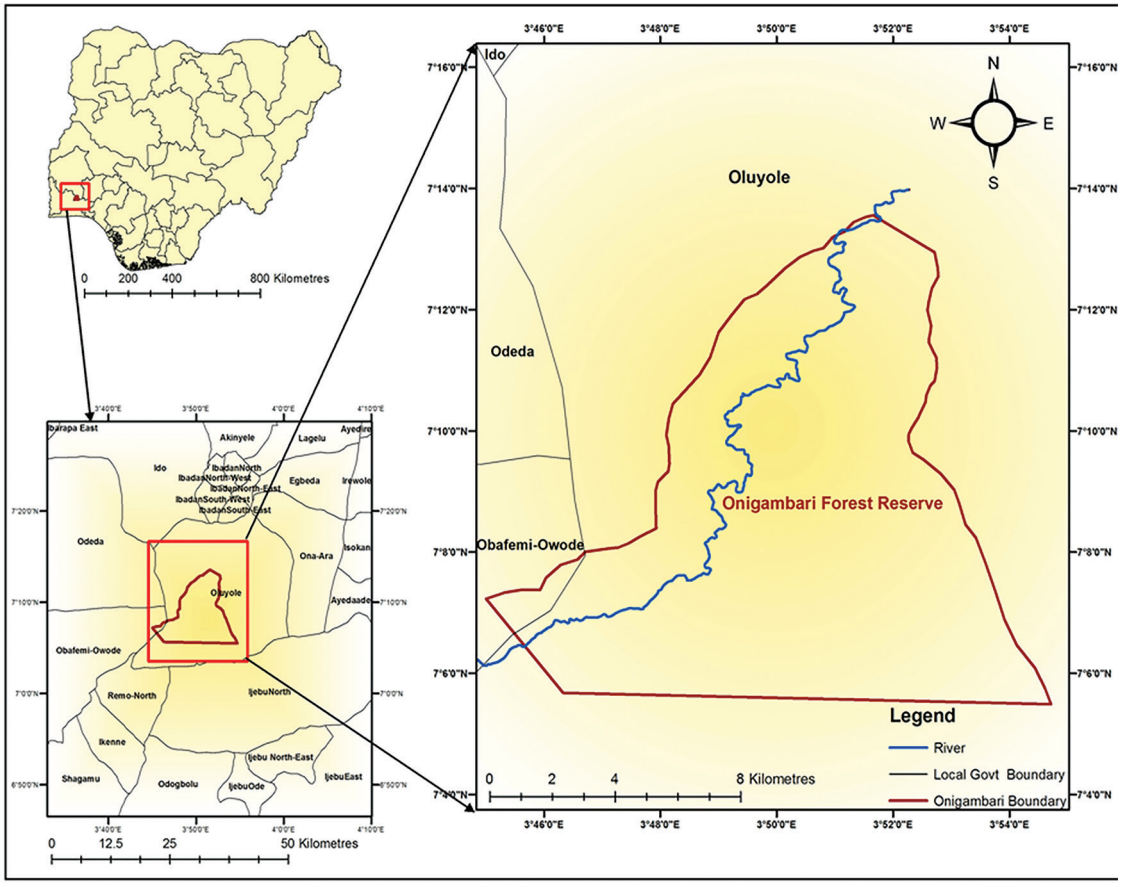


Figure 1: *Map of the study area (Gambari Forest Reserve).*
Source: Adapted from the study by Adedeji et al. [18].

Table 1: *Data set acquired and its sources*

S/N	Data Sets	Resolution/ Scale	Year of Production	Date of Acquisition	Source
1	Landsat 5	30 M	1984	18/12/1984	USGS
2	Landsat 7	30 M	2004	06/02/2004	USGS
3	Landsat 8 OLI	30 M	2020	15/02/2020	USGS
4	Gambari Forest Reserve boundary map	1:50,000	2015	23/11/2018	Adedeji et al. [18]

Collection of Satellite Data

Landsat images of the study area for three different years with the space span intervals of 20 and 16 years (for 1984, Landsat 5; for 2004, Landsat 7; and for 2020, Landsat 8 OLI) are used for this study, and the orthorectified images for 1984, 2004, and 2020 were downloaded from the United States Geological Survey (USGS), as shown below (Table 1). The software package ArcGIS 10.1 (2013) version was used to visually and digitally process and interpret the Landsat satellite images.

RS Image Pre-processing and Accuracy Verification

The RS image data of 1984, 2004, and 2020 were radially calibrated and atmospherically corrected. The relative geometric corrections of the three images were conducted to remove geometric distortion caused by the sensor or

Table 2: *LULC classification scheme*

S/N	Code	LULC Classification Category	Definition of Terms
1	DF	Dense forest	Area with dense intensity of forest with thick closed canopy
2	LF	Light forest	Area with low intensity of forest with light closed canopy
3	NF	Non-forest	Area covered with shrubs and grasses with no canopy

GPS is used for navigation, location of sample plots and recording of coordinate points. Ground distance is measured by surveyors using a tape.

the Earth's rotation. Considering the study area and the goal of this study, the land-use types are divided into three categories: dense forest (DF), light forest (LF) and non-forest (NF) (as shown in Table 2). With the help of the maximum likelihood method classifier, classification was carried out on these three images.

Results and Discussion

The data collected and analysed for this study are satellite images that are classified and presented in the form of maps and statistical tables and represent the analysis of the various research data used in this study.

Trend in the LULC distribution of the Gambari Forest Reserve in 1984

The Gambari Forest Reserve area in 1984 recorded more LF than NF. DF covered an area of 31.7 km^2 (23.4%), while LF covered 79.2 km^2 (65.4%), and NF covered 14.7 km^2 (11.2%), as shown below (Table 3). The LULC distribution for the study area in 1984, as derived from the map, showed that LF occupied the largest class, with 65.4% of the total classes, which implies that the forest reserve was still intact or minimally tampered with at the time under study. The Gambari Forest Reserve is a reserved area allocated to the Forestry Research Institute of Nigeria for experimental purposes, which restricted the Gambari Forest from being encroached (Figure 2).

Trend in the LULC Distribution of the Gambari Forest Reserve in 2004

The static LULC change detection for the Gambari Forest Reserve area in 2004, as derived from the imagery, indicates that there

Table 3: *LULC distribution of Gambari Forest in 1984 showing area (km^2) of the LULC classes*

Classes	Area (%)	Area (km^2)
Non-forest	11.20	14.70
Light forest	65.40	79.20
Dense forest	23.40	31.70
TOTAL	100.00	125.60

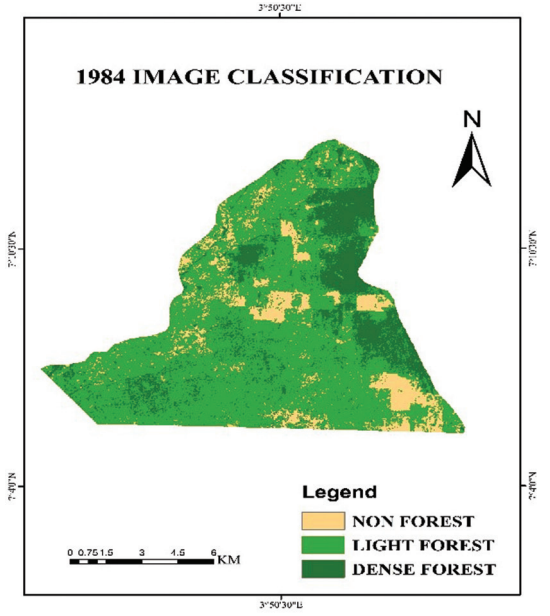


Figure 2: *Land-cover classification of Gambari Forest in 1984.*

is a significant increase in DF and NF areas, while the area of LF reduced over the 20 years (1984–2004). DF covered an area of 36.6 km^2 (31.2%), while LF covered 51.2 km^2 (43.7%), and NF covered 37.8 km^2 (25.1%), as shown in Table 4.

The area of DF increased from 23.4% in 1984 to 31.2% in 2004, which resulted from re-afforestation (amounts to 7.8%), while the area of LF decreased from 65.4% in 1984 to 43.7% in 2004, which implied a percentage size loss of –21.7% due to anthropogenic activities

Table 4: *LULC distribution of Gambari Forest in 2004 showing area (km²) of the LULC classes*

Classes	Area (%)	Area (km²)
Non-forest	25.10	37.80
Light forest	43.70	51.20
Dense forest	31.20	36.60
TOTAL	100.00	125.60

Table 5: *LULC distribution of Gambari Forest in 2020 showing area (km²) of the LULC classes*

Classes	Area (%)	Area (km²)
Non-forest	4.10	2.60
Dense forest	54.40	72.80
Light forest	41.50	51.20
TOTAL	100.00	125.60

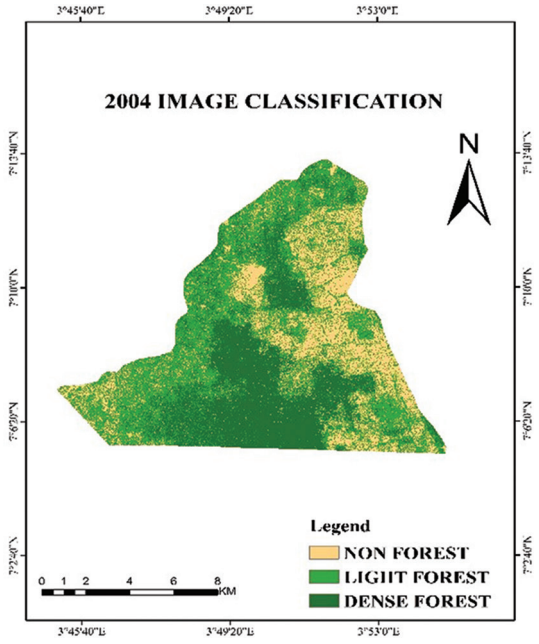


Figure 3: *Land-cover classification of Gambari Forest in 2004.*

such as selective logging and legal felling, which led to the reduction of the volume of trees left in the area.

For the NF area, there was also a geometric increase from 11.2% in 1984 to 25.1% in 2004, which implies that a percentage size of 13.9% could be a result of the above stated anthropogenic activities such as major felling of trees without replanting (Figure 3).

Trend in the LULC Distribution of the Gambari Forest Reserve in 2020

The Gambari Forest Reserve area in 2020 recorded more DF than LF. DF covered an area of 72.8 km² (54.4%), while LF covered 51.2 km² (41.5%), and NF covered 2.6 km² (4.1%).

An assessment of the classification data in 2020 imagery reveals that there has been a transition in the status of the forest reserve in the span of 36 years, which indicates that the DF area increased from 23.4% in 1984 to 54.4% in 2020, which implies a percentage change of 31.0%, due to favourable environmental factors such as climatic weather, decomposition, and conservation.

For the LF area, it was established that there was a decrease from 41.5% in 2020 to 65.4% in 1984, with a percentage variation of −23.9%, which is a decrease from what was classified in 1984. This could be as a result of poor management of the experimental plots, illegal fellers, and climate variability.

Furthermore, the NF status stands at 4.1% in 2020, which is also a decrease compared to 11.2% in 1984, with a percentage variation of −7.1% due to increase in sizes of both the DF and LF, respectively, which increased their LU over time.

The LULC distribution for the study area in 2020, as derived from the map, shows that DF occupied the largest class, with 54.4% of the total classes due to anthropogenic activities that occurred to the other classes (Table 5, Figure 4).

Changes in Land Cover of Gambari Forest Reserve from 1984 to 2004

The changes outlined in Table 6 occurred over the past 20 years in the Gambari Forest Reserve area from 1984 to 2004, where changes of the land covers are presented. LF declined in percentage size drastically by −21.7%, NF increased drastically by 13.9%, while DF also increased by 7.8%.

Changes in Land Cover of Gambari Forest Reserve from 2004 to 2020

The changes mentioned below occurred over the past 16 years in the study area during

2004–2020. As shown in Table 7, representing 2004 to 2020 satellite images, changes of the land cover during this period show that DF changed by 23.20%, LF changed by – 2.20%, and NF changed by – 21.00%.

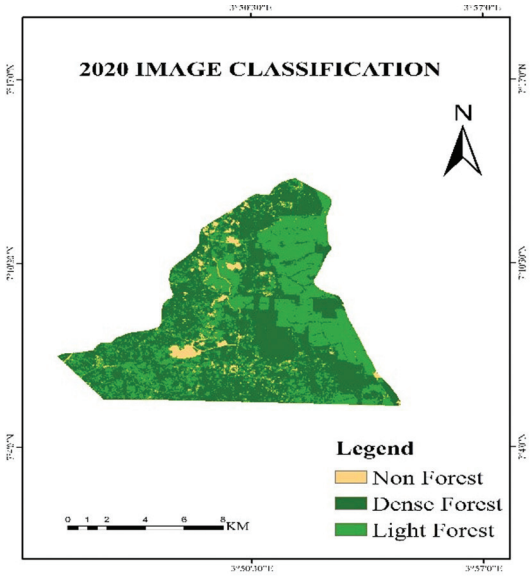


Figure 4: *Land-cover classification of Gambari Forest in 2020.*

Changes in Land Cover of Gambari Forest Reserve from 1984 to 2020

The overall trend of thr e36-year change that occurred between 1984 and 2020—as shown in Table 8—indicates that the DF area positively increased in percentage change by 31.00%, from 31.7 km² (23.4%) to 72.8 km² (54.4%), which could be as a result of environmental factors such as climatic weather, decomposition, and conservation. The LF area decreased in percentage change by –23.9% from 79.2 km² (65.4%) to 51.2 km² (41.5%). And finally, the NF area also decreased in percentage change by –7.1% from 14.7 km² (11.2%) to 2.6 km² (4.1%). These above declines in both the LF and NF areas were attributed to anthropogenic activities such as degradation, poor management of the experimental plots, and legal fellers.

Table 6: *Changes in land cover of Gambari Forest Reserve from 1984 to 2004*

Classes	Area in 1984 (km²)	Area in 1984 (%)	Area in 2004 (km²)	Area in 2004 (%)	Percentage Change from 1984–2004
NF	14.70	11.20	37.80	25.10	13.90
LF	79.20	65.40	51.20	43.70	–21.70
DF	31.70	23.40	36.60	31.20	7.80

Table 7: *Changes in land cover of Gambari Forest Reserve from 2004 to 2020*

Classes	Area in 2004 (km²)	Area in 2004 (%)	Area in 2020 (km²)	Area in 2020 (%)	Percentage Change from 2004–2020
NF	37.80	25.1	2.60	4.10	–21.00
LF	51.20	43.7	51.20	41.50	–2.20
DF	36.60	31.20	72.80	54.40	23.20

Table 8: *Changes in land cover of Gambari Forest Reserve from 1984 to 2020*

Classes	Area in 1984 (km²)	Area in 1984 (%)	Area in 2020 (km²)	Area in 2020 (%)	Percentage Change from 1984–2020
NF	14.70	11.20	2.60	4.10	–7.10
LF	79.20	65.40	51.20	41.50	–23.90
DF	31.70	23.40	72.80	54.40	31.00

Conclusions

It is very important to study LULC changes due to natural causes such as climate variability or climate change, resulting in floods, drought, or anthropogenic causes, such as industrialisation and urbanisation. LULC analysis can provide important information for global environment change and sustainable development studies, which can also be useful for decision-makers. A long time series (1984, 2004, and 2020) of RS images with a resolution of 30 m were used in the present research. Findings show that the Gambari Forest Reserve area in 1984 had a total DF cover of 31.7 km^2, while LF covered 79.2 km^2, and NF covered 14.7 km^2, representing 23.4%, 65.4%, and 11.2%, respectively, of the land area. In sum, the LULC classification using Landsat imagery of 1984 reveals that LF occupied the largest area size both in percentage and kilometre due to the fact that the forest was still intact, devoid of deforestation.

In 2004, in the Gambari Forest Reserve, DF covered an area of 36.6 km^2, while LF covered 51.2 km^2, and NF covered 37.8 km^2, representing 31.2%, 43.7%, and 25.1%, respectively. In 2004, DF area increased by 7.8%. LF showed a reduction in both the percentage and area size in 2004 compared to the previous year studied (1984) due to the effects of deforestation. A summary of the findings in 2004 shows that LF still has the highest area and percentage cover.

Finally, in 2020, DF covered an area of 72.8 km^2, while LF covered 51.2 km^2 and NF covered 2.6 km^2, representing 54.4%, 41.5%, and 4.1%, respectively. To summarise, DF had the highest percentage and area cover size in 2020.

Many more reasons (also explained in the literature review) show clearly how LULC study is important for policy making and making decisions to prevent environmental degradation. There are many techniques that can be used in monitoring and assessment of LULC, such as RS and GIS.

Therefore, it is recommended that the concept of using satellite images of land cover change demonstrated the extent and status of land cover. Therefore, this study recommends that more efforts need to be taken seriously to halt deforestation and any other human activities that can have negative impacts on forests. In the near future, more studies should be conducted to complement the deployment of an integrated RS–GIS approach towards precision carbon management.

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