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RESEARCH ARTICLE

GEOSPATIAL ANALYSIS OF HABITAT FRAGMENTATION IN THE SOUTHERN GUINEA SAVANNA REGION OF KOGI STATE, NIGERIA

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ABSTRACT

The Guinea Savanna region of Nigeria is a biodiverse transition zone between Nigeria's tropical rainforests and the sahelian savannas. This ecological zone plays a critical role in supporting ecological balance and human livelihoods. The increase in population, agricultural expansion and other anthropogenic interferences has caused unprecedented levels of land cover changes and habitat fragmentation and consequent habitat degradation. The objective of this study focused on land use/land cover dynamics and the pattern of habitat fragmentation in the southern guinea savanna region of Kogi State from 1986 to 2023. Fragmentation assessment was performed based on the geospatial analysis of Land use and Land cover (LULC) analysis using Multispectral Landsat aerial imageries of 1986, 2001 and 2023 as datasets. The Spatial Metric was performed with the use of Landscape Fragmentation Tool (LFT) software. The results revealed that grassland/agricultural land and settlement constituted most extensive LULC in the study area and increased by 736.9% and 182.3% respectively between 1986 and 2023. On the other hand, forest cover reduced drastically by 64.9% between 1986 and 2023, indicating high rate of deforestation and habitat degradation. Fragmentation analysis showed increase in the number of patches, indicating that the vegetation cover has undergone significant fragmentation over the years. Therefore, this study recommends an urgent need for vegetation conservation measures and sustainable land-use planning which includes control of deforestation, promoting reforestation efforts, and improving landscape connectivity by establishing ecological corridors.

Keywords: Habitat fragmentation, biodiversity, savanna, GIS, landscape fragmentation tool (LFT), LULC.

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INTRODUCTION

Habitat fragmentation, the disintegration of contiguous ecosystems into smaller, isolated patches- is a defining environmental crisis of the Anthropocene. Globally, over 70 percent of earth's forests and grasslands are now within 1 km of human-modified edges, a phenomenon driven by agricultural expansion, urbanization and infrastructure development (Haddad et al., 2015; IPBES, 2019). Fragmentation leads to deprivation of habitat, biodiversity, ecosystem functions including detrimental impact on continuous patches and quality of forest (Mehta et al., 2022; Sharma et al., 2022). The three main consequences of habitat fragmentation are reduction in sizes (areas) of remaining patches, increased isolation and loss in connectivity, and increased edge effects (Finn & Cambell, 2019). Furthermore, the ecological consequences are profound. Fragmented habitats exhibit reduced genetic diversity, increased invasive species colonization, and disrupt ecosystem services such as pollination and carbon sequestration (Tilman et al., 2017).

In the Amazon rainforests, fragmentation has reduced biodiversity by 40% in edge habitats, disproportionately affecting large mammals and specialist bird species (barlow et al., 2016). Similarly, North American road networks and suburban sprawl have fragmented 85% of the Great Plains' native grasslands, threatening keystone species like prairie dog and disrupting migratory corridors (Fahrig, 2017; Theobald et al., 2020). The Brazilian cerrado also experienced habitat patches smaller than 100 hectares losing 80% of their native bee populations within a decade, directly compromising crop yields in adjacent farmlands (Mello et al., 2020)

In the Brazilian Cerrado, a biodiversity hotspot, has experienced significant habitat fragmentation, leading to a drastic decline in native bee populations, particularly in patches smaller than 100 hectares. This decline has severe implications for agricultural productivity, as bees are crucial pollinators for many crops. The loss of bee populations in these fragmented habitats directly affects crop yields in adjacent farmlands, as bees contribute to the quality and quantity of fruits and seeds produced(Oliveira, 2015; Caetano et al., 2024)..

Therefore, fragmentation disrupts ecosystem connectivity, isolating wildlife populations and diminishing landscape resilience to climate shocks such as floods and droughts (Jongman, 2019; Li et al., 2023). For example, the loss of tree cover in fragmented zones has reduced pollination services and soil fertility, directly threatening smallholder farmers' livelihoods and food security, a contradiction to SDG 2 (Zero Hunger) and SDG 15 (Life on land) which emphasizes halting biodiversity loss and restoring degraded ecosystems (Unites Nations, 2015; Ibrahim et al., 2024). African savanna ecosystems cover about 54 percent of the continent's landmass and are experiencing fragmentation rates comparable to tropical rainforests (Benitez, 2024; Osborne et al., 2018). The Nigerian guinea savanna region is a biodiverse transitional zone between Nigeria's tropical rainforests and the sahelian savannas.

The NGS plays a critical role in supporting ecological balance and human livelihoods. This region is characterized by a mosaic of grasslands, woodlands, and riparian forests that sustain endemic species such as economically vital shea trees (Vitellaria paradoxa), as well as supports over 60% of Nigeria's agricultural output, serving as backbone of food security for millions (FAO, 2020). However, the Nigerian Guinea Savanna is facing unprecedented levels of changes in land cover and habitat fragmentation due to a combination of natural and anthropogenic factors (Badhe et al., 2024).

Couvilion (2017) reported that agricultural expansion, driven by need to feed a growing population has resulted in the conversion of large tracts of natural vegetation into farmlands. Similarly, logging, urbanization and infrastructural development, such as roads construction and mining activities, have further fragmented the landscape, creating barriers to wildlife movement and reducing habitat connectivity (Laurence, 2014). These changes have significant implications for biodiversity conservation, as fragmented habitats are less able to support viable populations of many species. The problem is compounded by the lack of comprehensive data on the extent and pattern of habitat fragmentation in the region.

Therefore the main objective of this study to fill this gap by analyzing LULC dynamics and fragmentation pattern in the southern guinea savanna, Kogi State, using Landsat imagery (1986, 2001, and 2023) and spatial metrics generated via the Landscape Fragmentation Tool (LFT). By quantifying changes in vegetation, agricultural land, settlements and forest cover and evaluating fragmentation trends, this research offers vital insights for land use planning, conservation strategies, and sustainable management in a region critical to Nigeria's ecological integrity.

MATERIALS AND METHODS

The Study Area

The study area is located between latitude 7°38'0N and 8°34'0N and longitude 5°20'0E and 6°28'0E (figure1). The study area covers a total area of 2, 761.43km^2. The climate of this western African locality is governed by the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ), influencing both rainfall and air mass patterns (Tropical maritime - mT and Tropical continental - cT). The region has two distinct seasons: a rainy season and a dry season, with mean annual rainfall of approximately 1440mm occurring over roughly 240 days, characterized by double maxima. Rains commence in March, peak from June to September, and cease by late November.

The annual temperatures range from 18°C to 35°C, with the warmest period preceding the rains and cooler temperatures during the peak rainy season. The dry season exhibits the most significant diurnal temperature fluctuation, with afternoons reaching high 30s°C and nights cooling to the mid-20s°C. The study area is located in the Southern Guinea savanna ecological zone, featuring woodland interspersed with tropical rainforest outliers. Dominant tree species include *Parkia biglobosa* and *Daniella oliveria*, with common shrubs like

Alchornea cordifolia. Vegetation cycles are influenced by dry season fires and rainy season growth. Human activities such as logging, agriculture, mining, (Okoroafor, Umo & Ukwe, 2024) and wildfires have caused significant damage, leading to diverse plant communities and ecological consequences including biodiversity and habitat loss. The region's dominant land use is agriculture, which has resulted in ecosystem disruption, notably the conversion of canopy ecosystems to grasslands, leading to reduced forest and savannah stability. Intensified Fadama agriculture, severe erosion, desiccation, and desertification are significant issues. Agricultural practices include rain-fed farming on upland soils, facing rainfall and pest challenges, and more flexible irrigated farming.

The dominant staple crops include yam, cocoyam, cassava, maize, tree crops, and vegetables, with the area also being a trade center for coffee, cocoa, shea nuts, cotton, and woven cloth. Livestock grazing is a key source of revenue and nutrition. Commercial quarrying and mining are widespread, particularly for mineral resources. Forest land use involves plantations of Gmelina, Teak, and Eucalyptus, with Non-Timber Forest Products (NTFPs) important for nutrition and herbal remedies. The traditional land tenure system, predating the 1978 Land Use Act, distinguishes between communal and individual land rights. Access to cultivable land is increasingly unequal, and conflicts between pastoralists and farmers are prevalent due to demographic pressures and land use issues, negatively impacting crop yields and herd sizes. Unsustainable forest use, exacerbated by inadequate protection and lack of collective responsibility, drives deforestation and degradation.

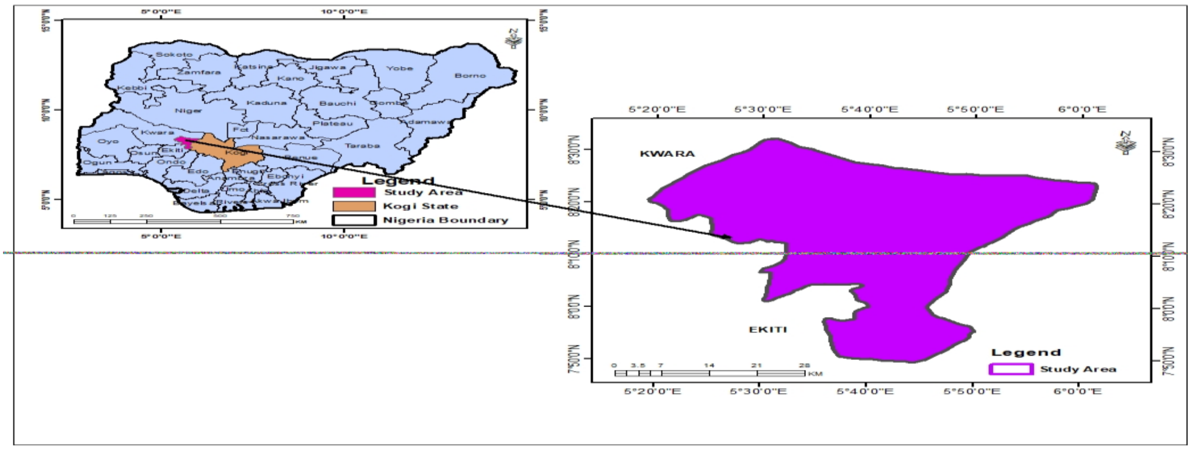

Figure 1: Map of the study area

Methods of Data Collection

This study integrated multi-temporal satellite imagery with the Landscape Fragmentation Tool (LFT 2.0), a GIS-based extension, to classify, quantify, and interpret fragmentation metrics over a 37-year period (1986–2023). The temporal scope encompasses three epochs which are 1986, 2001, and 2023, providing a temporal framework for detecting long term fragmentation dynamics and identifying periods of accelerated change. The remote sensing data were Landsat TM, Landsat EMT+ and Landsat OLI imageries obtained from the

United States Geological Survey (USGS) EarthExplorer platform, supplemented by QuickBird high-resolution data from Google Earth (Table 3.1). The utilization of these data sources significantly contributed to the visual interpretation of the images thereby ensuring accurate identification and categorization of landuse. Landsat TM, EMT and OLI/TIRS sensors all provide a spatial resoulution of 30m, which is quite sufficient for this analysis. All images were acquired during the dry season (October–January) to reduce cloud interference and ensure seasonal comparability (Batar et al., 2017).

Table 1: Types and sources of satellite image acquired

SN	Data Type	Acquisition Date	Path/ Row	Format	Spectral Resolution	Spatial Resolution (m)	Source
1	Landsat TM	31-Jan-1986	190/54	Digital	4 bands	30	USGS EarthExplorer
2	Landsat ETM+	31-Oct-2001	190/54	Digital	5 bands	30	USGS EarthExplorer
3	Landsat OLI/TIRS	31-Dec-2023	190/54	Digital	11 bands	30	USGS EarthExplorer
4	QuickBird	31-Jan-2024	Nil	Digital	4 bands	0.5	Google Earth

In this study, Arc GIS 10.3 for image preprocessing task. Arc GIS is a tool used for image processing and extracting vital information (Hussein et al., 2024). Image preprocessing was done to achieve geometric and radiometric consistency across the temporal datasets. The workflow included geometric correction, radiometric calibration, atmospheric correction and cloud masking. Satellite image classification is a key process in change detection frameworks (Hussein et al., 2024). These frameworks use time-based datasets to qualitatively evaluate the temporal evolution of different phenomena and measure the detected changes (Yu et al., 2023). Change detection involves identifying differences in the state of an object or phenomenon by observing it at different points in time (Alawamey et al., 2020). Image classification was done using the supervised classification approach using the Maximum Likelihood Algorithm (MLA). The LULC was categorized into forest, settlement, grassland and water bodies.

The habitat fragmentation assessment utilized the model created by Vogt et al. (2007), which defined landscape fragmentation through the analysis of image morphology. In view of this, this research was conducted using the Landscape Fragmentation Tool (LFTv2.0) from the University of Connecticut Center for Land-use Education and Research. This tool, functioning within the ArcGIS environment needed raster data, most especially land cover data categorized into forest and non-forest classes. This classification was done using ArcGis Spatial analyser tool, and only the forest class was utilized for LFT fragmentation analysis. The forest class was categorized into four main classes (Table 2), which are core, perforated edge and patch. The core was further subdivided into 3 smaller classes based on their size.

They are small core (less than 250 acres), medium core (250-500 acres) and large core (above 500 acres).

Table 2: Fragmentation Classes

Fragmentation class	Description
Core	Interior areas of a patch beyond the influence of edge effects at a specified edge width (for example 100m from the boundary)
Large core	Areas greater than 500 acres
Medium core	Areas 250-500 acres,
Small core	Areas less than 250 acres.
Perforated	Areas of interior openings or "holes" within larger patches (for instance clearings, small agricultural plots) that fragment from inside, counted as individual perforated patches.
Edge	Forest areas within the specified edge distance from non-forest boundaries where abiotic and biotic conditions differ from the interior, influencing light, temperature, and species interaction.
Patch	Small isolated fragments entirely subject to edge effects, often remnants of larger habitat broken off by disturbance.

ArcGIS LFT has proven to be effective in assessing forest fragmentation in earlier studies. An example is the study by Hussein et al., (2024) which used LFT v2.0 to accurately assess forest fragmentation in Rawalpindi district of Pakistan, and it revealed that there was an increase in fragmentation and a decrease in large core forests from 20.3 % of the total area in 1992 to 7.2 % in 2023. Additionally, the patch forest area increased from 2.4 % in 1992 to 5.9 % in 2023, indicating significant fragmentation. Badhe et al., (2024) employed LFT to assess forest fragmentation in North Western Ghats, and reported an increase in the number of forest patches and decrease in patch size over the period. These investigations confirm that the Landscape Fragmentation Tool (LFT) is reliable and resilient, making it appropriate for this study. The results validate the approach and provide an accurate representation of the historical forest changes in the studied area.

PRESENTATION OF RESULTS AND DISCUSSIONS

Presentation of Results

Land use and Land cover change Analysis (1986-2023)

This study explores the temporal analysis of anthropogenic and ecological changes in land use from 1986 to 2023 (figure 1a, b, and c), thereby, revealing a dynamic interplay throughout different classes. As presented on figure 2, in 1986, forest land use was the dominant land cover class, covering 2073.43km^2 (75.08%) of the study area. Grassland covered an area of 667.34km^2 (24.17%) while settlement covered 13.75km^2(0.5%) and wetland only covered 6.94km^2 (0.25%). forest covered over to-thirds of the study area due to limited disturbance at that time as agriculture, infrastructural development and logging were still at small scale. By 2001, forest cover had decreased to 1064 km^2 (38.55%) while grassland, settlement and wetlands/river all increased significantly to 1643 km^2 (59.53%), 18.72 km^2 (0.68%) and 34.57 km^2 (1.25%) respectively. The drastic decline of forest cover by

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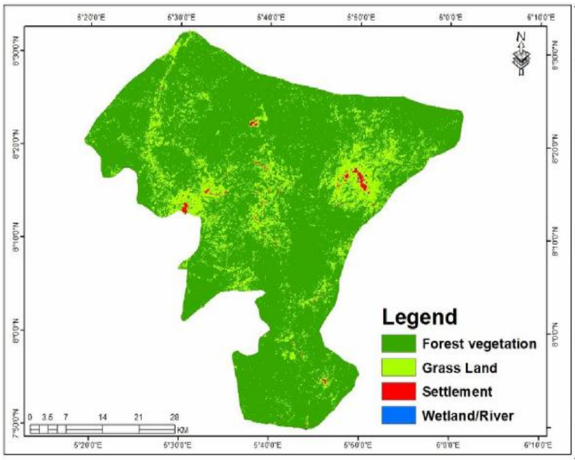
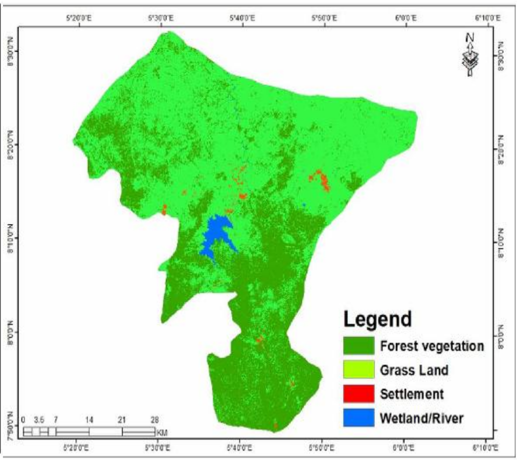
2001 was as a result of agricultural expansion, logging, fuelwood/charcoal production, and increased human activity.

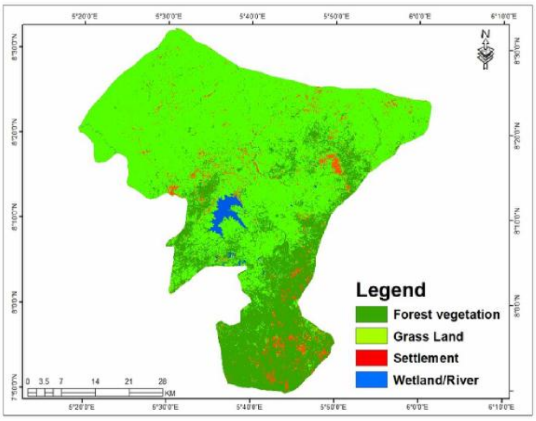
In 2023, grassland constitute the largest share of land cover extending over 1883.75 km^2(68.22%) Similarly, settlement and wetlands/river also witnessed a slight increase as they covered 36.25 km^2 (1.31%) and 115.06 km^2 (4.17%) in the same year. However, Area covered by forests further declined to 726.37 km^2 (26.3%). The dominance of grassland reflects characteristics of guinea savanna ecology of the region. This also indicates the fact that the area is a keyzone for agricultural activities and livestock grazing. The continuous expansion of settlement reflects growing urbanization and infrastructural development within the area.



a. Land Use/Land Cover Map 1986



b. Land Use/Land Cover Map 2001



c. Land Use/Land Cover Map 2023

Figure 2. Land Use Land Cover maps of the study area.

Overall, there has been a significant loss in forest cover from 1986-2023 in the study area. Forest land cover lost 1347.06km^2, settlement recorded the highest gain, gaining 128.91km^2 within the study period. Grassland also increased markedly, and gaining 1216.41km^2 within 37 years. Wetland areas also increased by 29.31km^2 in the study area over the study period. This result is consistent with studies of Oludare.(2021), and Razaq and Adetoro (2019).

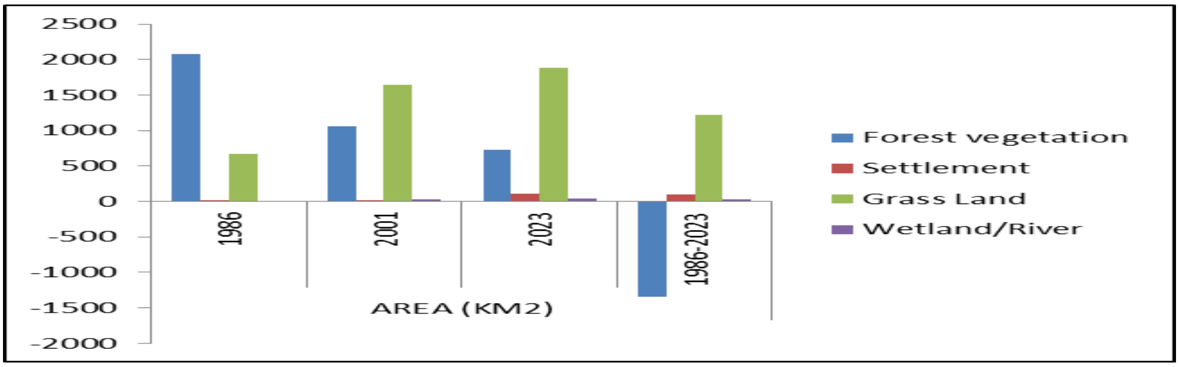


Figure 3: LULC area coverage

Temporal analysis of habitat fragmentation pattern from 1986-2023

Fragmentation in 1986

In 1986, the landscape was predominantly intact, with core habitat (particularly the >250 acre category) comprising over 258853.61 ha and accounting for nearly the entire undisturbed area as presented on Table 3. Edge habitat (677.56 ha across 13 patches) was truly limited, while isolated patches (6.47 ha across 18 patches) and small cores of less than 250 acres (8.48 ha, 12 patches) were negligible while perforated patches has 199 patches across an area of 2293.94 ha. The large contiguous cores represent minimally disturbed savanna woodlands, which are ecologically critical for maintaining biodiversity hotspots, support migratory wildlife and regulating regional hydrological cycles. High number of perforated patches during this period suggests numerous internal "holes" within the core, likely roads or small clearings. This is further supported by the limited presence of patch and edge classes which suggested localized disturbances, likely from subsistence farming, seasonal grazing, or small-scale fuel wood extractions.

The spatial pattern of fragmentation as shown on the fragmentation map of 1986 in Figure 2a, shows an unbroken green tract covering the central and southern parts of the area. In the inset on the upper left corner of the map, small peach-coloured holes depict the concentration of clusters of internal clearings (roads and small agriculture plots) in the northern parts, which punctured the forest from within. The narrow yellow ribbon-like appearance on the map confirms that true "edge" habitat was still quite limited in 1986. In the same vein, the Red dots (patches) and light green polygons (small core < 250 ac) on the map which appear as a few isolated points, mostly in the northeast quadrant, signals minimal outright loss of connectivity into completely isolated remnants.

Therefore, the yagba axis of the guinea savanna ecological zone of Kogi State remained predominantly intact due its role as a transitional zone between Nigeria's forest and Sudan savanna regions which limited large-scale exploitation. However, the zone already exhibited the first signs of internal fragmentation in the 1980s due to land clearing for agriculture and road construction that was necessitated by nascent population growth. Ecologically, this pattern, where there few edges but many interior perforations, implies that while overall connectivity remains high, species sensitive to even small clearings may experience habitat disruption at fine scales.

Table 3: Forest habitat area under each fragmentation class

Fragmentation class	1986		2001		2023	
	Area (ha)	No of patches	Area (ha)	Patch count	Area (ha)	Patch count
patch	6.47	18	68.60	342	464.85	1987
edge	677.56	13	1673.97	20	5176.68	91
perforated	2293.94	199	4998.62	650	44627.51	4080
Core (< 250 acres)	8.48	12	46.25	87	1377.50	1166
Core (250-500 acres)	912.06	1	129.25	1	105.08	7
Core (> 500 acres)	257941.61	1	254923.37	1	210088.44	5
Total	261840.06		261840.06		261840.06	

Habitat Fragmentation Pattern in 2001

By 2001, significant changes had occurred, the study area had transitioned into a mosaic of fragmented cores, edges and patches (Figure 2b). Table 2 shows an increase in all fragmentation classes particularly in the size of patch class and perforated areas. Patch area increased from 6.48 ha in 1986 to 68.60 ha in 2001, and patch count surged from 18 to 342, while edge habitat increased to 1673.97 ha and number of patches increased to 20. Perforated areas surged to area coverage of 4,998.62 ha with patch count of 650. Small core patches (< 250 acres) increased dramatically to from 12 (8.48 ha) to 87 (46.25 ha). Meanwhile, the lone largest patch saw a slight reduction from 258941.61 ha to 254923.37 ha and was reclassified into the > 500 acre core class, denoting a modest contraction of the principal contiguous habitat block. Therefore, the fragmentation map indicates more visible intrusion into core areas, with increasing spatial disintegration. Although large core areas persisted, their extent was beginning to diminish, and the landscape was becoming more heterogeneous, and perforated.

Habitat fragmentation pattern in 2023

As of 2023, habitat fragmentation had intensified considerably, demonstrating advanced habitat fragmentation and ecological disruption. As presented on table 2, patch class exploded to 464.85 ha across 1987 patches while edge and perforated habitats increased from 1673.97 ha (20 patches) and 4,998.62 ha (650 patches) respectively in 2001 to 5176.68 ha (91 patches) and 44627.51 ha (4080 patches) respectively in 2023. Meanwhile, the one largest core (> 500 acres) had split into 5 totalling 210088.44 ha, signaling progressive loss of uninterrupted interior refuge. This expansion of edge and perforated areas, alongside the decline in large cores and explosion of small patches, reflects increasing anthropogenic pressure. These spatial changes pose serious implications for ecological integrity, species survival, and long term conservation planning in region (Chaves et al., 2022).

Figure 2c corroborated these statistics by showing a severely fragmented landscape, with numerous small and isolated patches in red colour across the northern and southeastern quadrants. Edge zones, depicted in yellow have become broader and more continuous, especially along the margins of the core area. The proliferation of small core areas (< 250 acres) is represented by the increase in the extent of the areas covered by light green colour. Therefore, the 2023 map vividly depicts this spatial reorganization, showing a fragmented matrix dominated by edge-affected zones and numerous isolated fragments surrounding the residual core areas.

A comparative analysis of fragmentation classes from 1986 to 2023 is presented on table 4. This analysis shows a dramatic shift from large core areas to fragmented and perforated landscapes. Between 1986 and 2001, patch area surged by 62.14 ha (960%) while perforated area increased by an additional 2704.68 ha (117%) reflecting an early-stage habitat subdivision from agricultural encroachment and localized resource extraction. Rapid population growth and the adoption of cash-crop farming during this period drove massive land clearing, consequently fragmenting cores into smaller patches. This is consistent with land use transitions in West African savanna (Atsri et al., 2018). Similarly, the near-total loss of Core (250-500 acres) areas by -258,724.36 ha (-99%) indicates the rapid conversion of intermediate-sized habitats due to road construction (kabba-Isanlu highway) and settlement expansion which bisected habitats, hence, creating linear barriers that impede wildlife movement.

Furthermore, the period from 2001 to 2023 witnessed an increase of 3,502.71 ha (209.2%) in edge area and increase of 39,628.89 ha (792.9%) in perforated area, signifying habitat degradation. This finding aligns with a study by Haddad et al., (2015) where edge effects were linked to biodiversity decline in fragmented savannas. Core (>500 acres) witnessed 17.6% loss between 2001 and 2023, which underscores the collapse of large contiguous habitats, mirroring global trends where savanna cores shrink due to agro-industrial expansion (Veldman et al., 2015).

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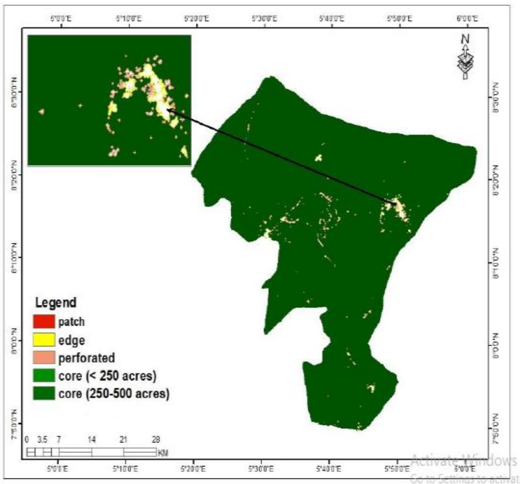
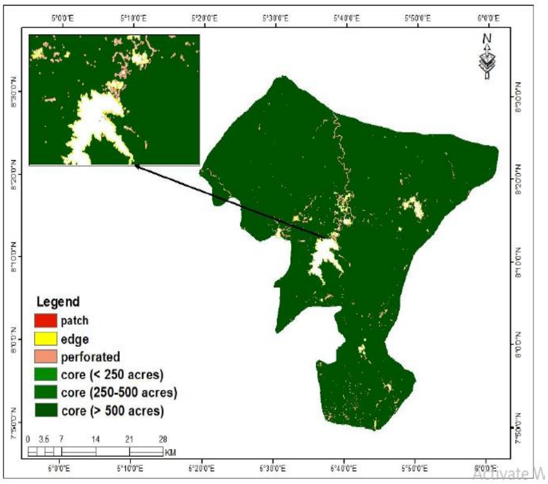
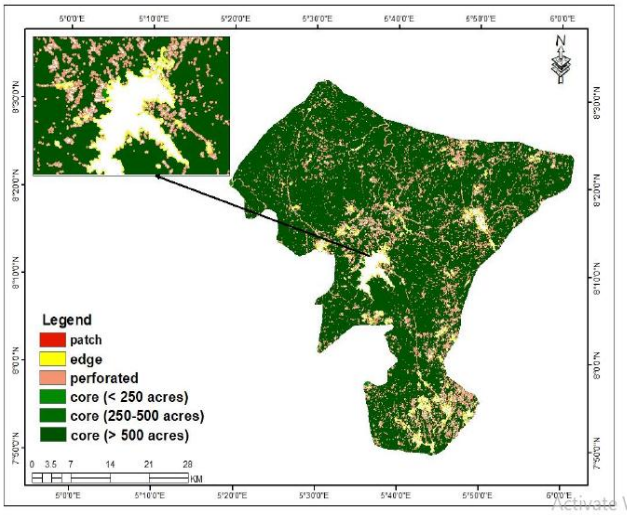




a: 1986 Fragmentation map b: 2001 fragmentation map



c: 2023 fragmentation map

Figure 4: Fragmentation map of the study area

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Table 4: Area and percentage rate of change of each fragmentation class

Fragmentation Class	1986–2001 Change (ha)	% Change	2001–2023 Change (ha)	% Change	1986–2023 Change (ha)	% Change
Patch	+62.13	+960.0%	+396.25	+577.6%	+458.38	+7,083%
Edge	+996.41	+147.0%	+3,502.71	+209.2%	+4,499.12	+664.3%
Perforated	+2,704.68	+117.9%	+39,628.89	+792.9%	+42,333.57	+1,845%
Core (<250 acres)	+37.77	+445.4%	+1,331.25	+2,877%	+1,369.02	+16,140%
Core (250–500 acres)	-258,724.36	-99.9%	-24.17	-18.7%	-258,748.53	-99.9%
Core (>500 acres)	-3,930.24	-1.5%	-44,834.93	-17.6%	-44,834.93	-17.6%

DISCUSSION OF RESULTS

The change in the pattern of the occurrence of habitat fragmentation in the study area from 1986-2023 has been as a result of the cumulative developments which have brought about a 1,845% increase in perforated landscapes and 7,083% increase in patch area. In 1986, the near-intact vegetation state revealed in this study reflects a pre-acceleration state of development where disturbances were only confined to small-scale activities in northern villages such Okoloke, Egbe where the early missionaries introduced localized farming. Subsistence farming dominated, with farmers in these rural settlements clearing small plots for yams, cassava, and grains, while other activities such as seasonal grazing and fuelwood extraction accounted for the number of perforated patches during this period. Practicing subsistence farming during this period indicated low population pressure, as the area had less than 250,000 inhabitants. Furthermore, the A123 hughway, which passes through Isanlu (headquarters of Yagba east LGA), though operational at this time, had not been expanded, partly accounting for the limited edge class.

The +960% and +117% surge in patches and perforated areas in 2001was directly linked to infrastructural booms. After the creation of Kogi State in 1991, yagba east and west LGAs became part of Kogi, hence the need for infrastructural development, especially in the Local Government headquaters. Construction and rehabilitation of the Kabba-Isanlu highway created Linear barriers that consequently perforated the core habitats and further expanded the edges, fragmenting the former large core into smaller sizes. This highway facilitated market access for cash crops (like cocoa, oil palm) in villages along the road, where land clearing for plantation increased isolated patches. In addition, population growth led to settlement expansion after the area was carved out of kwara state and became part of Kogi State, thereby converting intermediate cores.

The advanced level of degradation witnessed between 2001 and 2023 was as a result of recent developments in growing settlements. Urban fringe expansion as a result of about 25% opulation increase since 2016 in areas around the Local Government headquarters in Isanlu and Egbe, has further led to increased edges through housing and markets. The high influx of the Fulani herders into areas like ijowa, Ilafin, Okoloke, Odo ere further exacerbated the increase in perdorated area because of internal clearing of land for subsistent farming. In addition, commercial agriculture under Kogi State Ministry of Agriclture Medium-Term sector strategies has continued to increase, as it has emphasizes large scale farming of cash crops (rice and maize) in yagba. An example is the cultivation of rice on the floodplains of Omi river, along Egbe road and establishment of rice milling factory in the area, therby contributing immensely to the rise in perforated area. This rise in perforated habitats is similar to the study by Shimrah et al., (2022), where it was reported that perforated category increased tremendously between 1991 and 2020 in Ukhur district of Manipur, Northeast India.

Furthermore, cross border trade with kwara in Egbe has spurred informal settlements, boosting the increase in patch areas through fragmented farmlands, while rural-urban drifts has led to the abandonment or over clearing of lands that amplify small cores. Mining operations in the area have significantly contributed to environmentasl degradation, particularly since the early 2010, when exploration for solid minerals intensified under Nigeria's push for non-oil revenue diversification. While Yagba East (headquartered in Isanlu) has seen direct artisanal and semi-industrial lithium mining activities, Yagba West (including towns like Mopa and Egbe) hosts deposits of feldspar, tin, and columbite, with sporadic artisanal extraction.

The highlighted operations often unregulated or foreign-backed, have profoundly affected biodiversity in the Guinea Savanna ecosystem, exacerbating the habitat fragmentation patterns identified in this study. Lithium mining in yagba east LGA, through the controversial lithium mining project initiated around 2022-2023 by foreign companies has led to land grabs of over 1,000 ha of communal farmlands and forests, displacing local vegetation and creating isolated patches. In Yagba West, feldspar mining near Egbe has transformed natural areas into worksites, leading to deforestation and the loss of deciduous savanna species like iroko (*Milicia excelsa*) and mahogany (*Khaya senegalensis*), which are critical for the region's transitional ecology

In summary, developments have driven a 1,845% perforated increase and 7,083% patch surge from 1986-2023, with agriculture in villages accounting for about 60% of clearings via cash crop shifts, while infrastructure in LG HQs (Isanlu, Egbe) added edges/barriers. Population driven settlements have converted about 18% of large cores, mirroring Kogi's urbanization externalities like biodiversity loss in urban fringes. According to Reddy et al., (2018), the intensity of anthropogenic influence can be gauged by the expansion in patch area and the reduction in core forest area. The results of this study is consistent with the work of Devi, Reddy, and Shimrah (2021), where it was discovered that patch forest area increased while core forests area decreased in the Senapati district of Manipur North east India from 2013 to 2017. The study attributed the transformation of core forest into other forest categories patch, edge, and perforated forest as a result of fragmentation in the district to anthropogenic activities such as deforestation and shifting cultivation practiced inside the forest area.

Ecological implications and management

The fragmentation pattern experienced in yagba east and yagba west LGAs of Kogi state aligns with global patterns of habitat degradation, underscoring critical ecological consequences. The land use and land cover analysis from 1986 to 2023 revealed a significant shift in the various land use categories over the study period, with resultant effect on habitat fragmentation and ecological balance. The decrease in forest areas in the study area is a global pattern that is exacerbated by urban development, agricultural expansion and population growth. This is similar to the studies of Sloan and Sayer (2015), and Hessein et al., (2024).

On the other hand, the increase in grasslands and shrublands in the study area clearly signifies severe loss of habitat for wildlife, and this is similar to the study of Tashi and Thapa (2023). The findings of this study show that forest area in parts of the southern guinea savanna has been fragmenting over the period of about 39 years. This process of fragmentation has intensified as the substantial core forest areas have witnessed a notable reduction in size. However, the significant increase in the patch class, edge and perforated classes indicates that the forest area is becoming increasingly disconnected from the major core forest area. A study by Amin and Fazal (2017) found that increase in perforated areas in the forest interiors in the Shopian district of India indicated widespread degradation of tree cover.

The 7,083% increase in patch area (1986–2023) signifies pervasive habitat subdivision, a phenomenon linked to biodiversity decline in tropical savannas. Recent studies demonstrate that fragmented landscapes host 13–15% fewer species than intact ecosystems, with small patches failing to sustain viable populations of large mammals or specialist flora (Haddad et al., 2017; Taubert et al., 2018). The near-total loss of *Core (250–500 acres)* (-99.9%) exacerbates extinction risks, as intermediate-sized cores are critical for maintaining meta-population dynamics (Ramirez-Delgado et al., 2022). Mehmood et al., (2024) assessed forest fragmentation in the Himalayan temperate region where it was found that large core areas decreased significantly, while small forest cores increased with resultant effect on biodiversity. Similarly, the result of this study also aligns with work of Amin and Fazal (2017) where it was discovered that core forest between 250 and 500 hectares in the Shopian district of India decreased significantly over a period of time.

The expansion of edge habitat from external boundaries and internal holes alters microclimates, increases predation and invasive species ingress, and can reduce interior plant diversity. This aligns with the findings of Laurence et al., (2018), where it was reported that edge-dominated landscapes experience elevated desiccation, invasive species encroachment, and altered fire regimes. To further buttress this effect, Ayanu et al., (2021) asserted that edge-driven microclimatic shifts in the Nigerian guinea savanna reduce soil moisture by 20-30%, imperiling fire-sensitive tree species like Vitellaria paradoxa (shea butter), which underpins local livelihoods. The contraction and subdivision of the large core patch remove ecological buffering against anthropogenic impacts, core-dependent flora and fauna face heightened vulnerability as remaining cores shrink and fragment further (Muluneh & Worku, 2022). This also undermines carbon sequestration capacity. Large savanna cores store 30–50% more carbon than fragmented landscapes due to intact root systems and reduced decomposition rates (Dobson et al., 2021). Their loss exacerbates climate vulnerability, aligning with global estimates that tropical deforestation contributes 8–10% of annual CO_2 emissions (Harris et al., 2021). Therefore, this study analysed spatio-temporal changes in vegetation cover and pattern of habitat fragmentation in parts of the southern guinea savanna region from 1986 to 2023.

The results of this study revealed an increase in the intensity of fragmentation in the area. Human activities have led to the conversion of vegetation cover to non-forested areas, thereby increasing the occurrence of habitat fragmentation with resultant effect on biodiversity. Habitat fragmentation in the study area is found to be caused majorly by human activities such as population growth, agricultural expansion, infrastructural development, urban sprawl, among others. Increasing transportation networks, poor land use planning and weak enforcement of environmental laws have further exacerbated the rate of fragmentation in the study area.

CONCLUSION

The rate of vegetation loss in parts of the southern guinea savanna region of Kogi state is leading to widespread habitat fragmentation. The study reveals a significant increase in the rate of fragmentation as patch class witnessed an increase of +7,083% between 1986 and 2023. Perforated areas also increased by about 1000% during the study period. Core (< 250 acres) areas also shows substantial increase during the study period, while core (250-500 acres) and core (>500 acres) areas diminished significantly. This trend indicates a significant increase in fragmented patches and decrease in large core forest areas, highlighting the dire need for targeted policy interventions and sustainable land management.

Competing Interest

The author declares that no conflicting interest exist in this manuscript.

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