

Vegetation Dynamics and Ecological Disturbances in Kanawa Forest Reserve, Gombe State, Nigeria

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ABSTRACT

The forest provides vital ecosystem services such as biodiversity conservation, carbon sequestration, water regulation, and soil protection. This study assessed vegetation dynamics and ecological disturbances in Kanawa Forest Reserve (KFR), Gombe State, Nigeria, using a combination of remote sensing, field surveys, diversity indices, and household questionnaires. Six vegetation types were identified, with Lowland Rainforest showing the highest cover (36.02%) and Grassland/Thorny the least (3.48%) in 2020. Site II (Lowland Rainforest) exhibited the highest species diversity, recording Simpson's index values of 0.79 for trees and 0.80 for shrubs, while Site III (Grassland/Thorny) had the lowest (0.42 and 0.45) respectively, indicating richer biodiversity in less disturbed areas. Medicinal species such as *Azadirachta indica* and *Guiera senegalensis* were recorded, with known antibacterial, antifungal, and antioxidant properties. The socio-economic survey revealed high reliance on forest resources for livelihoods, especially farming (54% of respondents), compounded by high illiteracy (85%) and low alternative income sources. Male dominance (86%) was observed in land-based activities. Despite socioeconomic pressures, communities reported no land-use conflicts, suggesting sustainable interactions with the landscape. Over the past 40 years, conservation policies such as fencing and restricted access have contributed to biodiversity recovery and ecosystem stability in protected zones. The study underscores the importance of strict conservation measures, sustainable land-use practices, and awareness programs for forest preservation. Continuous monitoring and integration of local communities into conservation plans are essential for long-term sustainability.

Keywords: Biodiversity, Conservation, Ecological Disturbance, Kanawa Forest Reserve, Simpson Index, Vegetation Dynamics

INTRODUCTION

Vegetation dynamics refers to the changes in the composition, structure, distribution, and abundance of plant communities over time and space. These changes occur in response to both natural factors (such as climate variability, fire, and ecological succession) and human activities (such as agriculture, deforestation, and urbanization (Turner *et al.*, 2022)). Vegetation dynamics in

ecotones like the Kanawa Forest Reserve are especially important because they reflect the sensitive balance between savanna and rainforest systems, showing how plant communities shift due to climatic fluctuations and anthropogenic pressures. In Nigeria and other parts of Africa, land-use change, deforestation, and agricultural encroachment have significantly altered natural vegetation



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patterns, clearing of forest land for subsistence and commercial farming reduces tree cover. Uncontrolled grazing leads to soil compaction, erosion, and vegetation degradation. Heavy dependence on wood for fuel results in selective logging and loss of indigenous species. Shifts in vegetation from forest to cropland or grassland alter the microclimate and soil quality (Ogunjinmi *et al.*, 2021). These disturbances impact forest regeneration, biodiversity, and vital ecosystem services such as carbon sequestration and water regulation (Measho *et al.*, 2021). Mosaic vegetation characterized by a mix of grasslands, woodlands, and farmlands enhances ecosystem resilience by creating diverse habitats that support various species and improve ecological functions. This variety allows for the coexistence of species with different ecological requirements—some adapted to dry, open conditions and others to moist, shaded environments. The interaction between tree cover, undergrowth, and open areas in mosaic vegetation helps regulate temperature, humidity, and wind patterns at the micro level. Forested patches act as carbon sinks, while grasslands contribute to soil moisture retention and reflectivity (Turner *et al.*, 2021). The Kanawa Forest Reserve in Gombe State, Nigeria, is a representative mosaic landscape containing grassland, Sudan savanna, lowland rainforest, and riparian vegetation. Although relatively intact, it experiences disturbances from seasonal variation, human activity, and climate-related factors. KFR harbors a unique mix of flora and fauna from both savanna and rainforest ecosystems. This blend supports: high species richness and endemism, ecological niches for species adapted to transitional conditions, medicinal and economically valuable plant species used by local communities. Acts as a buffer against desertification from the north and rainforest degradation from the south. Moderates climatic extremes and stabilizes local weather patterns. Supports resilience against climate change due to its ecological flexibility. The diverse vegetation cover: protects soils from erosion, enhances water infiltration and maintains watershed health, regulates stream flow and contributes to local hydrological cycles. Changes in vegetation and species composition in KFR reflect broader environmental trends, including land use change, climate variability, and human pressure. This study aims to assess the Vegetation Dynamics and Ecological Disturbances in Kanawa Forest Reserve, Gombe State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area

Kanawa Forest Reserve (KFR), located in Yamaltu/Deba LGA of Gombe State, Nigeria It lies between Latitudes 10°16'N–10°18'30"N and Longitudes 11°18'10"E–11°22'09"E at an altitude of 336–390 meters above sea level within the Southern Sudan Savanna. It was established by the Gombe Native Authority between 1940 and 1945, It has undulating terrain with a mix of Sudan savanna, rainforest, and grassland vegetation types.

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It experiences a wet season (April–October) with 500–1000 mm of rainfall and a dry season (November–March), with temperatures ranging from 24–28°C. Humidity is high during the rainy season and low in the dry season (Figures 1 and 2).

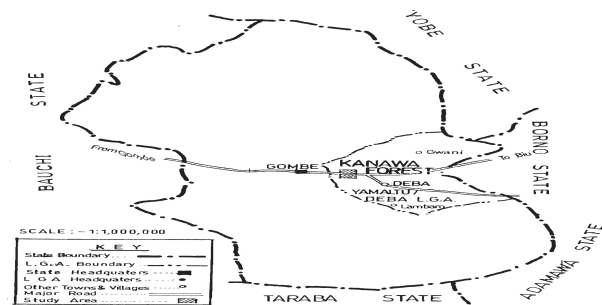


Figure 1: Map of Gombe State showing the location of Kanawa Forest Reserve (KFR).

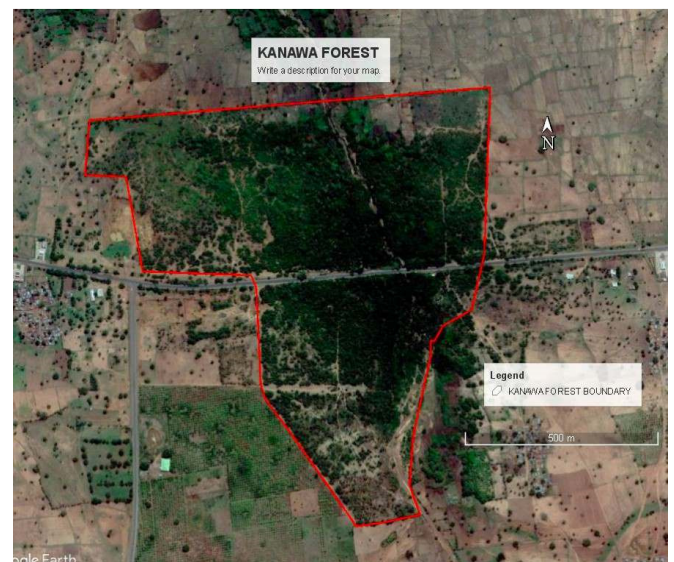


Figure 2: The Aerial view of Kanawa Forest Reserve in Yamaltu-Deba L.G.A

Methodology for Administering the Questionnaire

A questionnaire-based study was conducted around Kanawa Forest Reserve targeting diverse groups such as households, farmers, herders, and resource users. Using stratified random sampling, 100 respondents were selected to ensure representation across land use types. The questionnaire covered demographics, livelihood activities, and conservation challenges, and data were collected through the Kobo Collect tool to gather socioeconomic insights. Data were analyzed using descriptive statistics and thematic analysis for qualitative data.

Data Collection

A field survey in Kanawa Forest Reserve to assessed the plant diversity across various land use types using indices like Shannon-Weiner and Simpson's. Vegetation sampling was carried out using the Point Center Quarter (PCQ) method at ten

random points along transect, measuring distances to the nearest woody plants and identifying species. Data collected included species composition, density, dominance, and frequency, which were used to calculate metrics like mean point distance and tree density per hectare (Abba *et al.*, 2015)

Identification of Species

In each sampling point all species encountered were listed. Species were identified on site with the help of field guides and Floras and texts containing colored photographs. Also, morphological characteristics involving the fruits, flowers, leaves and stem, bark and sap were used for identification. The specimens were collected and compared with herbarium specimens of the Botanical Garden of Gombe state University, Gombe (Abba, 2014).

Remote Sensing and GIS Analysis

The study adopted the method of Normalized Difference Vegetation Index (NDVI) analysis using multi-temporal Landsat imagery (1980-2020) from the United States Geological Survey (USGS). to assess vegetation health and cover changes in Kanawa forest Reserve. This approach, which utilizes Near-Infrared (NIR) and red bands to compute NDVI values, was adopted from (Smith *et al.*, 2023).

RESULTS AND DISCUSSION

Species Diversity of Trees and Shrubs

Site II (Lowland Rainforest) recorded the highest species diversity for both trees and shrubs, with a high Simpson's Index of Diversity (1-D) and a Shannon-Wiener Index (H') (Trees:1-D=0.80, H=3.0, Shrubs: 1-D=0.79, H=3.5). In contrast, Site III (Grassland) had the lowest diversity in both categories, (Trees:1-D=0.45, H=1.8, Shrubs 1-D=0.42, H=1.78) (Table 1).

The Spatial-temporal Landcover and Vegetation Class Changes within KFR

The Figure 3 shows the spatial-temporal changes within Kanawa Forest Reserve (KFR)1980-2020.This helps to visualize how vegetation has changed over four decades. Between 1980 and 2020, Kanawa Forest Reserve (KFR) experienced significant shifts among four major vegetation types: Grassland/Thorny, Sudan Vegetation, Riparian/Marshy, and Lowland Rainforest.

The Identified Tree and Shrubs Species from Kanawa Forest Reserve (KFR) and their Families with their Medicinal Uses.

The Kanawa Forest Reserve (KFR) hosts a rich biodiversity, including 25 tree species from 15 families, with Combretaceae and Fabaceae: mimosoideae being the most diverse (four species each). An ethnobotanical survey highlighted the presence of 25 medicinal tree species, emphasizing the reserve's importance to

traditional medicine. Additionally, 24 shrub species from seven families were identified, with Fabaceae: caesalpinoideae being the most dominant (13 species), underscoring the ecological and ethnobotanical value of the understory vegetation (Table 2).

The Socioeconomic Importance of Mosaic Landscapes for Local Communities

The study highlights the strong dependence of local communities on mosaic landscapes, particularly for agriculture, firewood, wild fruits, and medicinal plants. Respondents were mostly male (86%), with an average age of 42 years and a high level of illiteracy (85%). Farming, car washing, and livestock rearing were the main occupations, and the average household size was four. About 90% of respondents emphasized that forest resources are vital to their economic well-being, demonstrating the socioeconomic value of the Kanawa Forest Reserve.

Assessment of Plants Diversity Levels across Different Land Use Types within Kanawa Forest Reserve

Table 2 outlines plant diversity across four land use types in Kanawa Forest Reserve, including agricultural zones, undisturbed forests, grazing areas, and human settlements. It highlights how ecological disturbances vary based on vegetation type, moisture levels, topography, and human activities. Despite the reserve's proximity to human settlements, protective fencing helps reduce disturbances like tree felling and vehicle washing by limiting access. This supports (Nwosu *et al.*, 2023), who found that fencing effectively mitigates human pressures in protected ecosystems.

Species Diversity of Trees and Shrubs

Site II (Lowland Rainforest) recorded the highest tree and shrub diversity, with Simpson's Index values of 0.80 (trees) and 0.79 (shrubs), and Shannon-Wiener Index values of 3.0 and 3.5, indicating rich and evenly distributed species. This is attributed to favorable conditions like high moisture, fertile soils, and complex canopy structure. In contrast, Site III (Grassland) had the lowest diversity, with lower index values reflecting species scarcity and unevenness due to disturbance and drought-resistant dominance. These findings are consistent with earlier studies by (Akinoyemi *et al.*, 2024; Ogundare *et al.*, 2021), (Olawuyi and Jimoh 2022), (Chigbo *et al.*,2023), and Yusuf and Adeoye 2022) who observed similar trends in northern Nigerian savannas.

The Spatial-Temporal Analysis of Land Use and Land Cover (LULC)

The spatial-temporal analysis from 1980 to 2020 shows

Table 1: Assessment of plant diversity levels across different land use types within Kanawa forest reserve.

Land use type zones	Dominant vegetation/land use type zones	Moisture type	Topography	Land use types/Disturbance activity
Human activities/Human settlement	Riparian/Marshy vegetation	Waterlogged soil	Shallow V-shaped stream channels that tend to broaden into plains as the streams in the area approaches the lowland	The practice of washing vehicles, such as cars and lorries, near the stream, Nursery bed for seedling cultivation, The removal of Raphia Sudanic trees for furniture crafting. The felling of trees for furniture crafting and fuelwood.
Undisturbed forest patches	Lowland rainforest vegetation	Moist soil	The terrain is a flat lowland	
Grazing Areas	Grassland/Thorny vegetation	Damp soil	The terrain is made up of open grasses, The terrain is also hilly with few short grasses, thorny climbers, shrubs	Grazing by animals
Agricultural zones	Sudan savanna	Dry soil	The terrain is generally undulating with presence of hills with low dense woodland in some parts of the sites.	Farming Activities.

Table 2: The identified Tree and shrubs species from Kanawa Forest Reserve (KFR) and their families with their medicinal uses.

S/N	Family	Name of species	Plant Type	Medicinal Uses	Parts Used	Mode of administration
1	Anacardiaceae	<i>Haematosiphis barteri</i> Hook.f.	Tree	Stomach problem	Bark	Infusion with tamarind. One small cup three times daily. Boil 5-10 fresh or dried mango leaves in water for 10-15 mins, Drink 1 cup (200-250 ml) once or twice daily
		<i>Mangifera indica</i> L.	Tree	Diabetes, Hypertension, Cough Ashtma	Leaves	
2	Bignoniaceae	<i>Newbouldia laevis</i> (P.Beauv).	Tree	Fever, cough, stomach upset	Leaves, bark, roots Flowers	Decoction, 1 cup (200-250 ml) once or twice daily
	Balanitaceae	<i>Balanites aegyptiaca</i> (L.) Dell.	Tree	Hernia, liver disease, ulcer	Root, fruits, seeds	Decoction, 1 ladle 2 times daily. much is toxic. Squeeze in water, sieve and drink half cup 2 times daily for 2 weeks Fry oil with onions and eat with food
3	Bombacaceae	<i>Bombax costatum</i> Pellegr & Vuill	Tree	Swelling of children body Jaundice	Bark	Decoction with water. One ladle 3 times daily
4	Leguminosae: Fabaceae	<i>Senna siamea</i> DC.	Tree	Fever, Constipation Stomach issues	Leaves Bark	Dry the leaves or bark then grind into fine powder Take 1-2 teaspoons mixed with water or honey daily
5	Combretaceae	<i>Anogeissus leiocarpus</i> (DC) Guill & Perr <i>Combretum ghasalense</i> Engl & Diels	Tree	Cough, stomach disorder and malaria fever	Bark	Decoction with garlic & (Cyperus) 1 tablespoon daily Dried powdered and apply on wound, Decoction with red potash, Drink the content 3 times daily.
			Tree	Dysentery and fever	Leaves	
		<i>Combretum glutinosum</i> Perr. Ex DC	Tree	Ulcer	Bark	Decoction and make with pap, or dried, powdered and take with pap 3 cups daily for 1 week.
		<i>Combretum hypopilinum</i> Diels	Tree	Headache, cough	Leaves root, bark	Decoction all the parts for 10 mins, make pap take 3 times daily for two weeks.
6	Leguminosae: Fabaceae	<i>Senna siamea</i> DC.	Tree	Skin infection	Leaves pods and seeds	Decoction, drink 1 cup once or twice daily
7	Leguminosae: Mimosaceae	<i>Albizzia lebeck</i> (L.) Willd	Tree	Wounds, rashes	Leaves, bark, flowers	Infusion, drink 1 cup once or twice daily Decoction, mouth rinse 7 times daily
		<i>Parkia biglobosa</i> (Jacq.) R.Br. ex G Don f.	Tree	Tooth ache	Bark	Infusion, small cup 2 times daily Decoction sieve 1/3 glass cup External wash the wound. mouth.
		<i>Prosopis africana</i> (Guill. & Perr.) Taud	Tree	Blood urine	Bark, root, stem & pods	

Table 2: Contd.

8	Myrtaceae	<i>Eucalyptus camaldulensis</i> <i>Dehnhardt T n Pap</i> <i>Psidium guajava L.</i> <i>Syzygium guineense (Willd.) DC</i>	Tree	Cough,fever Diarhea,dysentery	Leaves Leaves	Decoction,1 cup once or twice daily. Decoction,drink 1 cup once or twice daily
9	Moraceae	<i>Azadirachta indica A. Juss</i>	Tree	Malaria,fever skin conditions	Leaves,bark,seeds,	
10	Meliaceae	<i>Ficus syncomorus L.</i> <i>Khaya senegalensis (Desv.) A. Juss</i>	Tree Tree	Digestion,mild fever Fever,diabetes	Leaves,bark,fruit Leaves,bark,roots	Drink the infusion or eat the softened fruit,decoction,drink 1 cup once or twice daily. Decoction,1 cup saily.Infusion 1 cup once or twice daily
11	Palmae	<i>Elaeis guineensis A.Chev</i>	Tree	Wounds,headache	Leaves,roots.oil	Apply crude palm oil to dry skin,wounds or burns.Decoction for 20mins,1 cup daily.
12	Arecaceae	<i>Raphia sudanica A. Chev</i>	Tree	Fever,malaria	Leaves,roots,seeds	Boil the roots for 20-30 mins,drink 1 cup daily.Steep dried leaves in hot water for 10-15 mins,drink 1-2 cups daily
13	Rubiaceae	<i>Tricalysia chevalieri</i> <i>K.Krause.Med</i>	Tree	Digestive issues and mild infection	Leaves,roots barks	Infusion,1 cup daily.Decoction,half a cup daily
14	Ulmaceae	<i>Celtis integrifolia Lam</i>	Tree	Minor wounds,cuts,skin rashes	Leaves,bark,fruits	Decoction,1 cup once or twice daily,Infusion,1 cup daily.
15	Verbanaceae	<i>Vitex doniana</i>	Tree	Digestion,cough,malaria	Leaves,fruits,bark, Roots	Dry and grind the bark into powder,mix with water or honey to consume,boil the roots in water n drink 1 cup daily.
16	Leguminosae: Fabaceae	<i>Senna alata L.</i> <i>Senna tora Linn.</i> <i>Senna italica (Mill.) Spreng.</i> <i>Italica (mill).</i> <i>Senna occidentalis L.</i> <i>Senna singuena (Del.) Lock</i> <i>Chamaecrista mimosoides L.</i> <i>Crotalaria retusa L.</i> <i>Datura arborea (Willd.) Pers</i> <i>Desmodium velutinum (Willd.) DC</i> <i>Dichrostacys cinerea Wight et Am</i> <i>Indigofera arrecta Hochst.ex A.Rich</i> <i>Piliostigma reticulatum (DC.) HOCHST.</i> <i>Tephrosia linearis (Willd.) Pers</i>	Shrub	Skin infection Pain relief or wounds Fever reduction Skin conditions	Leaves,seeds Leaves,seeds Seeds,roots,bark	Squeeze the juice or crush tge leaves into paste,apply directly to the wound or cut. The seeds can be crushed into powder and consumed. Root decoction,drink 1 cup of decoction once or twice a day.
17	Combretaceae	<i>Combretum micranthum G.Don</i> <i>Combretum nigricans</i> <i>Lepr.ex.Guill et Perrott</i>	Shrub	Wounds,rashes	Leaves,bark	Boil fresh or dried leaves in water for 10-15 mins,drink 1 cup of the infusion 1-2 times daily.
		<i>Guiera senegalensis J.F. Gmel.</i>	Shrub	Digestive issues Malaria,wound healing	Leaves bark,stem,roots	Boil a small amount of stem or bark in 1-2 litres of water for 20-30 mins,drink 1 cup of the decoction 1-2 times a day for digestive issues or to support wound healing.
18	Malvaceae	<i>Hygrophila auriculata (Schumach.)</i> <i>Malvastrum coromandelianum (L.) Garcke</i> <i>Pavonia hirsuta Guill.& per</i> <i>Urena lobata L.</i>	Shrub Shrub	Pain relief,treatment of urinary tract infections Pain relief	Leaves,roots Leaves,roots	Boil the leave or roots in water for about 20-30 mins,drink 1 cup once or twice a day to aid in kidney function. Leaf decoction,drink 1 cup 1-2 times a day
19	Olacaceae	<i>Ximenia americana L.</i>	Shrub	Skin care and wound healing	Leaves,fruits	Grind fresh leaves into a paste,apply the paste directly to wounds,rashes or burns,apply the pulp to the affected skin areas.
20	Polypodiaceae	<i>Dryopteris fillix-mas (L.) schott.</i>	Shrub	Anti parasictic agent	Roots	Boil dried rhizomes in water to a decoction,half cup once daily to treat parasitic infections
21	Rhamnaceae	<i>Ziziphus mauritiana Lam</i>	Shrub	Stomach ache	Fruit,seeds	The dried fruits or seeds can be powdered and mixed with water or honey,1 teaspoon of powder taken once a day
22	Sterculiaceae	<i>Waltheria indica L.</i>	Shrub	Reduce risk of infection	Leaves	Decoction,drink 1 cup once or twice a day.

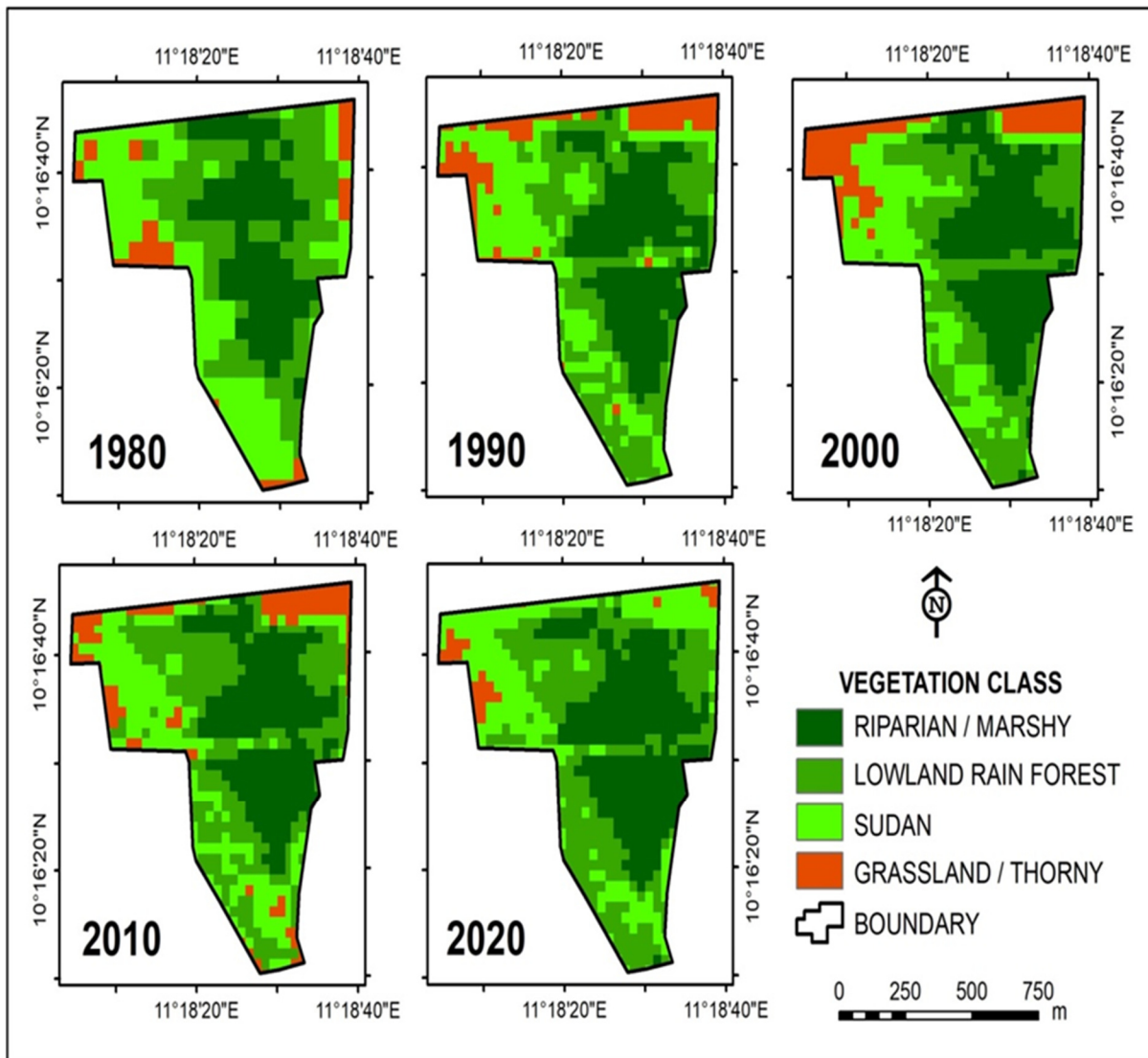


Figure 3: The spatial-temporal analysis of land use and land cover.

significant changes in vegetation types within Kanawa Forest Reserve (KFR), including Grassland/Thorny, Sudan Vegetation, Riparian/Marshy, and Lowland Rainforest. Grassland/Thorny vegetation initially expanded due to disturbances but declined sharply by 2020, aligning with (Adedeji *et al.*, 2022), who noted such declines following reduced human impact. Sudan Vegetation became increasingly fragmented as Lowland Rainforest expanded, supporting findings by (Mohammed and Tanko 2021) on savanna transformation due to climate and forest encroachment. Stable Riparian/Marshy areas and the consistent growth of Lowland Rainforest indicate ecological resilience and recovery, echoing studies by Dami and Akinyemi (2023), (Ajibade and Alaba 2020), and contrasting with (Yuguda *et al.*, 2023) who reported vegetation loss due to poor management in

Wawa Zange Forest Reserve (Tables 3-5; Figures 4-5).

Medicinal Tree and Shrub Species Diversity in Kanawa Forest Reserve (KFR)

Kanawa Forest Reserve (KFR) hosts a diverse array of medicinal plants, including 25 tree species from 15 families and 24 shrub species from 7 families, emphasizing its ethnobotanical value. Dominant tree families like Combretaceae and Mimosaceae include species such as *Albizia lebeck* and *Azadirachta indica*, known for antimicrobial and antidiabetic properties. Shrubs, mainly from Fabaceae, are widely used for treating fevers, infections, and wounds, with pharmacological support for their efficacy. Regional comparisons, such as with (Chikezie and Uwakwe, 2014) in Owerri and Tukur *et al.*,

Table 3: Vegetation Cover Changes Statistics in KFR

Vegetation Types	1980		1990		2000		2010		2020	
	AREA (Ha)	%	AREA (Ha)	%	AREA (Ha)	%	AREA (Ha)	%	AREA (Ha)	%
Grassland/Thorny	4.73	7.25	7.26	11.13	8.15	12.49	7.24	11.10	2.27	3.48
Sudan Vegetation	20.95	32.11	17.49	26.80	14.76	22.62	16.07	24.63	16.89	25.89
Riparian/Marshy	21.56	33.04	20.26	31.05	20.59	31.56	21.55	33.03	22.59	34.62
Lowland vegetation	18.01	27.60	20.24	31.02	21.75	33.33	20.39	31.25	23.5	36.02
Total	65.25	100	65.25	100	65.25	100	65.25	100	65.25	100

Table 4: The Diversity Indices of Trees.

Index	Values Riparian Site I	Lowland Site II	Grassland Site III	Marshy Site IV	Thorny Site V	Sudan Site VI
Simpson Index of Diversity (1-D)	0.60	0.80	0.45	0.75	0.45	0.71
Shannon Werner Index	2.0	3.0	1.8	2.5	1.8	2.0

Table 5: The Diversity Indices of Shrubs in KFR.

Index	Values Riparian Site I	Lowland Site II	Grassland Site III	Marshy Site IV	Thorny Site V	Sudan Site VI
Simpson Index of Diversity (1-D)	0.77	0.79	0.42	0.77	4.42	0.70
Shannon Werner Index	2.6	3.5	1.78	2.6	1.78	2.1

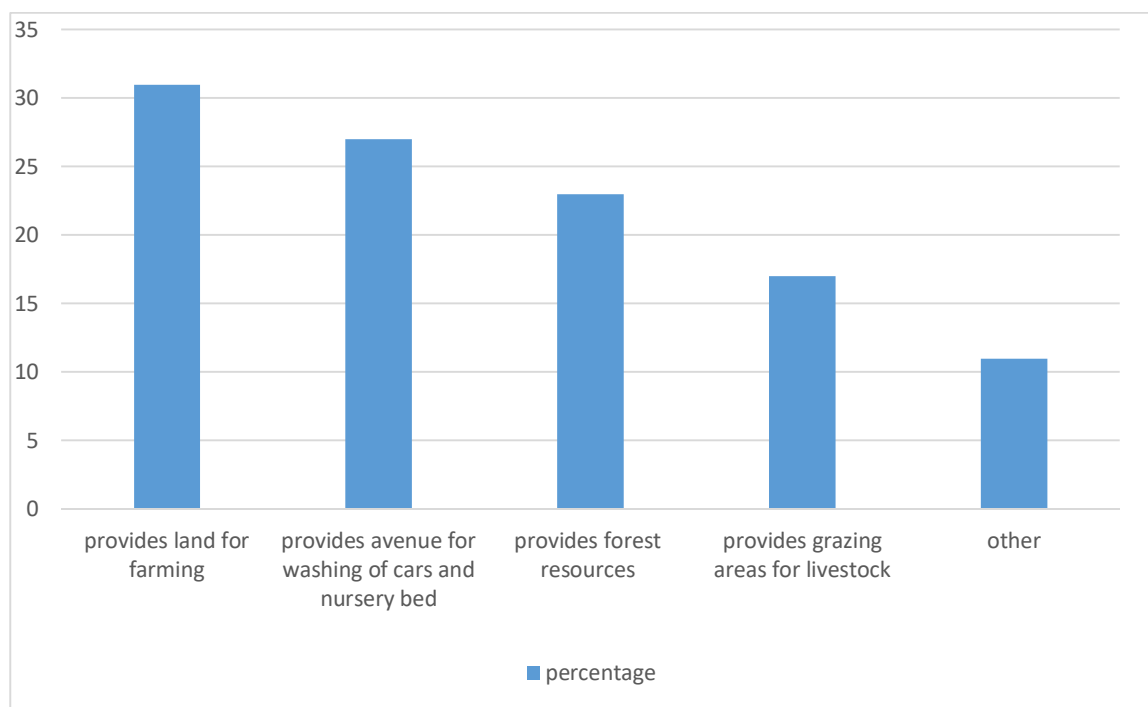


Figure 4: The livelihood activities in KFR

2024) in Zamfara, highlight variations in species composition and underscore the need for bio conservation and integration of traditional knowledge into modern medicine.

Socioeconomic Importance of Mosaic Landscapes in Kanawa Forest Reserve (KFR)

The mosaic landscapes of Kanawa Forest Reserve (KFR),

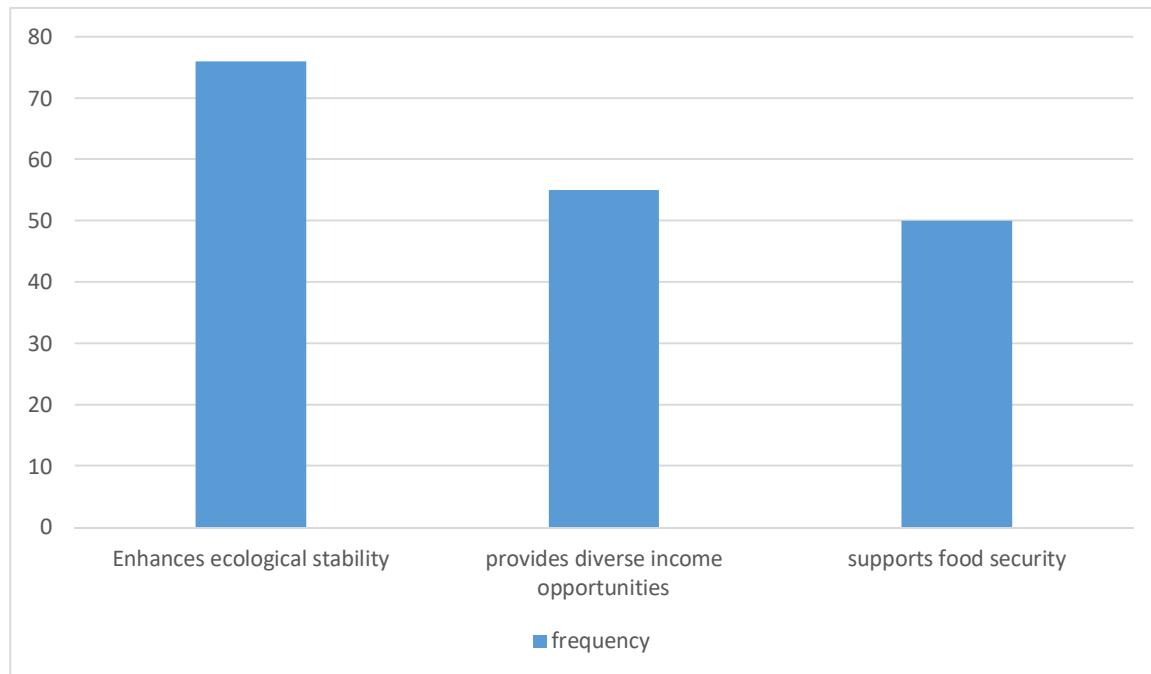


Figure 5: The Interactions with Mosaic Landscapes in KFR

consisting of forests, farmlands, and grazing zones, are crucial for local livelihoods and ecological balance. Most respondents, averaging 42 years in age, possess valuable Traditional Ecological Knowledge (TEK), with 86% being male and primarily engaged in farming, car washing, and livestock rearing. Despite low formal education levels (85% with none), forest dependence is high over 54% rely on it daily for resources like firewood, wild foods, and medicinal plants, this finding aligns with (Onyekwelu *et al.*, 2022), who highlighted the widespread use of traditional medicine and non-timber forest products in rural West Africa due to limited access to modern healthcare. The multifunctionality of these landscapes supports income, food security, and conservation, underscoring the need to integrate traditional practices into sustainable land management.

Conclusion

Kanawa Forest Reserve (KFR) has undergone significant ecological recovery over past 40 years, marked by increased vegetation cover and biodiversity due to effective conservation strategies, including perimeter fencing and natural regeneration. The reserve comprises six ecologically distinct zones, with the highest plant diversity found in lowland areas and the lowest in grasslands, influenced by topography, moisture, and human activities. Vegetation shifts from Grassland/Thorny and Sudan types to expanding Lowland and Riparian/Marshy zones indicate ongoing ecological succession and resilience. Ethnobotanical surveys identified 25 tree and 26 shrub species, predominantly

from the Fabaceae family, widely used in traditional medicine. Improved vegetation has enhanced soil stability, water retention, and climate regulation. KFR sustains the livelihoods of over half of the local population through farming, grazing, firewood, and water-based economic activities. However, unsustainable practices pose long-term risks. Sustainable management, community participation, agroforestry, alternative energy promotion, and support from NGOs like ACRoS AL are essential to balance conservation with livelihood needs and ensure lasting ecological stability.

Recommendations

1. To ensure the long-term sustainability and ecological integrity of Kanawa Forest Reserve, continuous monitoring is essential. It is recommended that a robust, community-inclusive monitoring framework be established, incorporating the use of remote sensing, GIS technologies, and periodic ground truthing to assess changes in vegetation cover, biodiversity, and land-use dynamics.
2. Public Awareness and Reporting Platforms: Develop community education programs and a user-friendly reporting platform (mobile app or hotline) to encourage locals to report illegal activities or environmental changes, fostering community vigilance and rapid response.
3. Periodic Socioeconomic Assessments: Alongside ecological monitoring, regularly assess the socioeconomic impact of the reserve on local livelihoods to balance conservation goals with community needs, ensuring

sustainable resource use

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Authors' Contributions

Prof. Halima Mohammed Abba: Conceptualization of the study, supervision, data interpretation, and manuscript review.

Murma Mari ALI: Field work, data collection, and initial draft of the Statistical analysis. All authors read and approved the final manuscript for publication.

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