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FLORA SPECIES COMPOSITION AND DIVERSITY ACROSS LAND USE TYPES IN JIGAWA STATE, NIGERIA

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ABSTRACT

This study examines the effects of land-use Types (LUT) on flora species (FS) diversity Jigawa's Sahel savanna, Sudan savanna, and wetland ecosystems. Anthropogenic have driven extensive vegetation changes, reduced FS diversity and compromised ecosystem services. Field data were collected using stratified sampling across five established LUT One 100m×100m sample plot sample plots with three replicates were established across three ecosystems. Within each sample plot, tree species (TS) with a diameter at stump height (DSH) ≥ 5.0cm were measured, while shrubs were considered under subplots of 5m×5m. Seedlings and wildlings were considered under the micro-plots of 1m×1m. the following indices: Species evenness, diversity (H') and Richness (D) were used to calculate the ecological indices of the specie, while ANOVA was used to compare between the means across the LUT. A total of 41 TS representing 12 families were recorded. Dominant species such as *Acacia sieberiana*, *Balanite aegyptiaca*, and *Hyphaenea thebaica* recorded 2, 2, and 1 stems/ha respectively in each of the LUT across the ecosystems. Species like *Acacia senegal* dominate agroforestry plots with a frequency of 100%. *Cymbopogon giganteus* (448 stands/ha) and *Crotalaria sp.* (368 stands/ha) were the most abundant species in the Shrub and herbs across the eco-zones. The highest TS, shrubs and herbs evenness (1.21, 0.85 and 1.32), H' (1.24,1.00 and 2.43) and D (1.68, 1.52 and 2.01) respectively.

The results inform conservation strategies and policy-making for mitigating biodiversity loss and ensuring ecological resilience in the face of land degradation.

Key words: Land-use; ecosystems; flora plants; flora shrub species; wetland protected areas

INTRODUCTION

Land use refers to the manner in which human beings employ land for different purposes such as agriculture, forestry, grazing, urban development, and for conservation of flora species. Each type of land use influences the natural landscape in unique ways (Oliver and Moorcroft, 2014). In Jigawa State, where the climate is predominantly semi-arid, extensive land-use practices such as subsistence farming, livestock grazing, extraction of fuelwood, and charcoal production play a major role in shaping the vegetation cover (Mustapha and Salisu 2018). These anthropogenic activities often lead to habitat degradation, a reduction in flora plant species diversity, and changes in ecosystem productivity (Bello *et al*., 2019).

The conversion of natural habitats into agricultural lands or settlements typically results in the loss of biodiversity and ecosystem stability (Pacifici *et al.,* 2015). The reduction in flora species diversity can lead to cascading effects on soil fertility, hydrological cycles, and climate regulation (Olawumi *et al*., 2020). Furthermore, changes in vegetation structure also influence carbon sequestration, an important ecosystem service for mitigating climate change. The shift in land use patterns may reduce the ability of ecosystems to store carbon, leading to increased greenhouse gas emissions (Tijani *et al*., 2023).

Flora plant species, including trees and shrubs, play an essential role in maintaining the health and stability of ecosystems. They provide habitat, food, and protection for various species and are key to maintaining ecological balance. In semi-arid regions like Jigawa State, flora plant species are particularly important for preventing desertification and soil erosion, as well as for maintaining local livelihoods. However, land use activities such as overgrazing, unsustainable agricultural practices, and deforestation threaten the diversity of these species (Ajayi *et al*., 2021).

The increasing demand for land for agricultural, urban, and other developmental activities has led to significant land use changes in Jigawa State, Nigeria, a region characterized by its semi-arid environment. These changes have resulted in the conversion of natural habitats into farmlands, settlements, and other land use types, which has led to the degradation of vegetation and biodiversity loss (Bello *et al*., 2019; Aliyu and Okpara, 2019). Flora plant species, which are essential for maintaining ecosystem stability, preventing desertification, and supporting local livelihoods, are particularly vulnerable to these land use changes. The reduction in species diversity and aboveground biomass accumulation due to deforestation, overgrazing, and unsustainable farming practices threatens ecosystem services such as carbon sequestration, soil fertility, and climate regulation (Olawumi *et al*., 2020; Bakare and Usman, 2021).

This study is critical for understanding how land use changes affect biodiversity and ecosystem functions in semi-arid environments. With land use practices significantly altering vegetation cover and affecting the carbon storage potential of ecosystems, this research will provide essential data for conservation planning and policy-making aimed at combating land degradation and ensuring the sustainability of ecosystem services in Jigawa State (Tijani *et al*., 2023; Yusuf and Bello, 2021).

MATERIALS AND METHODS

The study was carried out in Jigawa State, Nigeria. The state is located on longitude 11.00°N and 13.00°N; and longitudes 8.00°E and 10.15°E. The state has a population of 4,384,649 (NPC, 2016) projected to 6,914,343 in 2024 at 3.5% growth rate. It is largely occupied by the *Hausa/Fulanis* with a few other ethnic groups in some parts of the state.

The mean daily minimum and maximum temperatures are 27ºC and 35ºC respectively (Makama *et al.,* 2018). The temperature increases up to 45ºC between March and May while it reduces to 15ºC between December and January. The rainy season commences in May and lasts till September with an annual range of 600mm-1000mm (Makama *et al.,* 2018). The ecosystem is largely Sahel savanna type with scanty flora plants cover dominated with scattered plants comprising of xerophytes, shrubs and grasses. The state covers a land mass of 22,410km^2 while about 80% of its inhabitants engage in crop farming with livestock, or livestock farming. Arable crop farming, agroforestry, livestock grazing, farm fallows and pockets of protected areas are the major land-use types in the state (Ahmed *et al.,* 2019).

Methods of Data Collection

Jigawa State was stratified into its three ecological zones viz: Sudan Savanna, Sahel Savanna and Wetland Ecosystem. One Local Government Area was purposively selected from each of the ecological zones on the basis of presence of protected areas (Baturia wetland in Kirikasamma, Farin-Dutse Forest Reserve in Gwaram and Tarana Forest Reserve in Maigatari LGA). The other four identified land use types are: Crop Farm, Grazing Route, Agroforestry Plots, Farm Fallow. Baturia Game/Forest Reserve is protected by federal government laws, Farin-Dutse Forest Reserve is under the protection of the state government while Tarana Forest Reserve is under the protection of the nearby community laws. Crop Farm (CF): that is land being used for arable crop production such as sorghum, millet, cowpea, rice.

Protected Area (PA): Forested area protected by federal, state and community laws; not used at all for cultivation (this served as control). Grazing Routes (GR): that is part of land that is being used for livestock grazing. Agroforestry Plots (AP): land area where flora perennials and arable crops are deliberately grown together. Farm Fallow (FF): farm land that has been used for crop production but currently being rested to rejuvenate for at least three years.

Abundance and distribution of flora tree species was assessed from each of the five 100m x 100m (one ha) sample plots established on each land-use type (Brearley *et al.,* 2004 and Thomas, 2006). Within each one-hectare plot, one 5m x 5m quadrat was located at each of the four corners and the center for the measurement of shrubs and saplings. This makes a total of 75 sub-plots for every eco-zone. Furthermore, for the assessment of herbaceous species and seedlings, one 1m x 1m micro plot was located at each of the four corners and the center of each 5m x 5m quadrat. This gave a total of 375 micro plots for every eco-zone.

All flora tree species with Diameter at Stump Hight (DSH) ≥ 5.0 cm were recognized to species level, measured for height, and counted within each of the 100 m × 100 m sample plots. The DSH was measured at a height of 30 cm above the ground (Gehring *et al.,* 2008 and Daniel *et al.,* 2021). This is because most savanna trees are shorter than the conventional height of diameter measurement which is 1.3m above soil level. Taking diameter measurement at stump-height gave a better chance of covering larger percentage of the trees within the sample plots. All flora tree species with DSH ≥ 2cm but ≤ 4.99cm were enumerated within the 5×5m sub-plots. Also grasses, and seedlings of the flora species with stem diameter between greater than 0cm and 1.99cm were counted within the 1m×1m mini-plots.

Data Analysis

Plant community indices were estimated across the different land-use types. Analysis of variance was used to test for significant differences in the indices across the different land use types. A randomised complete block design was used while the ecological zones (Sudan savanna, Sahel savanna and Wetland ecosystems) served as the blocks. The community indices include:

Importance Value Index (IVI), frequency, relative frequency, density, relative density, species richness and abundance, species evenness and species similarity index.

Importance Value Index (IVI) = Relative Frequency + Relative Density + Relative Dominance ---------------------***eqn. 1***

This (IVI) was used to identify the dominant species in the study area.

Frequency

The number of occurrences of individual flora species in a land-use type

Frequency = $\frac{Number\ of\ quadrats\ in\ which\ a\ species\ occur}{Total\ number\ of\ quadrats\ sampled}$ ------------------------------***eqn.2***

Relative Frequency

The degree of dispersion of individual species in an area in relation to the number of all the species that occurred.

Relative frequency = $\frac{Number\ of\ occurrence\ of\ the\ species}{Number\ of\ occurrence\ of\ all\ the\ species}$ X 100 ------------------- ***eqn.3***

Density

This is the concentration of different tree species within an area (land use type).

Density = $\frac{Number\ of\ individual\ species}{Area\ sampled}$ -- ***eqn. 4***

Relative Density

This is the numerical strength of a species in relation to total number of individuals of all the species.

Relative density = $\frac{Number\ of\ individual\ of\ the\ species}{Number\ of\ individual\ of\ all\ species} \times 100$ ---------------------------- ***eqn.5***

Diversity Indices of Plants

The indices used include: Margalef's species richness index; Simpson's and Shannon-wiener diversity index; Hills species evenness and Jaccard similarity coefficient index.

Plant species composition was calculated using diversity indices such as species richness, diversity and evenness. Plant species richness was computed using Margalef (1951) as cited by Spellerberg (1991) and Magurran (2004).

D = $\frac{(S-1)}{In\ N}$ -- ***eqn.6***

Where, D = species richness index (Margalef index), S = number of species and N = the total number of individuals.

Species diversity was estimated using Shannon-wiener diversity index as cited by Spellerberg (1991); Turyahabwe and Tweheyo (2010). The formula is stated as:

$H' = -\sum_{i=1}^{s} P_i\ In\ P_i$---***eqn.7***

Where H' = Species diversity index P_i = the proportion of individuals or the abundance of i^{th} species expressed as a proportion of the total abundance.

Species richness and abundance was integrated into class of diversity measures using Hill's index. The formula is stated as:

$H\alpha = (\sum_{i=1}^{S} P_i^{\alpha})^{1/(1-\alpha)}$--- ***eqn. 8***

Where P_i = the proportional abundance of species *i*th in the sample and α = the order in which the index is dependent of rare species.

Species evenness was measured using Simpson's Index to determine the relative abundance of the different flora plant species. The formula is:

D = $\frac{\sum n\ (n-1)}{N\ (n-1)}$ -- ***eqn.9***

Where D = species evenness; n = total number of individuals of a particular species and

N = total number of flora plants of all species.

RESULTS

Flora species composition and distribution in the different land-use types

A total of 41 flora species representing 12 families were recorded in the land use types across the three eco-zones. In the wetland ecosystem, a total of 26 flora species was encountered, grazing route recording the highest species composition of 16 followed by crop farm with 12 respectively. *Acacia nilotica, Acacia sieberiana, Balanite aegyptiaca,* and *Hyphaenea thebica* were the most frequently occurring species in the protected area with 66.67% to 100% occurrence rates, indicating they are well-adapted to the forest conditions. *Diospyros mespiliformis* and *Hyphaenea thebiaca* show relatively high occurrences in the grazing route with 66.67%, while other species like *Acacia species* and *Balanite aegyptiaca* occur less frequently, reflecting the grazing pressure and land use dynamics. In the Crop Farm, *Balanite aegyptiaca* has the highest occurrence with 100%, indicating its resilience to agricultural disturbance, while other species like *Hyphaenea thebiaca* and *Mitragyna inermis* also show substantial occurrence (66.67%). Agroforestry Plot and Farm Fallow exhibits a lower species diversity but contain species like *Azadirachta indica, Balanite aegyptiaca,* and *Bauhinia rufescens* that appear across different land uses, suggesting their adaptability to diverse environmental conditions.

Diospyros mespiliformis exhibits the highest relative density (15.38%) and high frequency, indicating that it is among the most dominant species in this area. Species like *Acacia species* and *Bauhinia rufescens* show lower relative densities, highlighting their scarcity in heavily grazed lands. In the crop farm, *Balanite aegyptiaca* again stands out with a relative density of 25%, showing its dominance and resilience in agricultural landscapes. In agroforestry and farm fallow, the species are evenly distributed with equal relative densities of 14.29% and 12.50%, respectively, reflecting the small number of species found in these plots. In the protected area, *Acacia sieberiana* has the highest relative dominance (35.08%), followed by *Balanite aegyptiaca* (24.98%), indicating that these species contribute significantly to the forest structure in terms of biomass and canopy cover. *Azadirachta indica* is the dominant species in both agroforestry plot and fallow land, with the highest relative dominance of 57.73% and 14.71%, respectively, indicating its economic and ecological value. In the agroforestry plot, *Azadirachta indica* has the highest IVI (86.30), reflecting its widespread use and adaptability to the agroforestry system. In farm fallow, *Bauhinia rufescens* has the highest IVI (70.80), suggesting its dominance in areas with limited human activity, followed by *Azadirachta indica* (39.71), which is commonly planted and used for various purposes.

The overall observations in the results above indicates that; the most ecologically important species are *Acacia sieberiana, Balanite aegyptiaca,* and *Hyphaenea thebiaca*, reflecting their high occurrence, relative density, and dominance. Species with high IVI, such as *Terminalia superba* (53.93) and *Tamarindus indica* (40.23), are dominant but less frequent, suggesting they may be scattered trees providing essential ecosystem services. *Balanite aegyptiaca* is the most dominant species in farmland, showing resilience to human activities. *Azadirachta indica* dominates, likely due to its economic value and use in agroforestry systems. Species like *Bauhinia rufescens* and *Azadirachta indica* dominate, reflecting the ability of these species to thrive in abandoned or less-disturbed land.

Table 1. Flora plant species composition across different land-use types under the Wetland ecosystem

Species	No of occurrence	Frequency	Relative Density	Relative Frequency	Relative Dominance	IVI
Protected area						
Acacia nilotica	4	66.67	12.50	15.38	5.59	33.48
Acacia sieberiana	7	66.67	21.88	15.38	35.08	72.34
Balanite aegyptiaca	7	66.67	21.88	15.38	24.98	62.24
Bauhinia rufescens	1	33.33	3.13	7.69	0.90	11.72
Hyphaenea thebiaca	7	100.00	21.88	23.08	13.89	58.84
Mitrygna enermis	5	66.67	15.63	15.38	18.64	49.65
Ziziphus spinachristi	1	33.33	3.13	7.69	0.90	11.72
Grazing route	32					
Acacia macrostachya	1	33.33	3.85	5.26	0.18	9.29
Acacia nilotica	1	33.33	3.85	5.26	0.61	9.72
Acacia senegal	1	33.33	3.85	5.26	0.38	9.48
Anogeissus leiocarpa	2	33.33	7.69	5.26	1.67	14.63
Azadirachta indica	2	66.67	7.69	10.52	2.32	20.53
Balanite aegyptiaca	1	33.33	3.85	5.26	0.82	9.92
Bauhinia rufescens	2	33.33	7.69	5.26	1.57	14.53
Diospyros mespiliformis	4	66.67	15.38	10.52	6.02	31.92
Hyphaenea thebiaca	2	66.67	7.69	10.52	3.98	22.19
Mitragyna inermis	1	33.33	3.85	5.26	0.31	9.42
Piliostigma reticulatum	2	33.33	7.69	5.26	3.52	16.47
Prosopis africana	1	33.33	3.85	5.26	1.45	10.56
Tamarindus indica	1	33.33	3.85	5.26	31.12	40.23
Terminalia superba	1	33.33	3.85	5.26	44.82	53.93
Ziziphus mauritiana	3	33.33	11.54	5.26	0.77	17.57
Ziziphus spinachristi	1	33.33	3.85	5.26	0.48	9.59
Crop Farm	26					
Acacia nilotica	2	66.67	8.33	10.53	1.50	20.36
Acacia sieberiana	1	33.33	4.17	5.26	12.87	22.30
Adansonia digitata	1	33.33	4.17	5.26	18.91	28.34
Anogeissus leiocarpus	1	33.33	4.17	5.26	2.45	11.88
Azadirachta indica	2	66.67	8.33	10.53	5.09	23.95
Balanite aegyptiaca	6	100.00	25.00	15.79	26.54	67.33
Diospyros mespiliformis	1	33.33	4.17	5.26	5.72	15.15

Hyphaenea thebiaca	3	66.67	12.50	10.53	19.07	42.09
Mitragyna inermis	2	66.67	8.33	10.53	1.50	20.36
Piliostigma reticulatum	2	66.67	8.33	10.53	0.70	19.56
Tamarindus indica	2	33.33	8.33	5.26	4.66	18.26
Ziziphus spinachristi	1	33.33	4.17	5.26	1.00	10.43
Agroforestry Plot	24					
Azadirachta indica	1	33.33	14.29	14.29	57.73	86.30
Citrus sinensis	1	33.33	14.29	14.29	12.13	40.70
Detarium microcarpum	1	33.33	14.29	14.29	12.13	40.70
Mangifera indica	1	33.33	14.29	14.29	8.67	37.24
Musa sapientum	1	33.33	14.29	14.29	2.71	31.28
Terminalia catappa	1	33.33	14.29	14.29	3.61	32.18
Vernonia amygdalina	1	33.33	14.29	14.29	3.03	31.60
Fallow Land	7					
Acacia nilotica	1	33.33	12.50	12.50	5.72	30.72
Acacia senegal	1	33.33	12.50	12.50	4.12	29.12
Azadiracta indica	1	33.33	12.50	12.50	14.71	39.71
Balanite aegyptiaca	1	33.33	12.50	12.50	12.38	37.38
Bauhinia rufescens	1	33.33	12.50	12.50	45.80	70.80
Ficus sur	1	33.33	12.50	12.50	6.61	31.61
Piliostigma reticulatum	1	33.33	12.50	12.50	6.16	31.16
Ziziphus mauritiana	1	33.33	12.50	12.50	4.50	29.50

The result in Table 2 below indicates that species such as *Acacia sieberiana, Bauhinia rufescens, Diospyros mespiliformis,* and *Tamarindus indica* exhibit the highest frequency (66.67%) in the protected area, indicating their prominent presence in the forest. *Anogeissus leiocarpus, Celtis integrifolia,* and *Combretum glutinosum* show lower frequencies (33.33%), suggesting that they are less abundant or more scattered in the reserve.

The flora plant species in the Grazing route (*Acacia senegal, Acacia nilotica, Azadirachta indica,* and *Ziziphus spinachristi,* as well as *Cymbopogon giganteus* and *Euphorbia balsamifera*) all share a frequency of 33.33%, which indicates a relatively even distribution across the area. *Adansonia digitata, Azadirachta indica, Balsamodendron africanum,* and *Piliostigma reticulatum* show the highest frequency (66.67%) in the crop farm, suggesting these species' resilience to agricultural land use. *Acacia senegal* dominates the Agroforestry Plot, with a frequency of 100%. In fallow land, *Azadirachta indica and Euphorbia balsamifera* have frequencies of 66.67% and 33.33%, respectively. Their presence in fallow land highlights their ability to regenerate in abandoned or less-disturbed land. *Acacia sieberiana* has the highest relative density (23.08%) and a substantial relative frequency (16.67%), making it one of the most dominant species in the reserve. Species like *Piliostigma reticulatum* and *Tamarindus indica* have notable densities and frequencies, contributing to the structural diversity of the forest.

All species in the grazing route (*Azadirachta indica, Balsamodendron africanum,* and *Ziziphus spinachristi*) have an equal relative density (14.29%) and frequency, indicating a fairly even distribution of individuals across the site. *Adansonia digitat*a exhibits the highest relative density (20.00%) and relative frequency (20.00%), reflecting its dominance in the crop farm. *Diospyros mespiliformis* and *Parkia biglobosa* show lower relative densities, indicating that they are less abundant in the crop farm compared to other species. *Acacia senegal* dominates this plot with the highest possible relative density and frequency (100%), suggesting its critical role in the structure and function of the agroforestry system.

Under the protected area, *Piliostigma reticulatum* has the highest relative dominance (24.40%), meaning it has the largest contribution to the forest's basal area or biomass. *Tamarindus indica* and *Diospyros mespiliformis* also show significant relative dominance, suggesting these species provide substantial ecological functions in the forest. *Acacia nilotica* and *Ziziphus spinachristi* also have relatively high dominance (12.13%). *Adansonia digitata* has the highest relative dominance (57.48%), highlighting its considerable size and biomass, making it a key species in the crop farm land-use type. *Tamarindus indica* has the highest IVI (48.52), followed by *Acacia sieberiana* (46.75). These high IVI values suggest that these species are ecologically significant in the protected area, contributing to biodiversity, biomass, and ecosystem functioning. *Diospyros mespiliformis* and *Piliostigma reticulatum* also have relatively high IVI values, making them important species in maintaining the ecological balance of the forest. The result generally shows that, the most important species based on IVI are *Tamarindus indica, Acacia sieberiana,* and *Diospyros mespiliformis*, which contribute significantly to the forest's biomass, biodiversity, and ecosystem services. The species with the highest IVI are *Azadirachta indica, Balsamodendron africanum,* and *Euphorbia balsamifera*, suggesting their resilience and ability to thrive under grazing pressure

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Table 2. Flora plant species composition across different land-use types under the Sahel savanna ecosystem of the state

Species	No of occurrence	Frequency	Relative Density	Relative Frequency	Relative Dominance	IVI
Protected area						
Acacia sieberiana	3	66.67	23.08	16.67	7.00	46.75
Anogeissus leiocarpus	1	33.33	7.69	8.33	19.45	35.48
Bauhinia rufescens	2	66.67	15.38	16.67	4.48	36.53
Celtis integrifolia	1	33.33	7.69	8.33	8.99	25.02
Combretum glutinosum	1	33.33	7.69	8.33	7.97	23.99
Diospyros mespiliformis	2	66.67	15.38	16.67	11.24	43.29
Piliostigma reticulatum	1	33.33	7.69	8.33	24.40	40.43
Tamarindus indica	2	66.67	15.38	16.67	16.46	48.52
Grazing route	13					
Acacia senegal	1	33.33	14.29	14.29	6.82	35.40
Acacia nilotica	1	33.33	14.29	14.29	12.13	40.70
Azadirachta indica	1	33.33	14.29	14.29	18.96	47.53
Balsamodendron africanum	1	33.33	14.29	14.29	18.96	47.53
Cymbopogon giganteus	1	33.33	14.29	14.29	12.13	40.70
Euphorbia balsamifera	1	33.33	14.29	14.29	18.96	47.53
Ziziphus spinachristi	1	33.33	14.29	14.29	12.13	40.70
Crop Farm	7					
Adansonia digitata	2	66.67	20.00	20.00	57.48	97.48
Azadirachta indica	2	66.67	20.00	20.00	5.54	45.54
Balsamodendron africanum	2	66.67	20.00	20.00	5.64	45.64
Diospyros mespiliformis	1	33.33	10.00	10.00	8.14	28.14
Parkia biglobosa	1	33.33	10.00	10.00	14.47	34.47
Piliostigma reticulatum	2	66.67	20.00	20.00	8.74	48.74
Agroforestry Plot	10					
Acacia senegal	17	100.00	100.00	100.00	100.00	100.00
Fallow Land		0.00				
Azadirachta indica	3	66.67	42.86	50.00	33.95	126.81
Euphorbia balsamifera	3	33.33	42.86	25.00	54.79	122.65
Piliostigma reticulatum	1	33.33	14.29	25.00	11.26	50.55

Tamarindus indica, Acacia ataxacantha, Anogeissus leiocarpa, and *Dialium guineense* exhibit the highest frequency (66.67%) as shown in Table 3. This indicates that they are widespread and have a strong presence in the protected area, contributing to the ecological diversity of the area. Species like *Acacia sieberiana, Adansonia digitata, Balanite aegyptiaca,* and *Sterculia setigera* have lower frequencies (33.33%), suggesting a more limited distribution. *Diospyros mespiliformis* and *Parkia biglobosa* have the highest frequency (66.67%), suggesting these species are well-adapted to grazing routes, possibly due to their ability to withstand disturbance from grazing activities.

Tamarindus indica exhibits the highest relative density (14.81%) and frequency (11.11%) in the protected area, indicating it is the most abundant and widespread species in the reserve. This suggests that it plays a key role in maintaining the structure and biodiversity of the forest. *Acacia ataxacantha and Anogeissus leiocarpa* also have relatively high densities (11.11%), showing their importance in the protected area. Other species like *Combretum glutinosum, Ficus ovata, Piliostigma reticulatum,* and *Tamarindus indica* also have significant densities (14.29%) and frequencies, contributing to the crop farm's flora plant diversity. *Adansonia digitata* exhibits the highest relative dominance (44.62%), indicating its large size and biomass contribution, making it a key ecological species despite its lower frequency. *Tamarindus indica* and *Anogeissus leiocarpa* also show significant dominance (19.42% and 6.50%), reflecting their substantial contribution to the protected area.

Tamarindus indica has the highest IVI (45.34), suggesting its ecological importance in the protected area due to its frequency, density, and dominance. *Adansonia digitata* follows with an IVI of 57.59, reflecting its large contribution to the forest's biomass despite lower frequency. *Azadirachta indica* has the highest IVI (92.21), while *Combretum glutinosum and Tamarindus indica* also have notable IVI scores, reflecting their contribution to the structure and functioning of the farm ecosystem.

Table 3. Flora plant species composition across different land-use types under the Sudan savanna ecosystem of the state

Species	No of occurrence	Frequency	Relative Density	Relative Frequency	Relative Dominance	IVI
Protected area						
Acacia ataxacantha	3	66.67	11.11	11.11	1.13	23.36
Acacia sieberiana	1	33.33	3.70	5.56	0.55	9.81
Adansonia digitata	2	33.33	7.41	5.56	44.62	57.59
Afrormosia laxiflora	2	33.33	7.41	5.56	0.67	13.63
Anogeissus leiocarpa	3	66.67	11.11	11.11	6.50	28.73
Balanite aegyptiaca	2	33.33	7.41	5.56	9.02	21.98
Balsamodendron africanum	1	33.33	3.70	5.56	6.09	15.35
Combretum glutinosum	2	66.67	7.41	11.11	1.07	19.59
Dialium guineense	3	66.67	11.11	11.11	2.09	24.31
Gardenia aqualla	1	33.33	3.70	5.56	0.50	9.76
Sterculia setigera	2	33.33	7.41	5.56	7.45	20.42
Tamarindus indica	4	66.67	14.81	11.11	19.42	45.34
Ximenia americana	1	33.33	3.70	5.56	0.88	10.14
Grazing route	27					
Acacia sieberiana	2	33.33	16.67	10.00	0.99	27.66
Anogeissus leiocarpa	1	33.33	8.33	10.00	3.89	22.22
Azadirachta indica	1	33.33	8.33	10.00	1.28	19.62
Combretum glutinosum	2	33.33	16.67	10.00	0.37	27.04
Diospyros mespiliformis	2	66.67	16.67	20.00	1.00	37.67
Parkia biglobosa	2	66.67	16.67	20.00	84.06	120.73
Piliostigma reticulatum	1	33.33	8.33	10.00	2.33	20.67
Tamarindus indica	1	33.33	8.33	10.00	6.07	24.41
Crop Farm	12					
Azadirachta indica	3	33.33	42.86	20.00	29.35	92.21
Combretum glutinosum	1	33.33	14.29	20.00	19.88	54.17
Ficus ovata	1	33.33	14.29	20.00	14.61	48.89
Piliostigma reticulatum	1	33.33	14.29	20.00	16.28	50.56
Tamarindus indica	1	33.33	14.29	20.00	19.88	54.17
Agroforestry Plot	7					

Azadirachta indica	1	33.33	7.69	16.67	1.11	25.47
Eucalyptus camaldulensis	4	66.67	30.77	33.33	10.35	74.45
Parkia biglobosa	8	100.00	61.54	50.00	88.54	200.08
Fallow Land	13					
Acacia sieberiana	1	33.33	12.50	14.29	3.18	29.97
Diospyros mespiliformis	2	33.33	25.00	14.29	6.31	45.60
Ficus ovata	1	33.33	12.50	14.29	66.82	93.61
Piliostigma reticulatum	1	33.33	12.50	14.29	1.67	28.46
Tamarindus indica	3	100.00	37.50	42.86	22.01	102.37
	8					

Cymbopogon giganteus, *Piliostigma reticulatum* and *Cassia singueana* dominate the shrubs species layer recording an occurrence of 8, 8 and 6 respectively. In the herbs layer, it was *Crotalaria sp.*, *Digitaria debilis* and *Ocimum basilicum* that dominate with 34, 32 and 32 stands per land use type.

Table 4. Shrub and Herbs Species Composition Across Different Land-use Types in the Three Ecosystem

Species	No of occurrence	Frequency	Relative Density	Relative Frequency	Relative Dominance	IVI
	Shrubs Species					
Acacia senegal	1	0.03	0.01	2.56	0.89	3.47
Acacia sieberiana	1	0.03	0.02	5.13	1.79	6.93
Azadiracta indica	2	0.06	0.02	5.13	1.79	6.93
Balanite aegyptiaca	2	0.03	0.01	2.56	0.89	3.47
Bauhinia rufescens	1	0.03	0.01	2.56	0.89	3.47
Carica papaya	1	0.16	0.05	15.38	5.36	20.80
Cassia singueana	6	0.19	0.07	20.51	7.14	27.73
Cymbopogon giganteus	8	0.06	0.02	5.13	1.79	6.93
Euphorbia balsamifera	2	0.06	0.02	5.13	1.79	6.93
Leptadenia hastata	2	0.19	0.08	23.08	8.04	31.19
Piliostigma reticulatum	8	0.06	0.02	5.13	1.79	6.93
Ziziphus mauritiana	2	0.03	0.01	2.56	0.89	3.47
	Herbs Species					
Boerhavia diffusa	20	3	0.08	0.11	4.72	10.71
Senna occidentalis	21	3	0.08	0.19	8.27	18.75
Borreria stachydea	13	3	0.08	0.12	5.12	11.61
Crotalaria sp.	34	3	0.08	0.30	13.39	30.36

Borreria stachydea	12	3	0.08	0.11	4.72	10.71
Senna occidentalis	26	3	0.08	0.23	10.24	23.21
Digitaria debilis	32	3	0.08	0.29	12.60	28.57
Waltheria indica	19	2	0.05	0.17	7.48	16.96
Cyperus rotundus	16	3	0.08	0.14	6.30	14.29
Leptadenia hastata	18	3	0.08	0.16	7.09	16.07
Ocimum basilicum	32	3	0.08	0.29	12.60	28.57
Borreria stachydea	4	2	0.05	0.04	1.57	3.57

The result in Table 5 shows that Simpson and Shanonn diversity indices shows a significant difference across the land use types in the trees and Shrubs life forms. In the herbs layer, these diversity indices differ across the land use types, but the diversity is not statistically significant (P≤0.05). Species evenness and richness shows significant differences across the land use types, through the three life forms.

Table 5. Flora Species Diversity according to Life Forms across the Land-use Types

Life form	Land-use Type	Simpson	Shanonn	Evenness	Richness
	Agroforestry Plot	0.55^{c}	0.04^{c}	0.14^{c}	1.56^{ab}
	Crop Farm	1.24^{a}	0.02^{c}	0.32^{c}	0.63^{c}
	Farm Fallow	0.81^{ab}	1.09^{a}	0.52^{b}	1.34^{bc}
Trees	Grazing Route	1.10^{a}	1.42^{a}	1.21^{a}	1.68^{a}
	Protected Area	0.77^{ab}	0.10^{b}	0.72^{ab}	0.84^{c}
	Standard Error	0.02	0.01	0.04	0.17
	P-value	0.04	0.02	0.05	0.02
	Agroforestry Plot	0.45^{b}	0.08^{b}	0.11^{c}	1.52^{a}
	Crop Farm	0.82^{a}	0.04^{c}	0.25^{c}	0.32^{c}
	Farm Fallow	0.11^{c}	1.09^{b}	0.58^{b}	0.41^{c}
Shrubs	Grazing Route	1.00^{a}	0.42^{c}	0.53^{b}	1.32^{ab}
	Protected Area	0.77^{ab}	0.12^{d}	0.85^{a}	0.88^{b}
	Standard Error	0.62	0.03	0.12	0.19
	P-value	0.04	0.02	0.05	0.02
	Agroforestry Plot	1.01^{b}	0.93b	0.53^{bc}	2.01^{a}
	Crop Farm	2.05^{a}	0.85b	0.93^{ab}	1.84^{a}
	Farm Fallow	2.01^{a}	1.42ab	0.45^{c}	0.92^{bc}
Herbs	Grazing Route	2.43^{a}	1.97a	1.32^{a}	1.10^{b}
	Protected Area	1.87^{ab}	1.21ab	0.61^{b}	1.62^{ab}
	Standard Error	0.41	1.02	0.35	0.57^{c}
	P-value	0.06	0.45	0.04	0.03

Treatment bearing different alphabet across a column are significantly different from each other at p ≤ 0.05 using DMRT.

DISCUSSION

Flora species composition and distribution

The results presented align with findings from various studies on species distribution, diversity, and the impact of land use on plant communities in savanna and forest ecosystems. For instance, the dominance of *Acacia nilotica*, *Acacia sieberiana*, *Balanites aegyptiaca*, and *Hyphaenea thebiaca* in the protected area, with high occurrence rates (66.67% to 100%), reflects their adaptation to forest conditions, which is consistent with previous studies that emphasize the adaptability of these species to savanna ecosystems and their role in maintaining ecosystem functions such as nutrient cycling and canopy cover (Oduro *et al*., 2021; Ezeaku *et al*., 2020).

These species' prominence in protected areas demonstrates the success of forest conservation efforts in maintaining species diversity and structure.

In grazing routes, the relatively high occurrence of *Diospyros mespiliformis* and *Hyphaenea thebiaca* (66.67%) suggests their ability to persist under grazing pressure. This finding corresponds with other research indicating that certain flora species have developed resilience to moderate grazing by herbivores, contributing to their ecological significance in heavily grazed landscapes (Ayodele and Ibrahim, 2019). However, the lower frequency of *Acacia species* and *Balanites aegyptiaca* in these areas may suggest overgrazing or competition for limited resources, a phenomenon noted by Oyinlola *et al*. (2022), who found similar patterns of reduced abundance of certain species in heavily grazed areas.

In crop farms, the dominance of *Balanites aegyptiaca* with a 100% occurrence rate highlights its resilience to agricultural disturbance, confirming previous studies that demonstrate its robustness in disturbed environments (Aliyu *et al*., 2020). Species like *Hyphaenea thebiaca* and *Mitragyna inermis*, with substantial occurrences (66.67%), also reflect their ability to thrive in agricultural landscapes, corroborating findings by Nwosu and Adebayo (2023) who reported that certain tree species could coexist with crops, providing shade and soil fertility improvements in farming systems.

The analysis of relative density, frequency, and dominance further supports the ecological importance of certain species across different land uses. For example, the high relative density and dominance of *Hyphaenea thebiaca*, *Balanites aegyptiaca*, and *Acacia sieberiana* in the protected area reflect their significant contribution to the forest structure and biomass. This is consistent with the findings of Musa *et al*. (2022), who reported that these species are key to maintaining the structural integrity and ecological functions of forested areas.

In grazing routes, the dominance of *Diospyros mespiliformis* and the high IVI of *Terminalia superba* and *Tamarindus indica* suggest that even less frequent species can provide essential ecosystem services, such as carbon sequestration and soil stabilization, despite grazing pressures. This supports the argument made by Abdulazeez *et al*. (2020) that certain large-canopy trees can sustain ecosystem functions even in degraded areas. Also, the dominance of *Azadirachta indica* in agroforestry plots and fallow land, with high IVI values (86.30 and 126.81, respectively), highlights the species' economic and ecological value, as also emphasized by Adesina *et al*. (2021). This tree is widely planted for its medicinal, shade, and soil restoration benefits, making it a key species in agroforestry systems across West Africa (Kareem *et al*., 2019). Similarly, the high IVI of *Bauhinia rufescens* in fallow lands aligns with findings from Adeola and Omotosho (2020), who noted its capacity to thrive in abandoned or less-disturbed areas, contributing to the regeneration of degraded lands.

In conclusion, the results of this study are consistent with recent research on the resilience and adaptability of key flora species in savanna and forest ecosystems, particularly in relation to land use dynamics. The dominance of species like *Balanites aegyptiaca*, *Azadirachta indica*, and *Acacia sieberiana* across different land uses underscores their ecological importance and resilience to both natural and anthropogenic disturbances, reinforcing findings from similar studies in the region (Oyinlola *et al*., 2022; Kareem *et al*., 2019).

Conclusion and Recommendations

This research has provided important insights into the effects of land use on plant species diversity, distribution across different ecosystems in Jigawa State, Nigeria. The findings align with previous studies that emphasize the significant role of land-use practices in shaping ecosystem structure and function. Specifically, protected areas demonstrated higher species diversity and dominance of key species such as *Acacia nilotica*, *Acacia sieberiana*, and *Balanites aegyptiaca*, which are critical for maintaining ecosystem stability and nutrient cycling. This highlights the success of conservation efforts in preserving biodiversity and ecosystem functions in forested areas.

In grazing routes, certain species like *Diospyros mespiliformis* and *Hyphaenea thebiaca* showed resilience to grazing pressures, though overgrazing likely reduced the abundance of species like *Acacia* spp. This is consistent with concerns raised in previous studies about the negative impacts of overgrazing on species richness and abundance. Crop farms, while generally having lower species diversity, exhibited the persistence of species such as *Balanites aegyptiaca*, indicating the species' adaptability to agricultural disturbances.

The analysis of Importance Value Index (IVI) across land-use types further highlighted the ecological importance of dominant species, such as *Azadirachta indica* in agroforestry systems and fallow lands, and *Tamarindus indica* in grazing routes, demonstrating the roles these species play in providing ecosystem services, including carbon sequestration, soil stabilization, and biodiversity conservation.

Overall, this research reinforces the understanding that land-use types significantly influence plant species composition, abundance, and ecosystem functioning. Protected areas, agroforestry systems, and fallow lands appear to support higher biodiversity and soil health compared to grazing routes and crop farms, which are subject to greater anthropogenic pressures.

In conclusion, the findings of this study highlight the complex interplay between land-use types, and biodiversity. Sustainable land management practices, such as agroforestry and the use of fallows, can enhance soil fertility, biodiversity, and ecosystem productivity. However, intensive land-use practices, such as continuous cultivation and overgrazing, can deplete essential soil nutrients and reduce biodiversity, particularly in more fragile ecosystems like the Sahel savanna. These results underscore the need for sustainable land management strategies that balance soil health, biodiversity conservation, and agricultural productivity to ensure long-term ecosystem resilience.

The study recommends that there should be an expansion, the designation and enforcement of protected areas to safeguard resilient species like *Acacia sieberiana* and *Hyphaenea thebaica*. Implement participatory community-based monitoring systems to ensure compliance. Encourage the integration of indigenous and economically valuable species, such as *Azadirachta indica* and *Adansonia digitata*, into farming systems to enhance biodiversity while supporting livelihoods. Initiate reforestation and afforestation programs, prioritizing degraded farmlands and grazing zones with native tree species to rehabilitate ecosystems and restore biodiversity. Develop grazing management systems that reduce overgrazing pressure, maintaining species diversity and preventing soil compaction in grazing lands.

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