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Research Article

Species Abundance in Savanna Site-Specific Ecotone of Nigeria

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ABSTRACT

In the savanna ecosystems of Nigeria, quantitative data on species abundance, frequency, and density across different ecotone types remain limited. This study assessed species abundance in five site-specific ecotones within the savanna zone of Nigeria. Five site-specific ecotones were identified as: Forest-Savanna Ecotone, Riparian-Upland Ecotone, Agricultural-Mosaic Ecotone, Rocky Outcrop-Savanna Ecotone, and Wetland-Dryland Ecotone, with the aid of a Moving Split Window Technique of 20m × 20m. Five transects of 200m each were established perpendicular to the confirmed ecotones. Three plots 50m × 50m each representing community before ecotone (A), ecotonal community (B), and community after ecotone (C) were established at 10m intervals. Each plot was gridded into 10m × 10m cells (25 grid cells per plot). All plant species were identified and enumerated in each grid cell. Species density and frequency of occurrence were calculated using standard ecological formulas. The results show that, in the Forest-Savanna Ecotone, *Nelsonia canescens* was most dominant (10 individuals, 28% frequency, 0.40 m^2). At the Riparian-Upland Ecotone, *Cienfuegosia heteroclada* dominated (15 individuals, 40% frequency, 0.60 m^2). In the Agricultural-Mosaic Ecotone, *Anogeissus leiocarpus* was dominant (14 individuals, 40% frequency, 0.56 m^2). At the Rocky Outcrop-Savanna Ecotone, *Uapaca togoensis* recorded the highest abundance (20 individuals, 40% frequency, 0.80 m^2). In the Wetland-Dryland Ecotone, *Crossopteryx febrifuga* was dominant (16 individuals, 28% frequency, 0.64m2). Species dominance in savanna ecotones of Nigeria is highly site-specific, with no single species universally dominant across all transition zones, which is a clear reflection of localized environmental gradients, disturbance regimes, and edaphic conditions.

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1 Introduction

The ecosystem is identified by species-rich and diverse plant communities, with its distributional patterns remaining a central question in ecology (Gaviria et al., 2017). Efforts to unravel such patterns abound and have spanned a long period of time, with testimonials of such seen in the development of theories, models, and hypotheses surrounding tropical ecology, biogeography, and more recently its biogeochemical cycles. The impact of environmental changes on future habitat suitability and its influence on species occurrence and species abundance is necessary in ecological research (Guisan et al., 2017). Abundance means the number of species or population density, or a measure of dominance and evenness, which reveals the ability of a species to occupy a given area (Ren et al., 2009; Shi et al., 2015). The transition zones (ecotone) often portray a pattern of increased species richness, density, frequency, diversity, and biomass (Chase, 2014; Igu, 2023).

The increased biodiversity and density in transition zones can be due to overlapping distribution ranges from species occurring on either side of the transition zone. They can result in an additional set of species that are specifically adapted to withstand the rapidly changing environmental gradients at the transition zone, relative to the two adjoining habitats (Kark, 2013). Site-specific ecotones are distinct, localized transition zones between two or more adjacent ecological communities (such as Forest-Savanna Ecotone, Riparian-Upland Ecotone, Agricultural-Mosaic Ecotone, Rocky Outcrop-Savanna Ecotone, and Wetland-Dryland Ecotone) that possess unique characteristics, species compositions, and physical properties adapted to that specific location.

Many ecotonal studies have been on species conservation, speciation (Igu, 2023; Lemessa et al., 2023), Vegetation response to climate warming, Ecological Gradients (Løkken et al., 2020; Rahman et al., 2021), and distribution of dominant trees and plant functional groups (Marod et al., 2019; Ross, 2016). Nevertheless, there is a dearth of knowledge on species abundance at the site-specific (localised) ecotone of the Northern Guinea savannah ecosystem of Nigeria. Southern Kaduna is found at the transition zone between the Northern Guinea savannah ecosystem and the Southern Sahel ecosystems (Adeofun, 2019).

At the ecotonal zone, there exists a remarkable climatic gradient that differs significantly from either side of the ecotone, and because of this, there is a general argument that the species composition and diversity development at the ecotone is diversified compared to what is observable on either side of the ecotone, and because of the nature of the transition zone, there tends to be more species abundance. However, in the current study area, there is

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no empirical study to confirm this assumption and constitute the focus of these studies. This work focused specifically on the species abundance and frequency of species occurrence at the site-specific ecotone of the Guinea Savanna ecosystem of Nigeria.

2 Materials and Methods

2.1 Study Area

The study was carried out in the Northern Guinea-savanna forest mosaic of southern Kaduna, Kaduna State, Nigeria (9°10'N to 10°10'N and 7° 10'E to 8° 10'E (Figure 1). The mean daily minimum and maximum temperatures are 16°C to 22°C and 30°C to 36°C (Ibrahim, 2011). The mean relative humidity is 70-85%. The rainy season begins at the end of March and ends in late October with an annual rainfall of 1,300 - 1,450 mm (Odunuga & Raji, 2012). The landscape is made up of an undulating plain dotted with granitic inselbergs underlain by Basement Complex rocks of igneous and metamorphic origin, characterized by a hilly and dissected landscape with rocks consisting mainly of Migmatite (gneiss) and Schists (Mallo, 1987). The study area is within the Guinea savanna ecosystem of Nigeria.

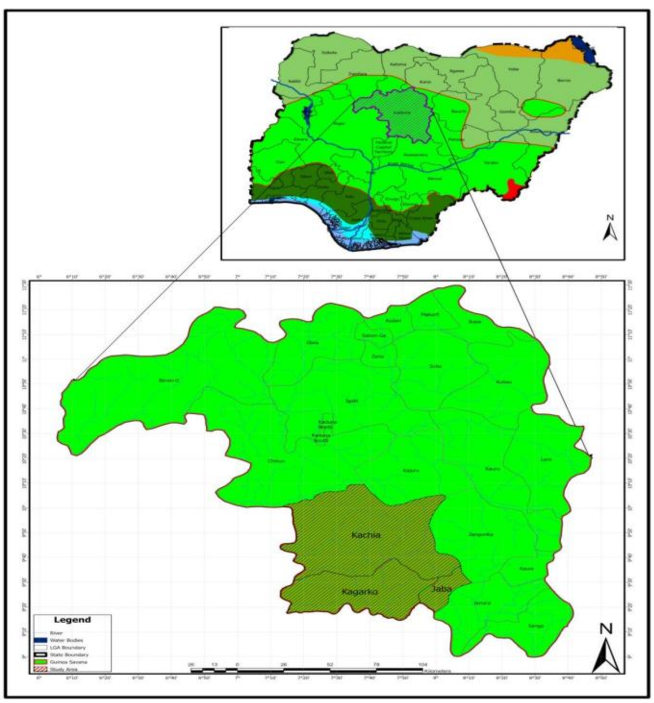


Figure 1: Map of the study area with local government, State and Nigeria

The vegetation is characterised by open deciduous woodland with tall grasses (1 to 3m high) in open areas and trees (up to 15m high) possessing short boles and broad leaves. The vegetation is transitional woodland situated between the high forest with complete tree cover in the Gallery forests (fringing forests) at the foot of rocky hills, deep gorge-like rivers, valley heads, and adjacent interfluves. The common the tree species include *Afromosia laxi Flora, Vitexdoniana, Khayasenegalensiis, Terminalia Spp, Daniellia oliveri, Hymenocardia acida, Detarium microcarpum Afzelia africana Acacia sieberana, Annona senegalensis, Bombax buonopozense, Combretum lamprocarpum, Commiphora africana, Ficus spp, Piliostigma reticulatum, Sphaeranthus augustifolius, Sterculia setigera, Strychnos spp., Vitellaria paradoxa,* among others (Mallo, 1987; Ibrahim, 2011).

2.2 Data Collection

Five (5) site-specific ecotones were identified: Forest-Savanna Ecotone, Riparian-Upland Ecotone, Agricultural-Mosaic Ecotone, Rocky Outcrop-Savanna Ecotone, and Wetland-Dryland Ecotone.

The presumed ecotone was confirmed using a Moving Split Window Technique with continuous plots of 20 m x 20 m set up perpendicular to the presumed boundary and was split into half-windows of 10 m x 10 m. All plant species presence was enumerated and recorded within each plot. The window was then shifted along the transect line by one plot in each step, and the observations were recorded in all positions. The dissimilarity function was plotted against spatial positions to mark boundary peaks. High and narrow peaks represent sharp boundaries; double peaks that merge represent transitional zones (Erdős et al., 2014). Figure 2 bellow show Ecotonal position of the identified ecotones.

Table 1: The identified site-specific ecotones.

Ecotonal type	Latitude	Longitude
Forest-Savanna	9°40',	7°55'
Riparian-Upland	9°42',	7°42'
Agricultural-Mosaic	9°42',	7°44'
Rocky Outcrop-Savanna	9°38',	7°48'
Wetland-Dryland	9°36',	7°38'

The ecotonal community at Forest-Savanna ecotone was found at the plot position 9 and 11, the high and narrow peaks was 23 while the double peaks that merge was 19 (Table 1 and Figure 2a). The ecotonal community at Riparian-Upland ecotone was found at the plot position 9 and 11, the high and narrow peaks double was 25 while the double peaks that merge was 18 (Table 1) and (Figure 2b).

At the Agricultural-Mosaic ecotone, the ecotonal community was found at the plot position 13 and 15, the high and narrow peaks double was 23 while the double peaks that merge were 20 and 19 respectively (Table 1) and (Figure 2c).

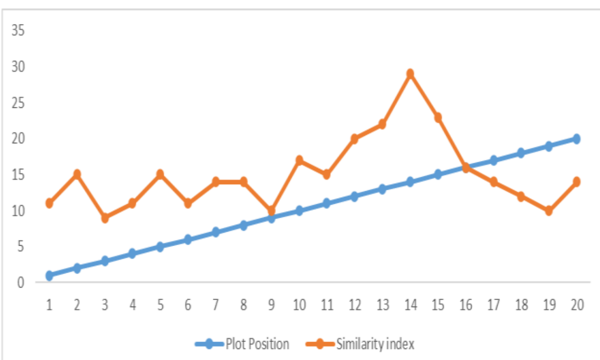
The ecotonal community at Rocky Outcrop-Savanna ecotone was found at the plot position 6 and 8, the high and narrow peaks was 27 while the double peaks that merge were 23 and 22 respectively. (Table 1) and (Figure

2d).

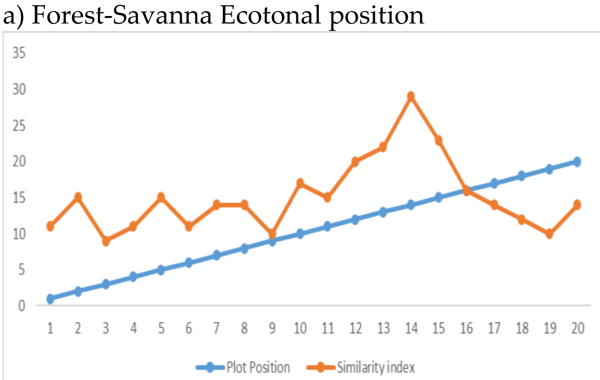
The ecotonal community at Wetland-Dryland ecotone was found at the plot position 13 and 15, the high and narrow peaks double was 29 while the double peaks that merge were 22 and 23 respectively (Table 1) and (Figure 2e).

A total of five (5) transects line of 200m were set up perpendicular to the identified ecotones.

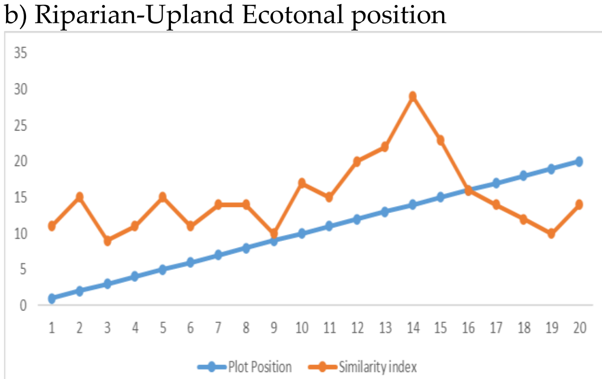
Three (3) plots; A (community before the ecotone), B (Ecotonal Community), C (Community after the Ecotone) of 50m × 50m at interval of 10m were established along the Transact with the ecotone in-between the two communities). The three plots each was gridded into 10m ×10 cells which sum up to 25 grid cells per plot. All the plants species were identified, enumerated, in each grid cell of each plot. The procedure was repeated at the identified ecotone until the required data was obtained.



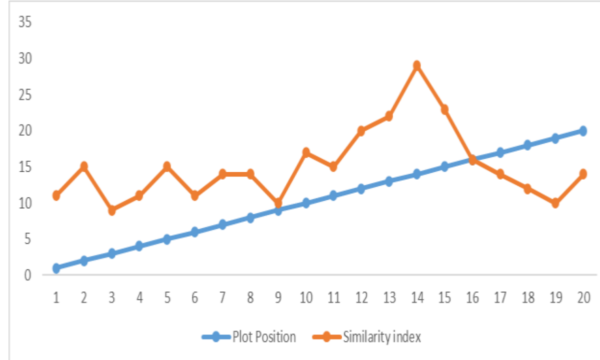
a) Forest-Savanna Ecotonal position



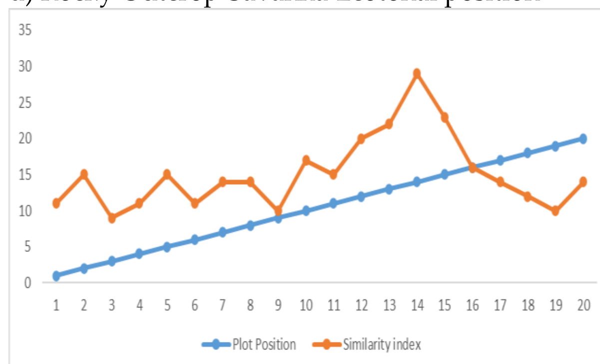
b) Riparian-Upland Ecotonal position



c) Agricultural-Mosaic Ecotonal position



d) Rocky Outcrop-Savanna Ecotonal position



e) Wetland-Dryland Ecotonal position

Figure 2: Similarity index of Ecotonal position

2.3 *Methods of Data Analyses*

Density and Frequency of species occurrence were calculated. The density was calculated as;

$$\textbf{Density} = \frac{\Sigma(\mathbf{SPP})}{\mathbf{A}} \qquad \text{i}$$

Where:

Spp = sum of individual species
A = Sampled area

$$\textbf{Frequency} = \frac{q}{Q} \qquad \text{ii}$$

Where: q = number of quadrats in which the species occurred
Q = total number of quadrats sampled.

3 Results

The detailed statistics on frequency and density characteristics of the species in the study area, as presented in the results is shown in Table 2.

In the forest-Savanna Ecotone, the most dominant species was *Nelsonia canescens*, having 10 individuals, 28% frequency of occurrence, and covered a unit area of 0.40 m², followed by *Anogeissus leiocarpus* and *Crossopteryx febrifuga*, with 10 individuals, 20% frequency of occurrence, and covered a unit area of 0.32 m² each, as seen in Table 2.

The most dominant species at Riparian-Upland Ecotone was *Cienfuegosia heteroclada* with 15 individuals, 40% frequency of occurrence, and covered a unit area of 0.60 m2, followed by *Anogeissus leiocarpus* with 12 individuals, 32% frequency of occurrence, and covered a unit area of 0.48 m^2 (Table 2).

At Agricultural-Mosaic Ecotone, the most dominant species was *Anogeissus leiocarpus*, with 14 individuals, 40% frequency of occurrence, and covered a unit area of 0.56 m^2, followed by *Dioscorea bulbifera* with 12 individuals, 28% frequency of occurrence, and covered a unit area of 0.56 m^2 (Table 2). The most dominant species at Rocky Outcrop-Savanna Ecotone was Uapaca togoensis with 20 individuals, 40% frequency of occurrence, and covered a unit area of 0.80 m^2, followed by Cienfuegosia heteroclada, with 19 individuals, 36% frequency of occurrence, and covered a unit area of 0.76 m^2 (Table 2).

At the Wetland-Dryland Ecotone, *Crossopteryx febrifuga* had 16 individuals and 28% frequency of occurrence. It covered a unit area of 0.64 m^2, followed by *Syzygium guineense* and *Hymenocardia acida* with 12 individuals, 32% frequency of occurrence, and covered a unit area of 0.48 m^2 each.

Table 2: Density and frequency distributions of species at the site-specific ecotone of the study area.

		Forest Savanna Ecotone			Riparian-Upland Ecotone			Agricultural-Mosaic Ecotone			Rocky Outcrop-Savanna Ecotone			Wetland-Dryland Ecotone		
S/N	Species Name	No. of individual	% Freq	Density	No of individual	% Freq	Density	No. of individual	% Freq	Density	No. of individual	% Freq	Density	No. of individual	% Freq	Density
1	*Ficus spp.*	6	16	0.24	5	12	0.20	2	8	0.08	5	8	0.20	9	20	0.36
2	*Vitex doniana*	3	8	0.12	2	4	0.08	4	12	0.16	3	8	0.12	5	12	0.20
3	*Syzygium guineense*	6	20	0.24	11	24	0.44	8	12	0.32	8	20	0.32	12	32	0.48
4	*Strychnos spp.*	1	4	0.04	2	4	0.16	2	4	0.08	1	4	0.04	-	-	-
5	*Piliostigma reticulatum*	7	16	0.28	7	12	0.28	9	20	0.35	9	20	0.36	10	20	0.40
6	*Daniellia oliveri*	4	8	0.16	3	8	0.12	4	16	0.16	3	4	0.12	4	16	0.16
7	*Gardenia aqualla*	2	4	0.08	1	4	0.08	-	-	-	2	8	0.08	2	4	0.08
8	*Erythrophleum guineense*	3	4	0.12	6	16	0.24	5	8	0.20	3	8	0.08	3	4	0.12
9	*Bombax buonopozense*	4	16	0.6	2	8	0.08	2	4	0.08	3	4	0.12	7	3	0.28
10	*Khaya senegalensis*	2	8	0.08	3	8	0.12	4	12	0.16	-	-	-	-	-	-
11	*Anogeissus leiocarpus*	8	20	0.32	12	32	0.48	14	40	0.56	8	12	0.32	8	3	0.32
12	*Milicia excels*	6	16	0.24	7	20	0.28	4	16	0.16	4	4	0.16	5	8	0.20
13	*Pterocarpus erinaceus*	2	8	0.08	-	-	-	4	8	0.16	3	8	0.12	3	12	0.12
14	*Berlinia auriculata*	-	-	-	5	12	0.20	2	8	0.08	2	8	0.08	-	-	-
15	*Ekpakpaga*	1	4	0.04	2	8	0.08	3	12	0.12	4	12	0.16	1	4	0.04
16	*Citharexylum spinosum*	6	20	0.24	7	20	0.28	12	24	0.48	11	20	0.44	7	12	0.28
17	*Vernonia amygdalina;*	2	4	0.08	4	16	0.16	3	12	0.12	1	4	0.04	2	4	0.08
18	*Commiphora africana*	5	12	0.20	5	12	0.20	6	16	0.24	5	12	0.48	7	20	0.28
19	*Gmelina arborea*	1	4	0.04	1	4	0.04	2	8	0.08	1	4	0.08	3	8	0.12
20	*Detarium microcarpum*	4	8	0.16	3	8	0.32	1	4	0.04	3	4	0.12	4	16	0.16
21	*Boswellia dalzielli*	2	8	0.08	-	-	-	2	8	0.08	1	4	0.04	3	12	0.12
22	*Crossopteryx febrifuga*	8	20	0.32	10	20	0.40	10	28	0.40	18	26	0.72	16	28	0.64
23	*Ceiba pentandra*	1	4	0.04	2	8	0.32	2	8	0.08	1	4	0.04	-	-	-
24	*Elaeis guineensis*	3	8	0.12	3	12	0.44	3	8	0.12	1	4	0.04	4	12	0.16
25	*Afrormosia laxiflora*	7	16	0.28	9	20	0.36	6	24	0.24	12	20	0.48	9	20	0.36
26	*Cienfuegosia heteroclada*	6	20	0.24	15	40	0.60	11	28	0.44	19	36	0.76	10	32	0.40
27	*Diospyros mespiliformis*	4	8	0.16	4	8	0.16	6	20	0.24	4	16	0.16	5	20	0.20
28	*Thelepogon elegans*	2	4	0.08	3	12	0.12	4	8	0.16	4	8	0.16	-	-	-
29	*Parkia biglobosa*	6	12	0.24	8	20	0.32	3	4	0.12	6	12	0.24	6	8	0.24
30	*Piptadeniastrum*	4	16	0.16	3	8	0.12	5	8	0.20	2	8	0.08	-	-	-
31	*Hymenocardia acida*	6	12	0.24	6	16	0.24	6	20	0.24	8	16	0.32	12	20	0.48
32	*Acacia macrothyrsa*	3	8	0.12	5	8	0.20	6	12	0.24	5	12	0.20	4	12	0.16
33	Blighia sapida	3	4	0.12	4	12	0.16	4	16	0.16	2	8	0.08	2	4	0.08
34	*Hibiscus asper*	3	12	0.12	-	-	-	-	-	-	2	4	0.08	1	4	0.04
35	*Phoenix reclinata*	3	4	0.12	-	-	-	-	-	-	2	4	0.08	-	-	-
36	*Nelsonia canescens*	10	28	0.40	4	12	0.16	11	24	0.44	17	36	0.68	7	20	0.28
39	*Ficus tricopoda*	5	8	0.20	2	4	0.08	3	8	0.12	3	4	0.12	2	4	0.08
34	*Giparaam*	4	12	0.16	5	20	0.20	5	12	0.20	-	-	-	-	-	-
35	*Dialium guineense*	2	4	0.08	8	20	0.32	7	16	0.28	4	8	0.16	6	8	0.24
36	*Carissa edulis*	3	12	0.12	3	12	0.12	3	12	0.12	4	12	0.16	5	8	0.20
37	*Mangifera indica*	5	16	0.20	1	4	0.04	3	4	0.12	3	12	0.12	2	4	0.08
38	*Fagara zanthoxyloides*	1	4	0.04	2	8	0.08	3	12	0.12	-	-	-	-	-	-
39	*Ubinwoyenyenge*	3	8	0.12	3	8	0.12	-	-	-	-	-	-	1	4	0.04
40	*Psidium guajava*	5	16	0.20	3	12	0.12	2	4	0.08	2	8	0.08	3	12	0.12
41	*Vitellaria paradoxa*	5	12	0.20	5	20	0.20	5	16	0.20	2	8	0.08	8	12	0.32
42	*Cassia arereh*	3	8	0.12	5	20	0.20	6	12	0.48	18	32	0. 72	10	20	0.40

43	*Prosopis africana*	7	20	0.28	3	8	0.12	2	4	0.16	5	8	0.20	6	20	0.24
44	*Dichrostachys cinerea*	5	20	0.20	5	16	0.20	7	16	0.28	5	12	0.20	4	8	0.16
45	*Combretum lamprocarpum*	7	16	0.28	4	16	0.16	6	16	0.24	3	8	0.12	9	16	0.36
46	*Terminalia spp.*	5	8	0.20	5	12	0.20	3	12	0.12	6	12	0.24	4	4	0.16
47	*Wukpangu*	4	8	0.16	-	-	-	-	-	-	5	12	0.20	-	-	-
48	*Cussonia barter*	7	16	0.28	4	8	0.16	5	8	0.20	6	12	0.24	10	16	0.40
49	*Stereospermum kunthianum*	-	-	-	5	20	0.20	-	-	-	4	8	0.16	10	24	0.40
50	*Uapaca togoensis*	5	16	0.20	7	20	0.28	9	24	0.36	20	40	0.80	7	12	0.28
51	*Annona senegalensis*	5	12	0.20	4	12	0.16	5	4	0.20	5	12	0.20	4	8	0.16

4 Discussion

The tree species framework of the forest-savanna ecotone comprised 49 individuals (Table 2) that differed in species occurrences across the ecotone. This finding does not support the work of Ndah et al. (2013), who studied Species composition, diversity, and distribution in a disturbed Takamanda Rainforest, South West, Cameroon, using Linear transects and recorded A total of 99 species (72 trees and 27 shrubs) belonging to 87 genera and 34 families, which is less than what was currently observed in the present study area.

Furthermore, Igu (2023) observed 43 species within 22 families, which ranged from 1.82-2.5, and the results obtained contradict my findings, which are significantly higher than those obtained from his study. The difference in value may be due to human intervention in natural vegetation, which tends to affect species composition and diversity.

The low presence of species in the forest savanna ecotone was due to fire-dependent savannas that bordered fire-sensitive forests, which are regularly exposed to savanna fire with its implications on species composition and diversity. This finding agreed with the work of Balchh et al. (2015).

The results at the riparian-upland ecotone revealed a low presence of species when compared with the findings of Cosmas (2016), who observed a total of 261 plant species in 68 families in the Wami River system. Furthermore, the findings contradict the records of Humnessa (2022), who recorded *Acacia abyssinica, Juniperus procera, and Olea africana* as the most dominant tree species. The finding also contradicts Dolanc et al. (2017), who found that Species richness was three to four times greater in riparian areas compared with upland areas, and there was little overlap of the more-abundant herbaceous species. In addition, riparian forests were generally denser, with smaller trees in mixed-conifer forest.

The findings at Rocky outcrop-savanna ecotones contradicted Van der Plas and Olff (2024), who observed a total of 41 woody species, with 37 found on kopjes and 18 found on matrix plots. Twenty-three species were exclusively found on kopje (Scattered steep-sided hills) plots, and four species exclusively on matrix plots. The five most frequently observed species were *Commiphora schimperi* (present in 34 plots), *Grewia bicolor* (present in 23 plots), *Turraea fischeri* (present in 22 plots), *Cordia ovalis* (present in 20 plots) and *Vachellia tortilis* (present in 20 plots). Of these, *Grewia bicolor* and *Cordia ovalis* were exclusively found on kopje plots. The present study recorded lower numbers of species when compared with Mignaut et al. (2010), who recorded a total of 709 vascular plant species, and 394 morpho-species were recognized within the 191 plots. The four plant communities recognized correspond to three groups of inselbergs distinct by their geographical location.

The findings at Agricultural-Mosaic Ecotone contradict Aguiar et al. (2023), who found that agricultural ecotones in the Canadian prairie were dominated by herbaceous plants (weeds). *Anogeissus. leiocarpus* is native to tropical Africa and experiences different disturbance regimes that can persist in agricultural mosaics because it resists fire and drought, and may be retained by farmers for shade, fodder, or medicine. The finding aligns with Del Barrio's et al. (2006), who observed that woody vegetation can persist at ecotones when the adjacent matrix is not intensively tilled annually. However, unlike the Mediterranean study where woody edges were diverse, in the present study, the ecotone is dominated by one woody species (*A. leiocarpus*) with relatively low diversity. This suggests that the site may be under moderate disturbance or early succession, where a single pioneer tree dominates before other species establish. The total number of species recorded in the current study was less than what was recorded by Nautiyal et al. (2020), who observed a total of 81 species, comprising 29 species of trees, 21 shrubs, and 31 herbs at the field margin vegetation in the rural-urban interface of Bengaluru, India.

At the wetland-dryland ecotone, the finding partially confirms Del Barrio et al. (2006), whose studies emphasized high diversity within those woody edges (many species, each with unique roles) rather than low woody diversity at the dominance level where three species make up the majority. The finding contradicts Cawood et al. (2025), who recoded highest Species richness in the drier zones (grassland, wet meadow, and shallow marsh zones), decreasing in the deep marsh zone, and lowest in the open water zone. The finding also contradicts Li et al. (2007), who found that the ecotone had the highest richness indices (R) and comprehensive diversity indices (Y), reflecting the edge effect. The findings disagree with Zhang et al. (2008), who observed that the transition zone between wetland-dry grassland ecotone is dominated by meadow vegetation species, which are mainly mesophytic, and their representative association is *Nitraria tangutorum* + *Pennisetum flaccidum*. Whereas in the current study, the ecotone was dominated by tree species such as *Crossopteryx febrifuga, Syzygium guineense,* and *Hymenocardia acida.*

5 Conclusion

Species dominance in savanna ecotones of Nigeria is highly site-specific, with no single species universally dominant across all transition zones. Each ecotone supports a distinct dominant species: *Nelsonia canescens* (Forest–Savanna), *Cienfuegosia heteroclada* (Riparian–Upland), *Anogeissus leiocarpus* (Agricultural–Mosaic), *Uapaca togoensis* (Rocky Outcrop–Savanna), and *Crossopteryx febrifuga* (Wetland–Dryland), which is a clear reflection of localized environmental gradients, disturbance regimes, and edaphic conditions.

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