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COMPARATIVE ANALYSIS OF DENSITY, DIVERSITY AND SIMILARITY OF FOREST TREE SPECIES IN THREE SELECTED STATES OF NORTHERN NIGERIA

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ABSTRACT

This study compared forest tree density, species diversity, and similarity in some selected States of northern Nigeria. Fifteen percent intensity of the survey was carried out on 150 ha, 50ha in each of the States for the studies. A total number of two hundred and forty-nine Quadrants of 30m x 30m, (83 Quadrates in each of the States under study) were randomly distributed within the plot of 10,000m²/ha. Number of species, corresponding number of individuals, and diameter of individuals found in the Quadrates were taken. Basal Area, Frequency, Relative Frequency, Relative Density, Relative Dominance, and Importance Value Index (IVI) were analyzed. Shannon-Wiener diversity Index, Species Evenness, Species Richness, Index of Dominance, Index of Similarity, and Index of Dissimilarity analysis were carried out. ANOVA was used to evaluate the differences in the stand densities. The results revealed that 47 species, 17 Families, 13 Orders, and 1 Kingdom were encountered in the Study area. Adansonia digitata had the highest value of BA; Relative Dominance; and IVI. Relative Density ranged from 1.09 to 7.14. The result of Shannon-Wiener Diversity Index ranged from -68.31 to -42.33; Species Richness ranged from 8.30 to 13.49; Evenness Index ranged from -48.86 to -26.08; Index of Dominance ranged from 294.11 to575.47. Index of Similarity ranged from 0.60 to 0.86. There were no significant differences (p>0.05) between the tree densities in the Study Area. Evaluating tree density patterns and tree species diversity is important for the forest managers to understand the complexity and resources of forests.

Keywords: Comparative Analysis; Forest Trees; Species Diversity; and Tree Density

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INTRODUCTION

Devastating effects of unsustainable human activities on forest trees and forest resources has resulted in the reduction of tree density and species diversity and therefore reduction in the ecosystem functioning. Forest trees play an important role in mitigating the negative impact of climate change, in maintaining fundamental ecological processes as well as providing livelihoods and supporting economic growth. The nature of forest communities largely depends on the ecological characteristics of sites, species diversity, and regeneration status of tree species (Shuaibu and Ogunsola, 2018; Salami *et al.*, 2014). FRA (2000) defined trees as a woody perennial with a single main stem, or in the case of coppice with two or more stems, having a more or less definite crown which includes bamboo, palms, and other trees meeting the above criterion. Trees form the major structural and functional basis of forest ecosystems and can serve as very good indicators of changes in our environment (Shuaibu and Ogunsola, 2018). According to Rabi'u *et al.* (2013), trees are an

integral part of land resources that need careful management and sustainability for the utilization of future generations. In natural resource measurements, "density" is generally referred to the number of items per unit area (Bonham, 1989), for example, plants/m^2 or trees/ha. Tree Density is defined as the number of trees per unit area and is generally referred to as the number of trees per hectare. Tree stand density gives foresters an idea of how closely trees are growing in a given area.

Diversity is generally a function of the relative distribution of individuals among species. Tree species diversity refers to the abundance of different tree species living within a particular area or region (Shuaibu, 2014); the higher the tree diversity of an ecosystem, the more efficient the ecosystem functioning. Hengaveld (1996) stated that species diversity is an important attribute of a natural community that influences the functioning of an ecosystem. The density, species richness and diversity of trees are very important to total forest biodiversity, because trees provide resources and habitat for almost all other forest biological diversity. The diversity of trees is fundamental to the total tropical rainforest diversity as trees provide resources and habitat structure for almost all other forest species (Cannon *et al.*, 1998). Assessment of forest community composition and structure is very helpful in understanding the status of tree population, regeneration, and diversity for conservation purposes (Mishra *et al.*, 2013). Floristic inventory of forest helps to present accurate data on the vegetation composition which is desirable for issues of planning and the restoration of the degraded and disturbed forest areas (Salami and Lawal, 2018). Tree density and species diversity of tropical forest ecosystems is known to be very dense and high but that has changed because tropical forests are now being deforested every day unsustainably and converted to other uses without replanting the trees. Understanding species diversity and density patterns is important for helping forest managers evaluate the complexity and resources of forest (Shuaibu and Ogunsola, 2018). Fuwape (2003), stated that tree harvesting adversely affects the population and variety of plant and animal species in the forest. Humankind has over-exploited the forest resources and overloaded the environment which resulted in significant changes such as a reduction in vegetative cover, quality, species extinction, and reduction in water level, which are collectively disturbed as environmental degradation (Akinyemi *et al.*, 2020). Aluko *et al.* (2010), revealed that it is on record that open and closed forests in the tropics are being destroyed at the rate of between 3.8 and 7.5 million hectares per year.

Changes in stand density and tree species diversity due to human alterations and natural phenomenon may affect both the timber yield from a site and the sizes of the individual trees on it, and loss of some biological diversity within the forest ecosystem. Indiscriminate logging of forest stands for fuel, agriculture, construction purposes, and urbanization due population explosions coupled with the fact that some of the users of forest resources believed that it is a mere waste of time to plant trees since trees are known to grow naturally on land as a free gift of nature has resulted in the reduction and loss in forest stand density and forest tree species diversity. Quantitative and qualitative information on composition, distribution, and abundance of forest tree species is of key significance to understanding the form and structure of a forest community and also for planning and implementation of conservation strategies of the forest communities. Since efficient management of a forest necessitates careful regulation of tree stand density and forest tree species diversity, there is therefore a need for quantitative and qualitative descriptions.

The objective of this study was to compare tree density, tree species diversity and tree species similarity in the Study Area. Forestry practices require a great deal of information about the density of forest trees and forest tree species diversity. Understanding the patterns of stands density, forest tree species diversity and similarity is important for helping the individuals and forest managers to evaluate the complexity and resources of forests. Therefore, assessing the status of stand density, tree species diversity and their similarity in the Study areas will be very useful to determine the conservation strategies required to protect the forest stands, regenerate

species of interest and to manage the species diversity in a sustainable manner which could results in sustainable utilization, management, and conservation of tree stands by the communities in the Study areas.

MATERIALS AND METHODS

Study area

This study was carried out in three States of Northern Nigeria. They include Bauchi, Katsina, and Kogi States. Nigeria is a country in West Africa, it lies on latitude 7° 48N and longitude 10°E. It has a total area of 923,768km² with a population of 177,155,754. Nigeria is bounded by Benin on the South-West region, Cameroun on the South-East region, Niger on the North-West region, Lake Chad on the North-East region, and the Atlantic Ocean on the South-South region. The Study Area is classified under the Northern region of Nigeria. The Northern region of Nigeria lies between latitudes 10° 30' 59.99" N and longitudes 7° 25' 59.99" E. Bauchi State occupies a total land area of 49,119 km^2 (18,965 sq mi) representing about 5.3% of Nigeria's total land mass and is located between latitudes 9° 3' and 12° 3' North of the Equator and longitudes 8° 50' and 11° East of the Greenwich Meridian. Katsina State lies within Latitude 12 15'N and Longitude 7 30'E with a Population of 5,792,578 (National Population Commission, 2006). Katsina State is Located in the North-West region of Nigeria, it occupies 24,192 square kilometres. Kogi State is located in the North-Central of Nigeria, it has a total area of 29,833 square kilometers (km²) with a population of 3,278,487 (NPC, 2006). It lies on latitude 7°30′N and longitude 6°42′E.

Figure 1: Map of Nigeria showing the Study areas

Experimental Design and sample layout

Simple Random Sampling Design was applied during the experiment. Eighty-three (83) plots of size 30 x 30m were selected from 10,000m^2 ha^{-2} in each of the study site, making a total of two hundred and forty-nine plots (249) from the three study sites. Fifteen percent Sample Intensity was surveyed.

Data Collection

Fifteen percent (15%) intensity of the survey was carried out on 150 ha, 50 ha in each of the States for the studies. A total number of two hundred and forty-nine (249) Quadrants of 30m x 30m, (83 Quadrants in each of the three States under study) were randomly distributed within the plot of 100m x100m/ha (10,000m²/ha) in each of the States for the Study. Direct observations, enumeration, and measurement such as quadrate number of species, the number of tree species,

corresponding number of individual trees, and diameter at breast height (dbh) of individual trees equal or greater than 10cm found in the respective Quadrants were taken.

Data Analysis

The data collected were arranged in Microsoft Excel spreadsheets and the routine statistical analyses were performed. The following growth, density, diversity, and similarity indices were computed from the data: basal area, frequency, relative frequency, density, relative density, relative dominance, important value index, Shannon-Wiener diversity Index (H^1), species evenness, species richness, Index of Dominance, Index of Similarity, and Index of Dissimilarity. Analysis of Variance (ANOVA) was also used as the parametric statistic to evaluate the differences in the forest tree species density in the Study Area. Below are the formulae used for the computations: The basal area of all trees in the sample plots were calculated using:

$$\mathbf{BA=}\frac{л\boldsymbol{D^2}}{\mathbf{4}} \text{ ---------- (1)}$$

Where:
BA= Basal area (m^2),
D = Diameter at breast height (m) and
л=pie (3.143).

The total basal area (m^2) for each plot was obtained by adding all trees in the sample area and the mean basal area was calculated for individual tree species. The density and diversity indices were calculated using:

Frequency
$$=\frac{Number\ of\ quadrates\ in\ which\ species\ occurs}{Total\ number\ of\ quadrates}\times 100 \text{ ---------- (2)}$$

Relative frequency $= \frac{Frequency\ of\ a\ species}{Total\ frequency\ of\ all\ species}\times 100$ ---------- (3)

Density $= \frac{Total\ Number\ of\ Trees\ in\ all\ Sample\ Plots\ (Plot\ Density)}{Total\ Area\ Sampled\ in\ Hectares}$ -----(4)

Relative density
$$=\frac{Number\ of\ individuals\ of\ the\ species}{Total\ number\ of\ individuals\ of\ all\ the\ species}\times 100 \text{ -------- (5)}$$

Relative dominance $= \frac{Total\ basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ the\ species}\times 100$ ------- (6)

Importance Value Index (IVI) = Relative frequency + Relative density + Relative dominance (Phillips, 1959) ---------- (7)

Below are the formulae used for qualitative analysis:
H = -∑ $Pilog_n$ Pi Shannon (1948): ---------- (8)
Specie Richness = (S-1)/Log N ---------- (9)
Evenness Index (E) = H/Log S ---------- (10)
Index of Dominance (D) = ∑ $(pi)^2$---------- (11)
Index of Similarity (S) = 2C/A+B ---------- (12)
Index of Dissimilarity = 1 – S ---------- (13)

Where:
H^1 = Shannon-Wiener diversity Index;
∑ = sum; pi = number of individuals of a species/total number of all individual 100;
N = total number of individuals of all species;
lnPi = the logarithmic proportion of the species;
E = evenness,
S = total number of species present,
A = number of species in community/forest/state A,
B = number of species in community/forest/state B,
C = number of species common in both A and B

RESULTS

The results from the study revealed 47 species, 17 families and 13 orders were found in the study site (table 1). Also results showed that Kogi study site had the highest number of individual tree species (1092 tree/ha), mean dbh (14.51cm), mean BA (4.43) and frequency (1087.95) followed by Bauchi study site for the same parameter with the value of 882 tree/ha, 9, 2 and 902 respectively

Density and Important Value Important were also assessed. Results showed that Kogi study site had the highest density of 15.56. The total important value index of the study sites is equal (300). *Adansonia digitata* had the highest Important Value Index in the study area Katsina (58.17), Bauchi (26.31) and Kogi (15.00)

Table 1: Summary of all the Species Encountered in the Study Area

S/No.	All Species found in Study Area	Common name	Family	Order	Kingdom
1	*Acacia species*	Wattles	*Fabaceae*	Fabales	Plantae
2	*Adansonia digitata*	Baobab	Malvaceae	Malvales	Plantae
3	*Adeniu mobesum*	Desert rose	Apocynaceae	Gentianales	Plantae
4	*Afzelia Africana*	African mahogany or Apa	*Fabaceae*	Fabales	Plantae
5	*Albizia chevalieri*	Albiziadurazz	*Fabaceae*	Fabales	Plantae
6	*Anacardium occidentale*	Cashew	Anacardiaceae	Sapindales	Plantae
7	*Anogiessus leiocarpus*	African Birch	Combretaceae	Myrtales	Plantae
8	*Azadirachta indica*	Neem Tree	Meliaceae	Sapindales	Plantae
9	*Borassus aethiophum*	Fan palm	Arecaceae	Arecales	Plantae
10	*Cassia sieberiana*	Drumstick tree	*Fabaceae*	Fabales	Plantae
11	*Ceiba pentandra*	Kapok Tree	Malvaceae	Malvales	Plantae
12	*Chrysophyllum albidum*	African star apple	Sapotaceae	Ericales	Plantae
13	*Cola nitida*	Kola nut	Malvaceae	Malvales	Plantae
14	*Combretum hereroense*	Russet bushwillow	Combretaceae	Myrtales	Plantae
15	*Daniella oliverii*	African copaiba balsam tree	Fabaceae	Fabales	Plantae
16	*Diospyrus mespiliforms*	African ebony	Ebenaceae	Ericales	Plantae
17	*Elaeis guineensis*	Oil palm	Arecaceae	Arecales	Plantae
18	*Eucalyptus camadulenses*	African red gum	Malvaceae	Myrtales	Plantae
19	*Ficus thonningii*	Fig tree	Moraceae	Rosales	Plantae
20	*Gmelina arborea*	Beechwood	Lamiaceae	Lamiales	Plantae
21	*Hyphaene thebaica*	Doum palm	Arecaceae	Arecales	Plantae
22	*Irvingia gabonensis*	Bush mango	Irvingiaceae	Malpighiales	Plantae
23	*Irvingia wombuli*	Bitter bush-mango (Ogbono)	Irvingiaceae	Malpighiales	Plantae
24	*Khaya senegalensis*	Dry zone mahogany	Meliaceae	Sapindales	Plantae
25	*Kigelia Africana*	Sausage tree	Bignoniaceae	Lamiales	Plantae
26	*Mangifera indica*	Mango Tree	Anacardiaceae	*Sapindales*	Plantae
27	*Milicia excels*	Iroko Tree or African teak	Moraceae	Rosales	Plantae
28	*Moringa oleifera*	Drum stick tree	Moringaceae	Brassicales	Plantae
29	*Pakia biglobosa*	Locust bean tree	*Fabaceae*	Fabales	Plantae
30	*Philostigma thornningii*	Monkey bread tree	*Fabaceae*	Fabales	Plantae
31	*Phoenix dactylifera*	Date palm	Arecaceae	Arecales	Plantae
32	*Polyalthia longifolia*	Indian mast tree	Annonaceae	Magnoliales	Plantae
33	*Prosopis gabonensis*	Iron tree	*Fabaceae*	Fabales	Plantae
34	*Raphia hookeri*	Raffia Palm	Arecaceae	Arecales	Plantae
35	*Sclerocarya birrea*	Marula Tree	Anacardiaceae	Sapindales	Plantae
36	*Senna siamea*	Cassia tree	*Fabaceae*	Fabales	Plantae
37	*Sterculia setigera*	Tropical chestnuts.	Malvaceae	Malvales	Plantae
38	*Tamarindus indica*	Tamarind tree	*Fabaceae*	Fabales	Plantae
39	*Tectonagrandis*	Teak Tree	Lamiaceae	Lamiales	Plantae
40	*Terminalia avicennoioides*	Terminalia	Combretaceae	Myrtales	Plantae
41	*Terminalia glaucescens*	Terminalia L.	Combretaceae	Myrtales	Plantae
42	*Terminalia mentalis*	Step tree	Combretaceae	Myrtales	Plantae
43	*Triplochitonscleroxylon*	African whitewood or Obeche	Malvaceae	Malvales	Plantae
44	*Vitellariaparadoxa*	*shea* tree	Sapotaceae	Ericales	Plantae
45	*Vitexdoniana*	Black Plum	Lamiaceae	Lamiales	Plantae
46	Ximenia americana	*tallow wood*	Olacaceae	Santalales	Plantae
47	*Ziziphus mauritania*	Chinese date	Rhamnaceae	Rosales	Plantae
Total	**47**		**17**	**13**	**1**

Table 2: Summary of Growth and the Result of Quantitative Analysis of Tree Species in Bauchi State

Tree Species	No. of Individuals	Mean dbh (m)	Mean BA (m^2)	Freq (%)	Rel. Freq. (%)	Density (t/ha)	Rel. Den. (%)	Rel. Do (%)	IVI
Acacia species	63	0.19	0.03	59.04	6.55	1.26	7.14	1.31	15.00
Adansonia digitata	41	0.66	0.34	44.58	4.94	0.82	4.65	16.72	26.31
Adenium obesum	19	0.17	0.02	22.89	2.54	0.38	2.15	1.06	5.76
Albizia chevalieri	24	0.21	0.03	21.69	2.40	0.48	2.72	1.62	6.75
Anogeissus leiocarpus	38	0.33	0.09	40.96	4.54	0.76	4.31	4.14	12.99
Azadirachta indica	25	0.39	0.12	25.30	2.81	0.50	2.83	5.90	11.54
Borassus aethiophum	22	0.31	0.08	24.10	2.67	0.44	2.49	3.67	8.84
Cassia sieberiana	29	0.20	0.03	27.71	3.07	0.58	3.27	1.60	7.93
Combretum hereroense	25	0.16	0.02	26.51	2.94	0.50	2.86	0.92	6.72
Daniella oliverii	23	0.19	0.03	22.89	2.54	0.46	2.59	1.33	6.45
Diospyrus mespiliforms	21	0.24	0.05	20.48	2.27	0.42	2.38	2.22	6.87
Eucalyptus camadulenses	33	0.29	0.07	34.94	3.87	0.66	3.74	3.18	10.80
Gmelina arborea	24	0.23	0.04	25.30	2.81	0.48	2.72	2.02	7.55
Hyphaene thebaica	25	0.23	0.04	21.69	2.40	0.50	2.86	2.06	7.32
Khaya senegalenses	42	0.38	0.11	40.96	4.54	0.84	4.76	5.53	14.83
Mangifera indica	31	0.33	0.08	32.53	3.61	0.62	3.54	4.09	11.23
Moringa oleifera	31	0.22	0.04	26.51	2.94	0.62	3.51	1.93	8.38
Pakia biglobosa	28	0.35	0.10	33.73	3.74	0.55	3.13	4.69	11.56
Philostigma thornningii	20	0.20	0.03	19.28	2.14	0.41	2.31	1.48	5.93
Phoenix dactylifera	19	0.15	0.02	22.89	2.54	0.38	2.18	0.90	5.61
Polyalthia longifolia	18	0.29	0.06	16.87	1.87	0.36	2.04	3.11	7.02
Prosopis gabonensis	12	0.37	0.11	14.46	1.60	0.24	1.36	5.26	8.22
Sclerocarya birrea	10	0.14	0.01	12.05	1.34	0.19	1.09	0.71	3.13
Senna siamea	17	0.14	0.02	20.48	2.27	0.34	1.90	0.75	4.93
Sterculia setigera	20	0.21	0.03	19.28	2.14	0.41	2.31	1.69	6.14
Tamarindus indica	51	0.35	0.10	44.58	4.94	1.02	5.78	4.73	15.45
Terminalia avicennoioides	23	0.29	0.07	25.30	2.81	0.46	2.61	3.26	8.67
Terminalia glaucescens	21	0.31	0.08	22.89	2.54	0.42	2.38	3.77	8.69
Terminalia mentalis	28	0.35	0.10	27.71	3.07	0.56	3.17	4.62	10.87
Vitalleria paradoxa	44	0.22	0.04	38.55	4.27	0.88	4.99	1.80	11.07
Vitex doniana	21	0.21	0.03	25.30	2.81	0.42	2.38	1.70	6.88
Ximenia americana	18	0.19	0.03	21.69	2.40	0.36	2.04	1.31	5.76
Ziziphus mauritania	16	0.15	0.02	19.28	2.14	0.32	1.81	0.92	4.87
Total	**882/ha**	**9**	**2**	**902**	**100**	**18**	**100**	**100**	**300**

Freq = frequency; **Rel.** = relative; **Den** = density; **Do** = dominance; **IVI** = important value index; **BA** = basal area; **dbh** = diameter at breast height

Table 3: Summary of Growth and the Result of Quantitative Analysis of Tree Species in Katsina State

Tree Species	No. of individuals	mean dbh (m)	Mean BA (m^2)	Freq (%)	Rel. Freq. (%)	Density (t/ha)	Rel. Den. (%)	Rel. Do (%)	IVI
Acacia species	79	0.13	0.01	73.49	9.04	1.58	10.15	0.90	20.09
Adansonia digitata	95	0.83	0.54	89.16	10.96	1.90	12.21	35.00	58.17
Adenium obesum	31	0.12	0.01	37.35	4.59	0.62	3.98	0.73	9.30
Albizia chevalieri	36	0.15	0.02	38.55	4.74	0.72	4.63	1.11	10.48
Anogeissus leiocarpus	38	0.24	0.04	45.78	5.63	0.76	4.88	2.83	13.34
Azadirachta indica	53	0.28	0.06	51.81	6.37	1.06	6.81	4.03	17.21
Borassusa ethiophum	25	0.22	0.04	26.51	3.26	0.50	3.21	2.51	8.98
Cassia sieberiana	24	0.15	0.02	22.89	2.81	0.48	3.08	1.09	6.99
Combretum hereroense	21	0.11	0.01	20.48	2.52	0.42	2.70	0.63	5.85
Diospyrus mespiliforms	19	0.17	0.02	22.89	2.81	0.38	2.44	1.52	6.77
Eucalyptus camadulenses	57	0.27	0.06	46.99	5.78	1.14	7.33	3.85	16.96
Hyphaene thebaica	38	0.24	0.05	40.96	5.04	0.76	4.88	3.04	12.96
Khaya senegalenses	27	0.39	0.12	32.53	4.00	0.54	3.47	7.95	15.42
Mangifera indica	21	0.33	0.08	25.30	3.11	0.42	2.70	5.48	11.29
Moringa oleifera	41	0.20	0.03	43.37	5.33	0.82	5.27	2.07	12.67
Pakia biglobosa	24	0.30	0.07	28.92	3.56	0.48	3.08	4.46	11.10
Philostigma thornningii	33	0.14	0.02	37.35	4.59	0.66	4.24	1.01	9.85
Phoenix dactylifera	23	0.11	0.01	24.10	2.96	0.46	2.96	0.61	6.53
Polyalthia longifolia	17	0.28	0.06	20.48	2.52	0.34	2.19	4.12	8.82
Prosopis gabonensis	16	0.39	0.12	19.28	2.37	0.32	2.06	7.81	12.24
Tamarindus indica	11	0.30	0.07	13.25	1.63	0.22	1.41	4.67	7.72
Vitalleria paradoxa	10	0.18	0.03	12.05	1.48	0.20	1.29	1.68	4.45
Vitex doniana	8	0.12	0.01	9.64	1.19	0.16	1.03	0.76	2.97
Ximenia americana	14	0.17	0.02	13.25	1.63	0.28	1.80	1.52	4.95
Ziziphus mauritania	17	0.11	0.01	16.87	2.07	0.34	2.19	0.63	4.89
Total	**778/ha**	**5.94**	**1.54**	**813.25**	**100**	**15.56**	**100**	**100**	**300**

Freq = frequency; **Rel.** = relative; **Den** = density; **Do** = dominance; **IVI** = important value index; **BA** = basal area; **dbh** = diameter at breast height

Table 4: Summary of Growth and the Result of Quantitative Analysis of Tree Species in Kogi State

Tree Species	No. of individuals	Mean dbh (m)	Mean BA (m^2)	F(%)	Rel. Freq. (%)	Density (t/ha)	Rel. Den. (%)	Rel. Do (%)	IVI
Acacia Species	31	0.28	0.06	30.12	2.77	0.62	2.84	1.37	6.98
Adansonia digitata	25	0.75	0.44	30.12	2.77	0.50	2.29	9.94	15.00
Afzelia africana	28	0.47	0.18	33.73	3.10	0.56	2.56	3.98	9.64
Anacardium occidentale	52	0.19	0.03	44.58	4.10	1.04	4.76	0.64	9.50
Anogiessus leiocarpus	37	0.45	0.16	37.35	3.43	0.74	3.39	3.64	10.46
Azadirachta indica	27	0.44	0.15	32.53	2.99	0.54	2.47	3.38	8.84
Borassus aethiophum	14	0.43	0.15	15.66	1.44	0.28	1.28	3.34	6.06
Cassia sieberiana	11	0.29	0.06	10.84	1.00	0.22	1.01	1.45	3.46
Ceiba pentandra	26	0.48	0.18	28.92	2.66	0.52	2.38	4.09	9.13
Chrysophyllum albidum	21	0.48	0.18	25.30	2.33	0.42	1.92	4.02	8.27
Cola nitida	22	0.19	0.03	21.69	1.99	0.44	2.01	0.64	4.65
Combretum hereroense	16	0.20	0.03	14.46	1.33	0.32	1.47	0.72	3.51
Daniella oliverii	43	0.24	0.05	43.37	3.99	0.86	3.94	1.04	8.97
Diospyrus mespiliforms	19	0.31	0.08	18.07	1.66	0.38	1.74	1.74	5.14
Elaeis guineensis	73	0.21	0.04	53.01	4.87	1.46	6.68	0.79	12.35
Eucalyptus camadulenses	21	0.31	0.08	22.89	2.10	0.42	1.92	1.73	5.76
Ficus thonningii	17	0.18	0.02	20.48	1.88	0.34	1.56	0.55	3.99
Gmelina arborea	24	0.30	0.07	25.30	2.33	0.48	2.20	1.59	6.11
Hyphaene thebaica	18	0.30	0.07	16.87	1.55	0.36	1.65	1.61	4.81
Irvingia gabonensis	32	0.47	0.17	32.53	2.99	0.64	2.93	3.87	9.79
Irvingia wombuli	29	0.45	0.16	27.71	2.55	0.58	2.66	3.60	8.80
Khaya senegalensis	27	0.47	0.18	25.30	2.33	0.54	2.47	3.96	8.76
Kigelia africana	23	0.41	0.13	27.71	2.55	0.46	2.11	2.99	7.65
Mangifera indica	31	0.36	0.10	28.92	2.66	0.62	2.84	2.35	7.85
Milicia excelsa	18	0.41	0.13	21.69	1.99	0.36	1.65	2.99	6.63
Parkia biglobosa	38	0.44	0.15	30.12	2.77	0.76	3.48	3.42	9.67
Polyalthia longifolia	13	0.33	0.09	15.66	1.44	0.26	1.19	1.95	4.58
Prosopis gabonensis	39	0.44	0.15	38.55	3.54	0.78	3.57	3.46	10.57
Raphia hookeri	42	0.18	0.03	44.58	4.10	0.84	3.85	0.61	8.55
Sclerocarya birrea	16	0.18	0.02	16.87	1.55	0.32	1.47	0.55	3.57
Senna siamea	9	0.18	0.03	10.84	1.00	0.18	0.82	0.59	2.41
Sterculia setigera	11	0.27	0.06	13.25	1.22	0.22	1.01	1.32	3.55
Tamarindusindica	14	0.46	0.16	16.87	1.55	0.28	1.28	3.71	6.54
Tectona grandis	37	0.33	0.08	33.73	3.10	0.74	3.39	1.90	8.39
Terminalia avicennoioides	16	0.38	0.11	19.28	1.77	0.32	1.47	2.56	5.79
Terminalia glaucescens	19	0.41	0.13	18.07	1.66	0.38	1.74	2.96	6.36
Terminalia mentalis	22	0.45	0.16	20.48	1.88	0.44	2.01	3.63	7.52
Triplochiton scleroxylon	31	0.43	0.15	31.33	2.88	0.62	2.84	3.30	9.02
Vitellaria paradoxa	33	0.26	0.05	27.71	2.55	0.66	3.02	1.21	6.77
Vitex doniana	42	0.27	0.06	32.53	2.99	0.84	3.85	1.33	8.17
Ximenia americana	12	0.22	0.04	13.25	1.22	0.24	1.10	0.88	3.19
Ziziphus Mauritania	13	0.19	0.03	15.66	1.44	0.26	1.19	0.61	3.24
Total	**1092/ha**	**14.51**	**4.43**	**1087.95**	**100**	**22**	**100**	**100**	**300**

***Freq** = frequency; **Rel.** = relative; **Den**= density;**Do** = dominance; **IVI** = important value index; **BA** = basal area; **dbh** = diameter at breast height*

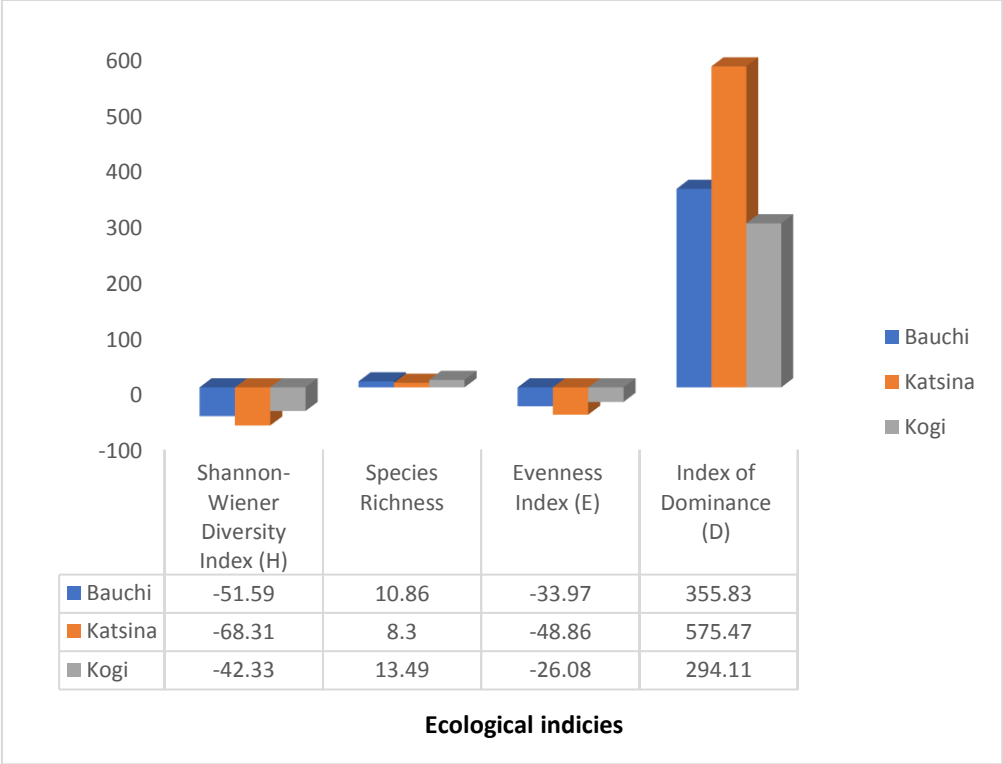
Table 5a: ANOVA Comparative Results of Density and IVI in the Study Area

Density Summary Result

Groups	*Count*	*Sum*	*Average*	*Variance*
Density (Bauchi)	33	17.644	0.5347	0.0512
Density (Katsina)	25	15.56	0.6224	0.1770
Density (Bauchi)	42	21.84	0.52	0.0652

Table 5b: ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.1766	2	0.0883	1.0006	0.3714	3.0902
Within Groups	8.5590	97	0.0882			
Total	8.7355	99				



	Shannon-Wiener Diversity Index (H)	Species Richness	Evenness Index (E)	Index of Dominance (D)
Bauchi	-51.59	10.86	-33.97	355.83
Katsina	-68.31	8.3	-48.86	575.47
Kogi	-42.33	13.49	-26.08	294.11

Figure 2: Diversity Index

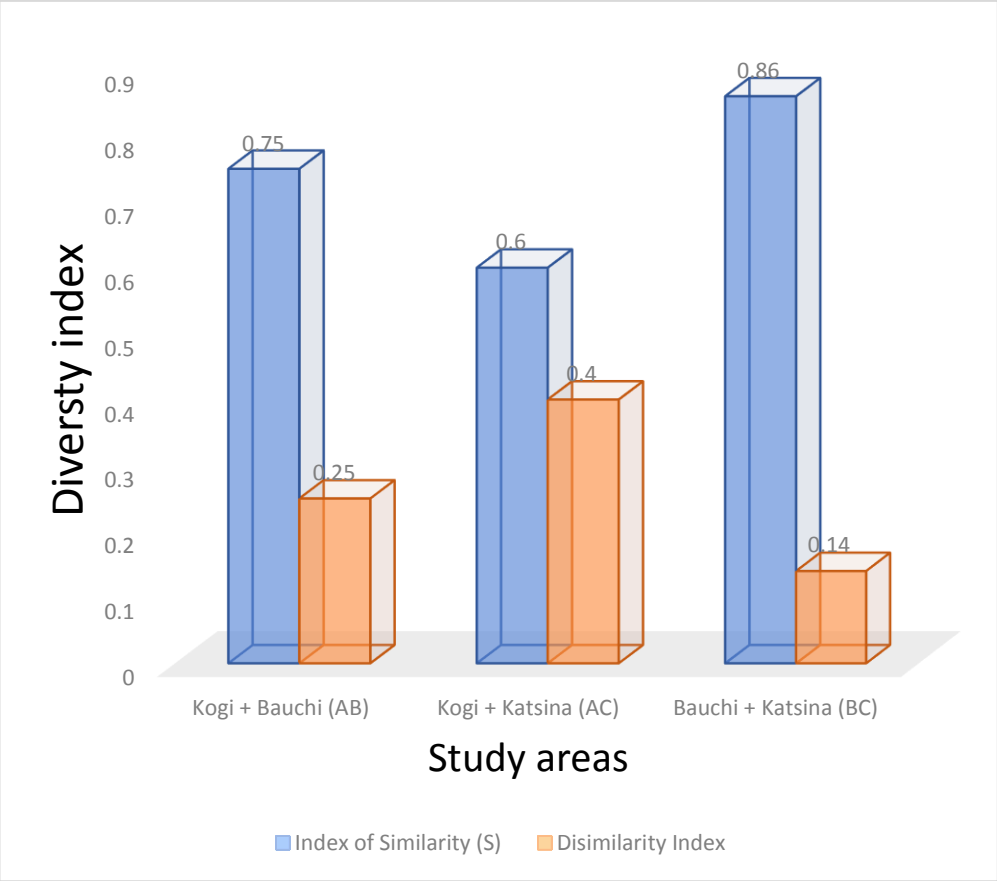


Figure 3: Index of Similarity and Dissimilarity

Table 6a : IVI Summary

Groups	Count	Sum	Average	Variance
IVI(Bauchi)	33	300.07	9.0930	19.0950
IVI(Katsina)	25	300.02	12.0008	111.5153
IVI(Kogi)	42	300	7.1429	7.5049

Table 6b :ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	370.26	2	185.1279	4.9950	0.0086	3.0902
Within Groups	3595.11	97	37.0629			
Total	3965.36	99				

DISCUSSION

Floristic composition

Total number of Forty-Seven (47) tree species, seventeen (17) Families, thirteen (13) Orders, and One (1) Kingdom were encountered in this Study. Table 1 presents the tree species results. The result is in line with the one reported by Zankan *et al.*, (2019; 50species) in Jemaa Local Government Area of Kaduna State; and higher than those reported by Ahmad (2012; 29 species) in Kogo Forest Reserve, Katsina State; Shuaibu (2014; 22 species) in Idah, Kogi State; Shuaibu and Ogunsola (2018; 18 species) in Dutsin-Ma, Katsina State, Nigeria. The study revealed Fabaceae and Malvaceae as the most common families in the study area. This is similar and contrary to the findings of Zakari (2015) which identified families Fabaceae and Apocynaceae as having the highest representation in a different ecological zone in Baturiya Wetland, Jigawa State; findings of Shuaibu and Ogunsola (2018) having Fabaceae

and Combretaceae as the common species in the diversity of tree species in natural forest within Dutsin-Ma, Katsina State; and findings of Zankan *et al.*, (2019) having Combretaceae and Fabaceae as the common species in density and diversity in Jemaa Local Government Area of Kaduna State, Nigeria. Most of the tree species found in the study area have the capacity to withstand harsh climatic conditions such as drought, flood, and desertification.

Density of trees

The result of the density of trees in Bauchi State, Nigeria revealed that the tree density of the 30 X 30m Quadrates laid ranged from 8 trees/ha to 13 trees/ha and tree species diversity ranged from 5 species/ha to 8 species/ha in each of the Quadrants. The result in Katsina revealed that the tree density of the 30 X 30m Quadrates laid ranged from 6 trees/ha to 12 trees/ha and tree species diversity ranged from 4 species/ha to 6 species/ha in each of the Quadrants; while that of Kogi ranged from 10 trees to 16 trees/Quadrates and tree species diversity ranged from 7 species to 9 species/Quadrates. The total number of individual trees in all the 83 Quadrates in Bauchi State were 882 trees/50ha (Table 2); Katsina was 778 trees/50ha (Table 3); and Kogi State 1092 trees/50ha (Table 4). The overall species density of trees per hectare found in the study area revealed that *Acacia* spp. has the highest (173t/ha), followed by *A. digitata* (163t/ha), *Anogeissus leiocarpus* (113t/ha), *Eucalyptus camadulensis* (111t/ha) and *Azadirachta indica* (105), These differences may be as a result of variability in terms of weather and climate between the two ecological zones or the level of exploitation of the woody species for wood fuel, timber, and farming, or overgrazing done by people in the two areas (Zankan *et al.*, 2019).

Mean Basal Area (m²); Frequency; Relative Frequency (%); Relative Density (%); Relative Dominance (%); and Importance Value Index

The result of the mean Basal Area in Bauchi State in Table 2 showed the (m²/ha) ranged from 0.01m²/ha to 0.34m²/ha with *A. digitata* having the highest mean BA (0.34m²/ha); the mean Basal Area (m²/species) in Katsina State ranged from 0.01m² to 0.54 m²/spp with *A. digitata* having the highest mean BA (0.54 m²/spp); while the mean Basal Area (m²/species) in Kogi ranged from 0.02 to 0.44 with *A. digitata* having the highest mean BA (0.44 m²). In this study, the overall sum of mean basal area (m²/ha) ranged from 1.54 – 4.43. These values are less or more similar to those reported by Singh et al (2016; 2.21 - 87.07 m²/ha), Shuaibu and Ogunsola (2018; 4.66m²/ha), Shuaibu (2014; 4.63), Koirala (2004; 56.90-69.80 m²/ha), Bhat (2012; 2.91-37.96 m²/ha) and Salami (2018; 86.45m²/ha) in Omo Biosphere Reserve. The diameter distribution of tree stands has been often used to represent the population structure of forests (Rao *et al.*, 1990). Tree distribution across different diameter classes revealed how well the growing forest is utilizing functional and structural resources (Naidu and Kumar, 2016).

In Bauchi State (Table 2), frequency result ranged from 12.05 to 59.04; relative frequency ranged from 1.34 to 6.55 with *Acacia species* having the highest frequency (59.04) and relative frequency (6.55); relative dominance ranged from 0.71 to 16.72 with *A. digitata* having the highest relative dominance (16.72); Relative density result showed that *Acacia species* (7.14) had the highest relative density while the result of Importance Value Index (IVI) shows that *A. digitata* (26.31) is the dominant species. In Katsina State (Table 3), frequency ranged from 9.64 to 89.16; relative frequency ranged from 1.19 to 10.96 with *A. digitata* having the highest frequency (89.16) and relative frequency (10.96%); relative dominance (%) ranged from 0.61 to 35.00 with *A. digitata* having the highest value (35.00%); relative density showed that *A. digitata* had the highest value (12.21); while the result of Importance Value Index (IVI) shows that *A. digitata* (58.17) is the dominant species. In Kogi State (Table 4), frequency ranged from 10.84 to 53.01; relative frequency ranged from 1.00 to 4.87 with *Elaeis guineensis* having the highest frequency (53.01) and relative frequency (4.87%); relative dominance ranged from 0.55 to 9.94 with *A. digitata* having the highest value (9.94%); relative density showed that *E. guineensis* had the highest value (6.68); while the result of Importance Value Index (IVI) shows that *A. digitata* (15.00) is the dominant species. *A. digitata* had the highest value of Basal Area, Relative Dominance, and Important Value Index in the three States for this study. There was a difference in the basal area within the same species and among other

species as a result of the age of trees, specie composition, light intensity, and climatic factor. This study confirmed the report of Naidu and Kumar (2016) that the differences in the basal area of tree species among the study plots may be due to differences in altitude, species composition, age of trees, and extent of disturbances and succession strategies of the stands. The results of Analysis of Variance (ANOVA) in Table 5 from the comparative analysis of density of the forest tree species in the three States of study shows that there were no significant differences [P-value (0.3714) > 0.05 and F-calculated (1.0006) < F-critical (3.0902)] between the tree density in the Study Area. The result of Importance Value Index (IVI) showed that there are significant differences [P-value (0.0086159) < 0.05 and F-calculated (4.99495845) > F-critical (3.090186675)] between the IVI of tree species in the three States.

Diversity Index and Similarity/Dissimilarity Index

The result of diversity index in Figure 2 showed that Shannon-Wiener Diversity Index (H) and Species Richness has higher values (-42.33 and 13.49 respectively) in Kogi State; followed by Bauchi State (-51.59 and 10.86 respectively); and Katsina State (-68.31 and 8.3 respectively). Diversity indices varied with location depending on the species available within an ecological zone (Zankan *et al.*, 2019). Orth and Colette (1996) revealed from their study that the Shannon diversity index has strong values for species with recoveries of same importance and it takes low values when some species have strong recoveries. Species Richness is higher than 5.14 recorded by Shuaibu and Ogunsola (2018); 2.12 recorded by Zankan *et al.* (2019); and 2.16 recorded by Onyekwelu *et al*. (2007). High species richness is a hallmark of many tropical forests (Gentry *et al.*, 2010). The Shannon-Wiener Diversity Index (H) and Species Richness revealed that Kogi State forest tree species are most diverse; followed by Bauchi State; and Katsina State. The Evenness Index (E) results show that Kogi State has the highest value (-26.08); followed by Bauchi State (-33.97); and Katsina State (-48.86). These values are lower than 0.779899 as recorded by Ahmed (2012); 0.84 recorded by Agbelade *et al.* (2017); and 0.973 by Shuaibu and Ogunsola (2018). The result indicates that the available woody species were not evenly distributed within the study area. This may be due to the high level of exploitation for wood fuel, timber, and farming suffered by the high forest in the south as compared to the Guinea savanna ecological zone (Zankan*et al.*, 2019). The Evenness Index (E) results revealed that individuals of all the forest tree species in Kogi State are the most uniformly distributed; followed by Bauchi State; and Katsina State pattern of distribution varies. The results of the Index of Dominance (D) showed that Katsina had the highest value (575.47); followed by Bauchi State (355.83); followed by Kogi State (294.11). The results of the Index of Dominance (D) revealed that one forest tree species is dominating more than the other species in Katsina State; the dominance is low in Bauchi State; and lower in Kogi State.

The results of Index of Similarity (%) and Dissimilarity Index (%) in Figure 3 showed that Bauchi State and Katsina State has the highest similarity (0.86) of forest tree species and lowest dissimilarity (0.14); followed by Kogi State and Bauchi State (0.75 similarity and 0.25 dissimilarity); while Kogi State and Katsina State has the lowest similarity (0.60) and highest dissimilarity (0.4). The values of the similarity index are higher than 50%, which enables us to conclude that there is clearly no difference in the species diversity and richness in the study area. More or less uniform environmental conditions are revealed by higher values of similarity index; in contrast, lower values indicate distinct heterogeneity (Ekta, 2012).

CONCLUSION

Quantitative, qualitative, and parametric analysis of forest tree species density, diversity, and similarity status recorded in this study will go a long way to provide baseline information for formulating conservation and management strategies required to protect, regenerate species of interest and manage the species in a sustainable manner. Therefore, understanding the density, diversity, and similarity of forest tree species in the Study Area is a useful tool to compare the composition of different species, documenting the patterns and their distributions which will provides a good database that may be useful not only for their sustainable utilization but also for management measures of forests in these States.

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