Journal of Bioresource Management

Volume 10 | Issue 3 Article 9

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Recommended Citation

Japheth, D. H., Ugbe, J. A., & Alfa, J. I. (2023). Alpha Diversity and Species Status of Uneven Forests in Eco-Zones of Taraba State, Nigeria, *Journal of Bioresource Management, 10* (3).
ISSN: 2309-3854 online
(Received: Dec 17, 2021; Accepted: May 15, 2023; Published: Sep 30, 2023)

Alpha Diversity and Species Status of Uneven Forests in Eco-Zones of Taraba State, Nigeria

ALPHA DIVERSITY AND SPECIES STATUS OF UNEVEN FORESTS IN ECO-ZONES OF TARABA STATE, NIGERIA

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ABSTRACT

Alpha diversity indices quantify the uncertainty in predicting the species identity of an individual. Quantitative indices on species composition and distribution are vital to understanding the trend and species status of an ecosystem for conservation management. However, among the forest ecosystems in Taraba state, Bakin Dutse and Wasaji uneven forests are one of the least studied areas, especially in terms of tree species status. This research work aims at assessing alpha diversity and species status of selected uneven forests in Taraba state, Nigeria; to provide baseline knowledge for conservation management. In total, 102 tree species from 74 genera and 41 families were present. Wasaji forest had the highest number (51) of tree species with a diversity index of 3.01, followed by Ngel-Nyaki uneven forest which had 32 tree species, and Bakin Dutse forest had 19 species. The tree species were evenly distributed in Wasaji forest (0.631) and Bakin dutse (0.625). The study area is rich in tree species. Strict policies should be maintained, this could improve the growth and productivity of forest ecosystems of the study area. The tree growth variables had an optimum tree stand density in all the natural forests. If effective conservation efforts are made, the lower tree diameter class would grow into mature trees and eventually replace those at the upper tree diameter class in the forests, which showed an inverse "J-shape" diameter distribution.

Keywords: Conservation, diversity, reserve, sustainability, uneven forests.

INTRODUCTION

Between the 1990 to 2015 exploitation of forest resources in Nigeria has resulted in the loss of more than 47 % of its natural forests (Humphrey and Godwin, 2015); and even more by the year 2023. Nigeria is currently one of the nations with the highest annual rate of deforestation (Amonum et al., 2019). In Nigeria, trees once covered 50 % of the country's area; today, 90 % of those trees have been indiscriminately felled, leaving less than 1 % as frontier woods. Sixty-six percent (66 %) of the nation's trees have been fell down by people in the previous 20 years (Dutch Green Business, 2021).

For many centuries, human activities have badly disrupted and exploited the tropical forests of Africa (Valentini et al., 2014; Cazzolla Gatti et al., 2017). These changes may have resulted in numerous plants and animals becoming endangered or going extinct, as well as a decline in the forest's biodiversity conservation status and environmental quality. Habitat is the interaction point between flora and fauna species. It comprises of oxygen, food, shelter, terrain, among others, which are paramount for species survival. Flora cover and other of its components are the paramount component in habitat for most fauna species; flora and its components provide for effective conservation management, it

is essential to comprehend the state of forest stands, regeneration, and variety. The ecological characteristics of a site, species diversity, and the rate of tree species regeneration all play a big part in how a forest is organized. Quantitative knowledge about the composition, abundance, or distribution of tree species is necessary for understanding the condition (composition and structure) of a forest estate as well as for decision-making, planning, and execution of the forest areas' conservation strategy. To manage disturbed and undisturbed ecosystems and comprehend the role of ecosystem services, species composition and distribution patterns must be defined (Neelo et al., 2015). Forest ecosystems have to be continuously studied for management or decision-making purposes. This could help to guide succession processes in a way that preserves species and habitat variety (Attua and Pabi, 2013).

This research work aims to assess the forest structure and tree species alpha diversity of three natural forests in Guinea savanna ecological zone of Nigeria specifically in Taraba region; in order to provide baseline knowledge for conservation management of the natural forest areas. This research monitored the current status of tree species that might be considered in abundance which could even be threatened, or species that might be considered threatened however, could be in abundance. Contribution to knowledge from this research work will helps to solve the problem of species uncertainty in Taraba region of guinea savanna eco-zone of Nigeria. It is important for preserving biodiversity and raising production in Nigeria's southern guinea woodland ecosystems.

MATERIALS AND METHODS

Study Area

A sub-montane to mid-altitude forest called Ngel Nyaki uneven forest can be found in Nigeria near the western escarpment of the Mambilla Plateau. Its size is roughly 46 km^2 and its altitude ranges from 1400 to 1500 m above sea level (Chapman and Chapman 2001). The reserve currently has about 10 km^2 of vegetation cover. Bakin Dutse and Wasaji each have estimated areas of 64.75 and 49.69 km^2, respectively. Taraba state is home to the three uneven forest areas (Nigeria), which have an approximately 54, 473 km^2 of land in total. Taraba State is located between latitudes 7°00' 00" and 9° 58' 51" north and longitudes 9° 52' 28" and 12° 39' 51" east (Meer et al.,. 2018, Japheth and Meer, 2023). Taraba State is surrounded by Gombe State to the northwest, Plateau and Nassarawa States to the west, and Adamawa State to the northeast. It also shares a southwesterly border with Benue State. Taraba State and the Republic of Cameroon are separated by a global border on the east. According to Meer et al., (2018), the state is divided into three eco zones: the Montene Forest in the southeast, the Northern Guinea Savanna in the northeast, and the Southern Guinea Savanna in the southwest. Japheth et al., (2022) and Japheth and Meer (2023) also provide detailed descriptions of the region.

Data Collection

The research area was divided into various ecological zones (Northern Guinea Savanna, Southern Guinea Savanna and Montane Forest). From each eco-zone, one uneven forest (protected) area was purposively sampled (based on ease of access and cost effectiveness), given a total of three protected forest areas (i.e. Ngel Nyaki, Wasaji and Bakin Dutse protected forest areas).

Systematic sampling technique was used to lay sample plots. Prior to conducting the field survey, each protected forest area's coordinates were plotted on a

map using QGIS (version 3.22.1), and random numbers were generated using R computer software (version 64 4.1.0). According to FAO biomass estimation manure (2020), ten randomly chosen coordinates in each forest map were used to identify sampling plots quickly. The ten coordinates selected from each uneven forest area were marked and transferred to Garmin e-trex 10 GPS for tracking on the field (Chenge and Osho, 2018). Each coordinate in the study area was located in the field, and temporary sample plots (TSP) measuring 50 m x 50 m were systematically laid on the point of the coordinates for the evaluation of the trees. A total of thirty TSP were placed over the three protected forest areas, comprising ten TSP each protected area.

The total number of distinct tree species in each sample plot was counted and recorded. Tree species were formally identified in the field using the field identification guides (Neelo et al., 2015). All live trees in the TSP with a DBH of 10 cm had their total tree height (H) and diameter at breast height (DBH) measured. The diameter at breast height (DBH) of the tree was measured at 1.3 meters above the ground, and the overall tree height was measured to the nearest 0.1 meters. Diameter tape and a Haga altimeter were used to measure DBH and tree total height, respectively, as described by Dau et al., (2016) and Dau and Chenge (2016).

Statistical Analyses

To analyze the structure of the natural forest area, descriptive statistics (mean, standard deviation, minimum, maximum, and standard error) were used (Chenge et al., 2019; Amonum et al., 2019). The distributions of stem diameter and tree total height were plotted using pivot tables on an excel spreadsheet (2010 version) and evaluated in order to ascertain the management impact on the tree stand structure of the study area under the protection of the Taraba State Government in Nigeria.

i. Shannon-Weiner Index of Diversity (H'):

The study area's species diversity was analyzed using Shannon and Weaver's (1949) diversity index, which varies according to the number of species present. Greater diversity is indicated by the fact that it raises as the number of species increases. Using the techniques outlined by Kent and Coker (1992); Magurran (2004); Chenge et al., 2019), the Shannon-Weiner Index of Diversity (H') was calculated:

$$H = -\sum_{i=1}^{s} p_i \, ln \, p_i \qquad (1)$$

S is the total number of species, p_i is the proportion of individuals in the ith species, and *ln* is the natural logarithm.

ii. Species Evenness Index

From 0 to 1, the Pielou evenness index is available. (Pielou, 1969). When there is dominance, it is 0, and when there is homogeneous distribution of individuals among species, it is 1. The formula shown below was used to calculate the Pielou evenness index (Adekunle et al., 2013):

$$E = \frac{H}{lnS} \qquad (2)$$

E is Pielou Evenness Index, *H* is the Shannon–Wiener function and *S* is the total number of species.

iii. Species Richness

Oluwatos and Jimoh (2016) calculated species richness using the method described by Margalef (1968) and followed by Speller berg (1991) and Magurran (2004):

$$D = \frac{S}{\sqrt{N}} \qquad (3)$$

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

RESULTS

Forest Structure of the Eco-Zones of Taraba State, Nigeria

A total of 1,295 trees were sampled and measured from a temporary sample plots in the three uneven forest areas in Taraba state, Nigeria. Based on the result of this finding, the stocking density of trees was approximately 459 trees per hectare. The result showed diameter at breast height (DBH) ranged from 5.00-300.00 cm, 4.00-396.00 cm and 5.00-300.00 cm in Bakin-dutse, Ngel-nyaki and Wasaji natural forests, respectively.

Minimum and maximum tree total heights of 2.00-35.00 m, 2-73.00 m and 2-50.00 m were recorded in Bakin-dutse, Ngel-nyaki and Wasaji natural forests, respectively. The mean DBH and tree total height of 39.46 and 11.44 m were observed in Bakin-dutse natural forest, 39.59cm and 12.79 m (Ngel-nyaki natural forest), 45.72 cm and 14.94 m in Wasaji natural forests areas of Taraba state, Nigeria.

The majority of the trees in the three reserves (n = 1,667) had DBH sizes of less than 54.00 cm, followed by the DBH class of 54-104 cm, which had 334 trees; the density of trees in the larger DBH classes was relatively low. The diameter (DBH) distribution displayed the typical inverse "J-shape" pattern of tropical natural forests (Figure 1). Figure 3 shows the distribution of tree total height in the study's natural forests. The majority of the trees in the three reserves (n = 4,152) had tree total heights of less than 10.2 m, with 1,282 trees falling into the height distribution class of 10.2-20.2 m. (Figure 2).

Alpha Diversity of Tree Species in the Study Area

Table 2, 3, 4 and 5 presents the distribution, abundance, and species composition of trees in the study area. From the selected uneven forest reserves, 1,295 individual trees were counted. 102 tree species, 74 genera, and 41 families were identified in the study area. Pielou's evenness (E), Dominance D, Shannon-Weiner diversity (H'), Margalef of species richness indices had values of 0.0375, 3.802, 0.4389, and 11.52, respectively (Table 2).

The highest number of tree species, 51, was found in the Ngel Nyaki natural forest, followed by 32 in the Wasaji natural forest and 19 in the Bakin Dutse natural forest, according to the tree species diversity indices of the three study areas. Wasaji natural forest had the highest diversity of 3.005 than Ngel Nyaki natural forest (2.92) and Bakin Dutse natural forest (2.474).

Table 1: Descriptive Statistics of Tree Growth of Selected Natural Forests in Taraba State, Nigeria

Natural forest	Tree variables	Descriptive Statistics					
		N	Min.	Max.	Mean	SE	SD
Bakin Dutse	DBH (cm)	271	5	300.00	39.46	0.36	41.76
	THt (m)	271	2	35.00	11.44	0.15	6.48
Ngel Nyaki	DBH (cm)	512	4	396.00	39.59	0.17	46.33
	THt (m)	512	2	73.00	12.79	0.08	10.65
Wasaji	DBH (cm)	512	5	300.00	45.72	0.29	48.67
	THt (m)	512	2	50.00	14.94	0.14	10.81

DBH is Diameter at Breast Height, Ht for Total Height, N for Number of Trees Measured, SD for Standard Deviation, and SE for Standard Error.

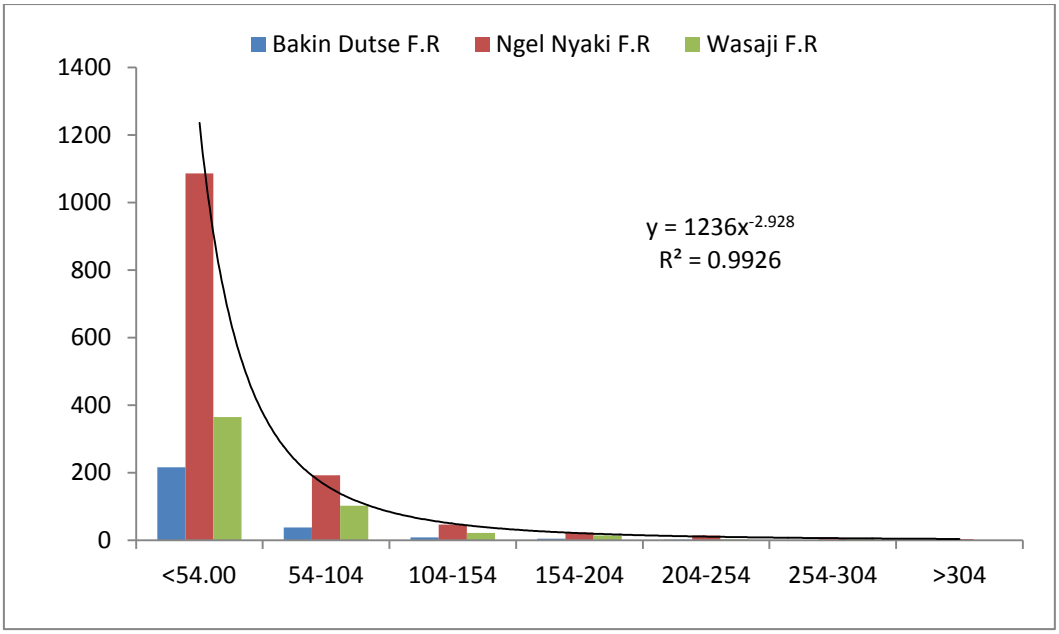

Figure 1: Diameter Distribution of Trees in the Natural forests

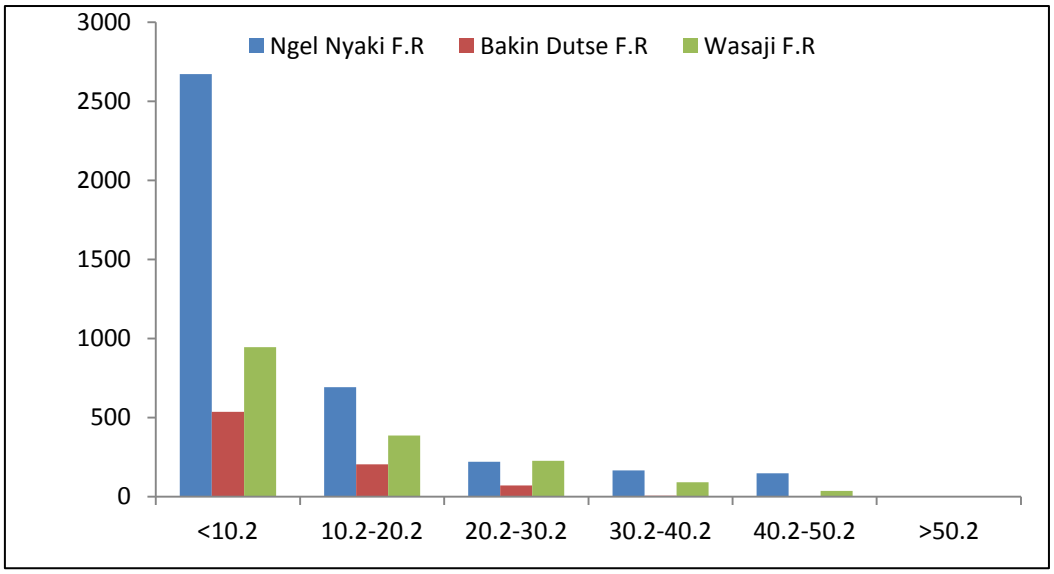

Figure 2: Tree Total Height Distribution of Trees in the Natural forests

Table 2: Pooled Alpha Diversity and Distribution of Tree Species in the Study Area

Indices	Values
Taxa_S	102
Individuals	1,295
Dominance_D	0.0375
Shannon_H	3.802
Evenness_e^H/S	0.4389
Margalef	11.52

Table 3: Tree Species Varied Diversity and Distribution between the Natural Forests in the Study Area

Indices	Bakin Dutse natural forest	Ngel Nyaki natural forest	Wasaji natural forest
Taxa_S	19	51	32
Individuals	317	543	435
Dominance_D	0.1169	0.08396	0.06477
Shannon_H	2.474	2.92	3.005
Evenness_e^H/S	0.6248	0.3635	0.6309
Margalef	2.684	6.047	4.173

Table 4: Tree Species Occurrence and Distribution in the Natural Forest in Taraba State

Species	Family	Occurrence		
		Ngel Nyaki F.R	Bakin Dutse F.R	Wasaji F.R
Acacia kirkir	Mimosoideae	0	24	0
Afzelia Africana	Ceasaphiniodeae	0	0	1
Albizia gummifera	Fabaceae	14	0	0
Allophylus Africana	Sapindaceae	1	0	0
Anonna senegalensis	Mimosoideae	0	22	35
Anthonatha noldeae	Leguminoceae	42	0	0
Beilshmeidia manii	Lauraceae	4	0	0
Bridelia ferruginea	Euphorbiaceae	0	7	10
Bridelia scleroneura	Euphorbiaceae	0	2	0
Campylospermum perexilis	Ochnaceae	15	0	0
Carapa oriophylla	Meliaceae	28	0	0
Celtis zenkeni	Ulmaceae	8	0	0
Chrysophylum albedum	Sapotaceae	5	0	0
Clausena anissata	Rutaceae	38	0	0
Crossopteryx febrifuga	Rubiaceae	0	0	18
Croton macrotachyus	Sterculiaceae	1	0	0
Daniellia oliverii	Fabaceae	0	11	24
Daslepis sp		4	0	0
Deinbolia pinnata	Sapindaceae	114	0	0
Diospyros camarunensis	Ebenaceae	10	0	0
Disloclaoxylum hexandrum	Euphorbiaceae	11	0	0
Drypetes floribunda	Euphorbiaceae	3	0	0
Entandrophragma angolense	meliaceae	4	0	0
Eugenia gilgii	Myrtaceae	14	0	0
Ficus lutea	Moraceae	22	0	24
Ficus sur	Moraceae	21	3	6
Garcinia smithmanii	Clusiaceae	149	0	0
Goria sp		1	0	0
Hymenocardia acida	Hymenocardiaceae	0	61	28
Hyptis suaveolens	Lamiaceae	0	3	0
Isolona capensis	Annonaceae	11	0	0
Khaya senegalensis	meliaceae	0	26	6

Leea guineensis	Leeaceae	2	0	0
Lenea alata	Asteraceae	0	0	18
Lonchocarpus laxiflorus	Fabaceae	0	3	0
Lophira alata	Ochnaceae	0	0	17
Macaranga monandra	Euphorbiaceae	6	0	0
Maranthes polyandra	Chrysobalanaceae	0	0	5
Millettia barteri	Fabaceae	11	0	0
Neocarya polyandra	Chrysobalanaceae	0	0	1
Newtonia buchananii	Leguminoceae	45	0	0
Nuclea latifolia	Rabiaceae	0	33	9
Oxyanthus sp	Rubiaceae	4	0	0
Parinari excelsa	Chrysobanaceae	0	12	53
Parinari polyandra	Chrysobanaceae	0	8	0
Parkia biglobosa	Fabaceae	0	0	14
Pavetta crombosa	Rubiaceae	1	0	0
Pericopsis laxiflora		0	15	0
Pericopsis laxiflora	Leguminoceae	0	0	59
Pilliostigma thorningii	Caesalpinioidae	0	0	4
Pleiocarpa pycnantha	Apocynaceae	200	0	0
Polyscias fulva	meliaceae	9	0	0
Poutaria altissima	Rubiaceae	12	0	0
Prosopis africana	Fabaceae	0	12	0
Psorospermum aurantiaca	Clusiaceae	3	0	0
Pterocarpus erinaceus	Fabaceae	0	0	10
Pychotria viridis	Rubiaceae	8	0	0
Rauvolfia vomiteria	Apocynaceae	3	0	0
Ritchea albesea	Capparridaceae	13	0	0
Rothmania hispida	Sapindaceae	83	0	0
Rytignia umbellatum	Polygonaceae	207	0	0
Santeria sp		2	0	0
Schefferia abyssinica	Poaceae	3	0	0
Sherubapsis sp		5	0	0
Sterculia setijera	Sterculiaceae	0	14	0
Strombosia postulate	Olaceae	90	0	0
Strychnos innocua	Loganiaceae	0	0	6
Strychonos spinosa	Loganiaceae	0	2	0
Symphonia glubolifera	Cutiferae	1	0	0
Syzigium guineense	Myrtaceae	0	0	9
Tabernamontana contata	Apocynaceae	5	0	0
Terminalia sp	Loganiaceae	0	0	62
Trichilia emetica	meliaceae	0	4	0
Trilepisium madagascariansis	meliaceae	3	0	0
Uapaca togoensis	Phyllanthaceae	0	0	41
Vetellaria paradoxa	Sapotaceae	0	9	10
Vitex donianna	Verbenaceae	0	0	15
Voacanga africana	Apocynaceae	18	0	0

Weanekia sp		14	0	0
Xymalus monospor	Monimiaceae	4	0	0
Zanthoxylum zanthoxyloidea	Rutaceae	72	0	0
Unknown		28	0	27

Table 5: Threatened Tree Species and their Occurrence in the Natural Forest in Taraba State

Species	Family	Ngel Nyaki F.R	Bakin Dutse F.R	Wasaji F.R	IUCN Red List (2021)
Afzelia africana	Ceasaphiniodeae	0	0	1	Decreasing
Allophylus africana	Sapindaceae	1	0	0	(NA)
Beilshmeidia manii	Lauraceae	4	0	0	NA
Bridelia scleroneura	Euphorbiaceae	0	2	0	Stable
Croton macrotachyus	Sterculiaceae	1	0	0	NA
Daslepis sp		4	0	0	NA
Drypetes floribunda	Euphorbiaceae	3	0	0	NA
Entandrophragma angolense	Meliaceae	4	0	0	Decreasing
Goria sp		1	0	0	NA
Hyptis suaveolens	Lamiaceae	0	3	0	NA
Leea guineensis	Leeaceae	2	0	0	NA
Lonchocarpus laxiflorus	Fabaceae	0	3	0	Stable
Neocarya polyandra	Chrysobalanaceae	0	0	1	NA
Oxyanthus sp	Rubiaceae	4	0	0	Dec
Pavetta crombosa	Rubiaceae	1	0	0	NA
Pilliostigma thorningii	Caesalpinioidae	0	0	4	NA
Psorospermum aurantiaca	Clusiaceae	3	0	0	NA
Rauvolfia vomiteria	Apocynaceae	3	0	0	NA
Santeria sp		2	0	0	NA
Schefferia abyssinica	Poaceae	3	0	0	NA
Strychonos spinosa	Loganiaceae	0	2	0	NA
Symphonia glubolifera	Cutiferae	1	0	0	NA
Syzigium guineense	Myrtaceae	0	0	9	NA
Trichilia emetic	Meliaceae	0	4	0	Stable
Trilepisium madagascariansis	Meliaceae	3	0	0	NA
Xymalus monospor		4	0	0	NA

The tree species richness of 6.047 (Ngel Nyaki natural forest), 4.173 (Wasaji natural forest) and 2.684 (Bakin Dutse natural forest) were recorded from the finding. The tree species were evenly distributed in Wasaji natural forest by 0.6309 index, 0.6248 index (Bakin Dutse natural forest) and less evenly distributed in Ngel Nyaki natural forest.

Deinbolia pinnata, Garcinia smithmanii, Newtonia buchananii, Hymenocardia acida, Nuclea latifolia, Parinari excels, Pericopsis laxiflora, Anthonatha noldeae, Carapa oriophylla, Pleiocarpa pycnantha, Rothmania hispida, Rytignia umbellatum, Zanthoxylum zanthoxyloidea among others are the most abundant and distributed tree species in Taraba state, Nigeria (Table 4).

Apocynaceae, Chrysobalanaceae, Chrysobanaceae, Clusiaceae, Leguminoceae, Hymenocardiaceae,

Loganiaceae, Fabaceae, Euphorbiaceae, Loganiaceae, meliaceae, Mimosoideae, Moraceae, Polygonaceae Sapindaceae and *Sapotaceae* were the most abundant families with tree species above 20 frequency in the study natural forests.

Tree Species Status on IUCN Red List in the Study Area

The status of tree species in the study forest areas was assessed to update the database of forestry department, Ministry of Environment. All tree species with occurrence of less than five (< 5) in the study area were determined and result shown on Table 5. *Allophylus africana, Croton macrotachyus, Goria sp, Pavetta crombosa and Symphonia glubolifera* occurred once in the three uneven forest areas. *Leea guineensis and Santeria sp* had occurrence of 2 in the study areas. *Drypetes floribunda, Rauvolfia vomiteria* and *Trilepisium madagascariansis* were occurred 3 times while *Beilshmeidia manii, Entandrophragma angolense, Oxyanthus sp* and *Pilliostigma thorningii* had occurrence of 4. This result implies that, tree species with the lowest value of occurrence (such as *Afzelia africana, Croton macrotachyus, Allophylus africana, Goria sp, Neocarya polyandra, Pavetta crombosa and Symphonia glubolifera)* were the least occurrence species in the study area; this can be regarded as most endangered or threatened species in the uneven forest areas. However, based on the IUCN red list, *Afzelia africana* and *Entandrophragma angolense* are the only species on the red list with decreasing status. *Bridelia scleroneura, Lonchocarpus laxiflorus* and *Trichilia emetic* are “stable” on the red list while other tree species are not applicable on the IUCN list.

DISCUSSION

Forest Structure of Taraba State, Nigeria

The descriptive summary of tree growths in the study area indicates an optimum tree stand density in all the uneven forests in the area. Tree stands structure in Wasaji natural area had live standing trees with high mean DBH (45.72cm) and mean total tree height (14.94 m). The study area's tree structure was like that of Nigeria's Akure Natural Forest in Ondo State, Oluwa Natural Forest in Southwest Ondo State (Ogana et al., 2015), and Shasha Natural Forest (Chenge et al., 2019) in Osun State. The reverse "J-shape" (an inverse "J-shape") diameter distribution indicated healthy regeneration potentials, according to Amonum et al., (2019) and Ouedraogo et al., (2019). If proper conservation measures are taken in the study area, the trees with lower diameter distribution could eventually mature and take the place of the older ones. When natural regeneration occurs in a natural forest over an extended period (with little or no disturbance), the number of trees increases from small to high diameters (Djomo, 2011; Chenge et al., 2019). Thus, in order to contribute to the local mitigation of climate change and the preservation of biodiversity, the implementation of effective policy to sustainably conserve these areas becomes imperative.

The tree total height distributions revealed from this finding implies that, there was high population of individual tree stands in the lower height stratum (< 10.2 m), with few number of tree stands at the upper (> 20 m) height stratum. According to Amonum and Japheth (2019; Vange et al., 2017), this may be due to competition for sunlight and available space for the expansion of stem and crown diameters. This may also explain why there are fewer individual tree stands with dominant heights than a larger population of trees in the area. According to Chenge et al., (2019), the study areas' total tree height distribution shared a similar height pattern with the Shasha natural forest in Osun State, Nigeria.

An emerging characteristic of vegetation is habitat structure, which includes the number of horizontal strata, the height and density of each stratum, as well as particular elements like tree hollows. By lowering surface temperatures through shading, for example, structures influence the microclimate and provide substrate for activities such as nesting, sheltering, foraging, avoiding predators, and other activities (Brown et al., 2021). In natural ecosystems, vegetation has an impact on the composition of animal communities (Louy, et al., 2011). There is evidence that the structure of the vegetation affects the composition of the animal community in agricultural systems (Brown *et al.*, 2021).

Alpha Diversity of Tree Species in the Selected Uneven Forest Areas

A diversity index is a quantitative indicator of the presence of various species and how evenly they are dispersed across a given geographic area (s). When the number of species increases, the evenness and diversity values increase. The Margalef index is a diversity metric that measures species richness; it has no set bounds and varies according to the number of species. The index is frequently used for location comparison (s). The study area had 102 tree species, 74 genera, and 41 families, according to the results of the study on the diversity and richness of tree species. The Margalef index value of 11.52, Pielou Evenness of 0.44, and Shannon-Weiner index value of 3.80 were all within the range of values reported for tropical forests (Adekunle et al., 2013; Chenge et al., 2019) and Rainforest of Oban Natural Forest, Nigeria (Aigbe and Omokhua, 2015).

Nur et al., (2016) reported a Shannon-Weiner index of 3.49 in a tropical rainforest in Bangladesh, which is higher than this research work (3.01). When compared to semi-evergreen forests of the Indian Eastern Ghats and Western Ghats, the forests with the highest number of 51 tree species and the lowest number of 14 species are considered to have low tree species richness. According to Moksia et al., (2012), 99 species from 62 genera and 32 families made up the richness of two woodlands in the Sudano-Sahelian zones of North Cameroon; the number of species was dispersed throughout the two zones investigated.

This finding indicates that the uneven forest areas are low in tree species when compared to other uneven reserves in Nigeria. Aigbe and Omokhua (2015) who obtained 3.80 for the Rainforest of Oban Forest Reserve, Nigeria and 3.74 reported by Adekunle et al., (2013) for Akure Forest Reserve, Nigeria. Amonum et al., (2019) reported 3.21 index. Typically, the number of ecological niches for fauna and under-storey flora rises with the number of tree species (Brown et al., 2021). Therefore, having a wide variety of tree species on a stand helps to conserve not only more trees but also other organisms.

The study area's total number of tree species is typical for the savanna ecosystem. The three study sites in the study area had different tree species densities. The differences in elevation gradient or location of the reserves from various ecological zones of Taraba state, as well as differences in the level of human interference, may be the cause of the variation in plant species density between the three forests. This outcome is consistent with a study carried out by Zomer et al., (2017), who reported that, the expansion of cultivated land has negative effects on the forest ecosystem, plant biodiversity, and carbon emissions.

A high number of families (41) with tree species were found in the study areas, according to this finding on family abundance. This result is consistent with research done by Oluwatosin and Jimoh (2016) in Nigeria's Onigambari Natural Forest and by Muazu (2010), who reported four families in Kuyambana Natural Forest

in Zamfara State, Nigeria. In a game reserve in the Falgore region of Kano state, Nigeria, he noted the dominance of the Caesalpinaceae, Mimosaceae, and Combretaceae families; Amonum et al., (2019) noted 23 of these families there.

Combrataceae and Fabaceae are significant families in tropical deciduous forests and are known to be native species in most savanna-woodland mosaics in Africa (Moksia et al., 2012), Combrataceae and Fabaceae, which are both found in natural forests in the Savanna region and are located in the Kalfou Cameroon and Tioga Forest, respectively, Moksia et al., (2019) and Sawadogo et al., (2007) reported. The main anthropogenic influence and the primary cause of species extinction in terrestrial forest eco-systems is timber extraction. It is challenging to compare studies and datasets because different strategies for conserving biodiversity have been adopted in various nations around the world (Cazzolla Gatti et al., 2017). Selective logging's detrimental effects on the variety of flora and fauna species have been questioned (Laurin et al., 2016).

According to the IUCN list, the population of the tree species *Afzelia africana* is declining (IUCN, 2021). This finding corroborates with the findings of Gaisberger et al., (2017), who noted that the value of native tree species to communities and livestock placed them at risk of extinction due to overuse and harvesting. According to Biara et al., (2021), *A. africana* is one of these indigenous tree species that is seriously endangered throughout much of its native range in Africa.

According to the IUCN Red List for *Entandrophragma angolense*, the population of the tree species is declining (Kasongo et al., 2021b, IUCN, 2021). In contrast, the IUCN classified *E. angolense* as vulnerable in 2019. A useful plant of west tropical Africa, *E. angolense* is a slow-growing semi-deciduous tree (Kasongo et al., 2021). While other tree species are not applicable on the IUCN list, *Bridelia scleroneura, Lonchocarpus laxiflorus, and Trichilia emetic* are "stable" on the red list.

CONCLUSION

The Wasaji uneven forest reserve had the largest mean stem diameter (at 1.3 m), 45.72 cm, and total tree height in the study area, indicating an optimal tree stand density (14.94m). An inverse "J-shape" (reverse "J-shape") diameter distribution was seen in the studied forest areas, which indicates a high potential for regeneration. Individual tree stands in the lower class diameter distribution may mature and eventually replace the older trees if proper conservation efforts are maintained in the study area. From the three uneven forests, 1,295 individual trees totaling 102 tree species, 74 genera, and 41 families were counted. Tree species variance diversity indices of the natural forest areas showed that, tree species occurrence of 51 was the highest recorded in Ngel Nyaki forest area. Thirty two (32) tree species were identified in Wasaji forest area; and 19 species in Bakin Dutse uneven forest. Wasaji forest area had the highest species diversity (3.005), Ngel Nyaki forest area (2.92) and Bakin Dutse forest (2.474). This finding revealed that, the three uneven forest reserves area are rich in tree species diversity with a pattern of a savanna ecosystem type. Tree species density varied across the forest areas; this might be due to variations in the amount of human interference or variations in the gradient of elevation (location of the reserves from different ecological zones of Taraba state). The status of *Afzelia africana* and *Entandrophragma angolense* population is decreasing (vulnerable) on IUCN list, further research should be carryout on their spatial distribution and regeneration potential in the study area in order to ensure fast regeneration. Also, the Taraba State Government should re-strengthen the policies protecting the areas in order to

ensure sustainable biodiversity management, due to the roles the protected areas play in climate change mitigation which cannot be overemphasize in Nigeria. Strict policies could improve the growth and productivity of forest ecosystems of the study area.

AUTHORS CONTRIBUTION

Japheth: conceptualization, formal analysis, methodology, roles, and writing (original draft); Ugbe and Alfa: review, editing, and funding.

DECLARATION OF COMPETING INTEREST

The authors certify that none of their known financial conflicts of interest or close personal ties might have appeared to have influenced the research presented in this study.

FUNDING

There was not any research support or grants for this research.

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