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Comparative Evaluation of the Species Richness and Diversity of Three Parallel Forest Ecosystems in South-Eastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors NCO, EIM and PCN designed the study, wrote the protocol, managed the analyses of the study and wrote the first draft of the manuscript. Authors NCO, KUE, GNN, CFI and CGU carried out the field work. Authors NCO, EIM, PCN, CFI and KUE performed the statistical analysis, wrote the final draft and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The comparative evaluations of the species diversity of three parallel forest ecosystems were evaluated to ascertain and establish the differences in species diversity and abundance. The Point Center Quarter method of plotless sampling was employed while Shannon Wiener's Index of diversity was used to analyze the accrued data. Results showed that *Newbouldia laevis* recorded

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the highest importance value index (28.80) while *Datarium microcarpius* has the least importance value index (2.77) in Ogugu-Nza Shrine forest. It was obvious that *Ceiba pentandra* had the highest importance value index (8.87) in Ukpor Community Forest while *Rauvolfia vomitoria* recorded the lowest importance value index (2.58). When compared to Osomari forest reserve, the importance value index proved that *Gmelina arborea* was the highest with (69.7), followed by *Tectona grandis,* (43.64) while the lowest was *Borassus aetheopicum*. It is crystal clear that there is no iota of relationship in the experimental forests when the observed abundances of different species in terms of importance value index were compared. This could be explained by the fact that the sampled forests were of different orientations, management motives etc (nature reserve, shrine, and community forests). Meanwhile, Ogugu- Nza shrine forest has species diversity of (0.949), with 31 plant species. The dominant species are *Newbouldia laevis, Pterocarpus sp, Gambeya albida,* among others (Table 4). Osomari forest Reserve had species diversity of (0.8), with 24 plant species. The dominant species are *Tectona grandis* and *Gmelina aborea* (Table 5). Ukpor community forest had high species diversity (0.976), with 35 number of plant species recorded in the forest. In Ukpor community forest, the dominant species are *Ceiba pentandra, Sarcocephalus latifolius* and *Pentaclethra macrophylla* (Table 6). Comparatively, it is glaring that Ukpor community forest ranked highest in species diversity, followed by Ogugu-Nza Shrine forest. This goes a long way to confirm that species richness of a particular forest ecosystem is also a function of its species diversity. Management, mode of exploitation and environmental factors could actually account for the paucity of plant species as well the low species diversity as observed in the Osomari forest reserve.

Keywords: Species diversity; shrine forest; forest reserve; community forest; species richness.

1. INTRODUCTION

Forests can be managed for single or multiple purposes to include protection of watersheds, production of timber, provision of wildlife habitat and recreation, regulation of stream flow, control of erosion, medicinal purposes and general aesthetics. It would be impossible for our country to maintain the standard of living it enjoys without the products and services which emanate from forests [1]. Anthropogenic factors that can affect forests include logging, urban sprawl, human-caused forest fires, acid rain, invasive species, and the slash and burn practices of swidden agriculture or shifting cultivation [1,2,3]. The loss and re-growth of forest leads to a distinction between two broad types of forest, primary or old-growth forest and secondary forest. There are also many natural factors that can cause changes in forests over time including forest fires, insects, diseases, weather, competition between species, etc [2,3]. In 1997 the World Resources Institute recorded that only 20% of the world's original forests remained in large intact tracts of undisturbed forest. More than 75% of these intact forests lie in three countries - the Boreal forests of Russia and Canada and the rainforest of Brazil. In 2006 this information on intact forests was updated using latest available satellite imagery [3,4,5].

However, South-eastern Nigeria has been blessed with a warm climate, abundant rainfall, a long growing season and soils which make rapid tree growth. Less time is required to raise a tree crop in the south-east than any other region in the Nation [6]. While there are variations in the activities performed by the several forestry agencies, [7] noted that, each state has the responsibility for the development of forest policy as it relates to state and private forest lands within its boundaries. Programs generally include forest fire control, operation of trees nurseries, assistance to small woodland owners in timber management problems, research, and operation of state forests and general education of the public. According to [8] experience in Africa has shown that, in the absence of careful forestry planning, in the broad context of general land-use planning, the nations' forest resources will not be used to best advantage and may be dissipated by unwise exploitation or neglect. The disappearance of the forest can be seen where communities clear the land on the forest edge, and where crops are introduced even on steep hillsides as in the montane regions of Kenya, Nyasaland and Southern Rhodesia, or in bordering savanna areas where the sub desert encroaches. Land-use planning should provide where essential for the maintenance of tree vegetation, since the new establishment of a tree cover in semi-arid zones with long periods of drought is most difficult and costly. In the Sudanian and Guinean zones of the Upper Volta and north Ghana, the need for the useful protective effects of tree cover is particularly evident. Sound management of the Volta watershed can help to achieve regular stream flow, limit flood damage, check river bank erosion, and reduce the silting of reservoirs for the hydroelectric industry and irrigation. "Gallery forests" along African rivers should be subjected to a very strong conservation effort [9].

Biological diversity encompasses the variety of existing life forms, the ecological roles they perform and the genetic diversity they contain. In forests, biological diversity allows species to adapt continuously to dynamically evolving environmental conditions, to maintain the potential for tree breeding and improvement (to meet human needs for goods and services and changing end-use requirements), and to support their ecosystem functions. While timber production often dominated the way in which forests were managed in the twentieth century, [10] reported that, new pressures in the twenty-first century drive a more balanced approach, calling for delivery of multiple goods and services. The process towards sustainable forest management is now considered consistent with the conservation of biological diversity. Also [10] stated that, there is also great variation in terms of forest tree species diversity, from limited numbers of individual species in boreal ecosystems to high species richness per area unit in Central and South America, South and Southeast Asia, and Western and Central Africa. Boreal forests tend to harbour the lowest species diversity. On average, the ten most common tree species in a country account for 76 percent of total growing stock. This work was carried out to study the species richness of these areas and the impact of human activities on them.

2. MATERIALS AND METHODS

2.1 The Study Area

The first step taken to carry out this research was a preliminary/reconnaissance survey of the forests to be sampled. This entailed a careful study of the areas in question to determine the heterogeneity and the technique to be used in sampling the areas. Anambra State has high potentials for agricultural development, because of stretches of fertile land on the plains in Ogbaru, Ayamelum, Oyi, Awka and Orumba Local Government Areas. Although annual rainfall is high in Anambra State, ranging from 1,400 mm in the north to 2,500 mm in the south, it is concentrated in one season, with about four months of dryness, November to February. Consequently, the natural vegetation in the greater part of Anambra State is tropical dry or deciduous forest, which, in its original form, comprised tall trees with thick under growth and numerous climbers [11]. The typical trees (silk cotton, Iroko and oil bean) are deciduous, shedding their leaves in the dry season. Only in the southern parts of the state, where the annual rain fall is higher and the dry season shorter, is the natural vegetation marginally the tropical rainforest type. Because of the high population density in the state, most of the forests have been cleared for settlement and cultivation. What exists now is secondary re-growth, or a forest savannah mosaic, where the oil palm is predominant, together with selectively preserved economic trees. Relics of the original vegetation may, however, be found in some "juju" shrines or some inaccessible community forests [11]. Anambra state is made up of five (5) forest zones which are also based on the five agricultural zones of the state. They include: Awka zone, Nnewi zone, Abagana zone, Otuocha zone, and Onitsha zone. Out of these five zones, three zones were randomly selected for sampling and characterization with a total land area of 4,416 sq. km, Anambra State is situated on a generally low elevation on the eastern side of the River Niger, and share boundaries with Kogi, Enugu, Imo, Abia, Rivers, Delta and Edo states. It lies within the following geographical locations: 5° 451N to 6° 451N and 6° 361E to 7° 081E [12]. It is bordered in the West by Delta state, on the North by Kogi State, on the east by Enugu State and on the South by Imo state.

2.2 Measures Based on Floristic

The species composition of each sampled forest was assessed floristically; this was accompanied by the abundance of each species present at a site. It is useful to distinguish between abundance and richness, the latter being the number of species present on a particular area. However, the forest area was marked out and randomly stratified, and then measurement by girth was made of trees above one meter in height. Species were identified using Flora of West Tropical Africa vol 2 by [13] and Nigerian Trees vol 2 by [14]. Also the service of Prof. J. C. Okafor, a renowned Nigerian Plant Taxonomist was employed in the identification of plants encountered in the study.

Stratified random sampling was used for sampling and this involves subdividing the field of study into relatively homogeneous parts and then sampling each subdivision according to its area, or some other parameter [15]. The use of plotless method was employed to estimate the abundance, frequency and the density of the species. This design could also be used for collecting information about the species composition (inventory), growth and environmental factors. The type of plotless method that was employed is the Point Center Quarter method. In the point center quarter method, four distances were measured at each sampling point. Four quarters were established at the sampling point through a cross formed by two lines. One line was the compass direction and the second line running perpendicular to the compass direction through the sampling point. The line cross can also be randomly established by spinning a cross over each sampling point. The distance to the mid-point of the nearest tree from the sampling point was measured in each quarter. The four distances of a number of sampling points were averaged and when squared were found to be equal to the mean area occupied by each tree. Cottam and Curtis [16] tested the reliability of this method on several random populations by checking the result with the plot method. The estimates of the correct mean area per tree (MA) were found to apply to each of the different sets of mean distance. Therefore no correction factor is needed when the four quarter distances were averaged; MA = D^2, where D = the mean distance of four points to the nearest tree distances taken in each of four quarters. The mathematical prove of the workability of this method has been given by [17]. According to [16] the accuracy increases with the number of sampling points and a minimum of 20 points was recommended. Newsome and Dix (1968) [18] noted that one of the limitations of this method for field application is that an individual must be located within each quarter and an individual must not be measured twice.

After sampling, the species diversity was calculated using the data that accrued from the sampling of the forests. Shannon-Winner Index of Diversity was used to analyze and determine the species diversity of each of the sampled sites, using the formulae:

$$H^{-} = \sum_{i=1}^{s} (\mathrm{Pi}) \times (\ln \mathrm{Pi})$$

H_{Max} = Ins

$\underline{H_{Max}}$

E, Equitability = H^{-}

Where; Σ = summation

S = number of tree species

i-I = individual species to one

pi = proportion of individual species

Ln pi = natural log of the proportion of the individual species

Dominance = Density of each species x Mean basal area of species

Relative dominance = (Dominance of species / Total dominance of all species) x 100

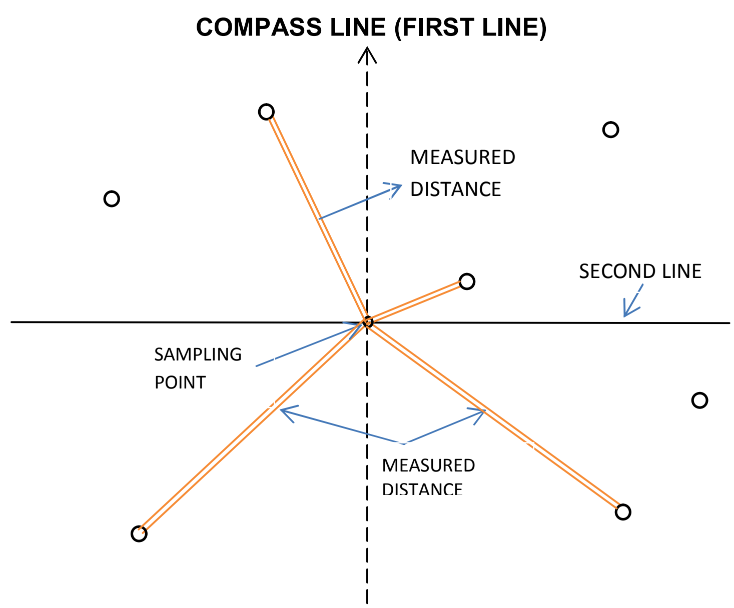

Fig. 1. Graphic representation of Points Center Quarter Method

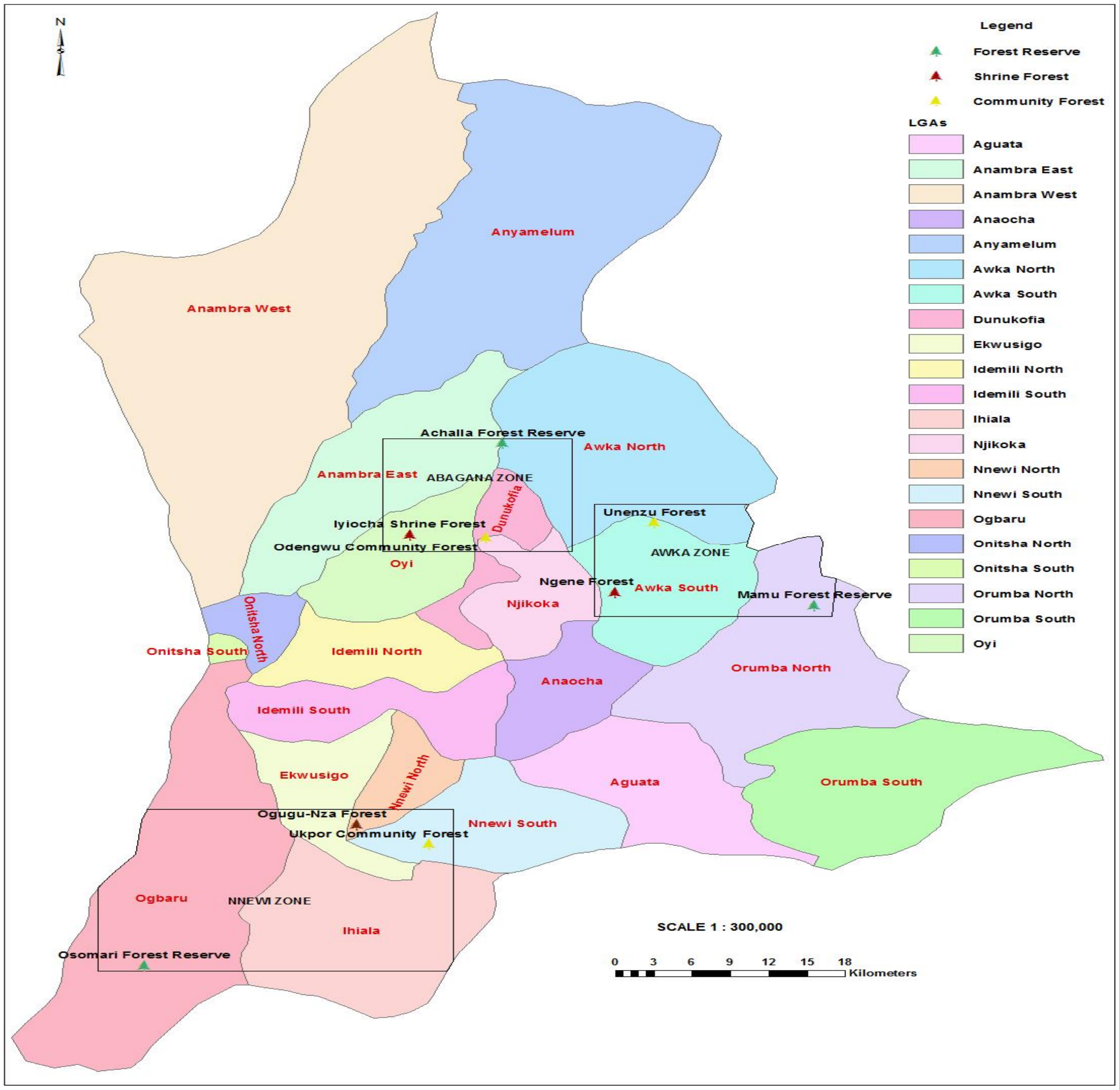

Fig. 2. Map of Anambra State South-Eastern Nigeria indicating the sampled sites

3. RESULTS

A total of 30 species of plant belonging to 17 families were recorded in Ogugu-Nza shrine forest. *Newbouldia laevis* and *Pterocarpus* sp have the highest Importance Value Index (IVI) (28.80) (21.82), respectively while *Datarium microcarpium* has the least importance value index (2.77). It is obvious that *Newbouldia laevis* is the most abundant species in Ogugu-Nza Shrine Forest (Table 1).

A total of 24 species of plant belonging to 12 families were recorded in Osomari forest reserve. *Gmelina aborea* and *Tectona grandis* have the highest importance value index (69.99) (43.64) respectively, while *Borassus aethiopicum* has the least importance value index (2.75). *Gmelina aborea* therefore becomes the most abundant species of Osomari Forest Reserve (Table 2).

A total of 35 spp belonging to 18 families were recorded in Ukpor community forest. *Ceiba pentandra* and *Gambeya albida* have the highest importance value index (8.87) (18.38) respectively while *Rauvolfia vomitoria* reported the lowest important value index (2.58). *Ceiba pentandra* and *Gambeya albida* are therefore the most abundant species of Ukpor community forest (Table 3).

Ogugu-Nza shrine forest has species diversity of (0.949), the dominant species are *Newbouldia* *laevis, Pterocarpus sp, Gambeya albida, Afzelia africana, Dacroydes edulis, Ficus capensis, Irvingia gabonensis, Parkia biglobosa* and *Prosopis africana* (Table 4).

Osomari forest Reserve has species diversity of (0.8), the dominant species are *Tectona grandis* and *Gmelina aborea* (Table 5).

Ukpor community forest has high species diversity (0.976), with 35 number of plant species recorded in the forest. In Ukpor community forest, the dominant species are *Ceiba pentandra, Sarcocephalus latifolius* and *Pentaclethra macrophylla* (Table 6)

4. DISCUSSION

The flora of the south-eastern Nigeria is characterized by a variety of tree species. Anambra state as a rainforest region is a biodiversity conservation unit typified by its richness, endemism in flora and fauna with a high potential for agricultural development as a result of the stretches of fertile land on the plains of its various communities. The species abundance and diversity in these forests were assessed and compared. Observations had it that *Newbouldia laevis* recorded the highest importance value index (28.80) while *Datarium microcarpius* has the least importance value index (2.77) in Ogugu-Nza Shrine forest. It was obvious that *Ceiba pentandra* had the highest importance value index (8.87) in Ukpor Community Forest while *Rauvolfia vomitoria* recorded the lowest importance value index (2.58). When compared to Osomari forest reserve, the importance value index proved that *Gmelina arborea* was the highest with (69.7), followed by *Tectona grandis,* (43.64) while the

Table 1. Species abundance of Ogugu-Nza shrine forest

Species	F (%)	RF (%)	D (Ind ha^{-1})	RD (%)	Dom	RDom (%)	IVI
Newbouldia laevis	45	11.25	0.17	11.25	191.12	6.3	28.8
Pterocarpus sp	25	6.25	0.09	6.25	282.82	9.32	21.82
Afzelia Africana	20	5	0.07	5	296.49	9.77	19.77
Gambeya albida	20	5	0.07	5	282.07	9.29	19.29
Melicia excels	15	3.75	0.06	3.75	261.49	8.62	16.12
Dacroydes edulis	20	5	0.07	5	107.68	3.55	13.55
Irvingia gabonensis	20	5	0.07	5	97.16	3.2	13.2
Prosopis Africana	20	5	0.07	5	89.35	2.94	12.94
Ficus carpensis	20	5	0.07	5	84.38	2.78	12.78
Parkia biglobosa	15	3.75	0.06	3.75	137.98	4.55	12.05
Syzigium guineense	15	3.75	0.06	3.75	124.04	4.09	11.59
Myrianthus arborea	15	3.75	0.06	3.75	113.15	3.73	11.23
Hildegardia barteri	15	3.75	0.06	3.75	104.84	3.45	10.95
Enantia chlorantha	15	3.75	0.06	3.75	90.74	2.99	10.49
Anthocleista djalonensis	15	3.75	0.06	3.75	84.44	2.78	10.28
Pentaclethra macrophylla	10	2.5	0.04	2.5	151.91	5	10
Adansonia digitata	10	2.5	0.04	2.5	122.23	4.03	9.03
Draecena arborea	10	2.5	0.04	2.5	49.96	1.65	6.65
Ceiba pantandra	10	2.5	0.04	2.5	45.59	1.5	6.5
Pointiana regia	10	2.5	0.04	2.5	37.32	1.23	6.23
Spondias mombin	10	2.5	0.04	2.5	32.86	1.08	6.08
Tetrapleura tetraptera	5	1.25	0.02	1.25	62	2.04	4.54
Buchholzia coriaceae	5	1.25	0.02	1.25	41.72	1.37	3.87
Daniella oliveri	5	1.25	0.02	1.25	30.69	1.01	3.51
Dialium guineense	5	1.25	0.02	1.25	30.15	0.99	3.49
Sarcocephalus latifolius	5	1.25	0.02	1.25	21.24	0.7	3.2
Sensepalum dulcificum	5	1.25	0.02	1.25	17.41	0.57	3.07
Aubrevillea kerstingii	5	1.25	0.02	1.25	16.52	0.54	3.04
Elaeis guineensis	5	1.25	0.02	1.25	16.42	0.54	3.04
Datarium microcarpium	5	1.25	0.02	1.25	11.47	0.38	2.88
Total		100	1.49	100	3035.22	99.99	299.99

Table 2. Species abundance of Osomari-East forest reserve

Species	F (%)	RF (%)	D (Ind ha^{-1})	RD (%)	Dom	RDom (%)	IVI
Gmelina aborea	95	26.76	0.14	30	68.79	12.9	69.66
Tectona grandis	50	14.08	0.08	17.5	64.29	12.06	43.64
Adansonia digitata	20	5.63	0.02	5	63.09	11.83	22.46
Beistsclemeidia manii	20	5.63	0.02	5	49.82	9.34	19.98
Daniella oliveri	25	7.04	0.03	6.25	27.53	5.16	18.45
Datarium macrophylla	15	4.23	0.02	3.75	37.14	6.96	14.94
Parkia biglobosa	15	4.23	0.02	3.75	23.09	4.33	12.3
Melicia excels	10	2.82	0.01	2.5	34.3	6.43	11.75
Vitex doniana	15	4.23	0.02	3.75	11.97	2.24	10.22
Draecena arborea	15	4.23	0.02	3.75	7.87	1.48	9.45
Pentaeclethra macrophylla	5	1.41	0.01	1.25	31.25	5.86	8.52
Hildegardia barteri	10	2.82	0.01	2.5	14.35	2.69	8.01
Enantia chlorantha	10	2.82	0.01	2.5	13.65	2.56	7.88
Afzelia Africana	5	1.41	0.01	1.25	21.53	4.04	6.7
Milletia thorningii	5	1.41	0.01	1.25	13.71	2.57	5.23
Aubrevillea kerstingii	5	1.41	0.01	1.25	13.51	2.53	5.19
Pointiana regia	5	1.41	0.01	1.25	8.79	1.65	4.31
Irvingia gabonensis	5	1.41	0.01	1.25	8.79	1.65	4.31
Piptadeniastrum africanam	5	1.41	0.01	1.25	6.93	1.3	3.96
Sarcocephalus latifolius	5	1.41	0.01	1.25	5.08	0.95	3.61
Anthocleista djalonensis	5	1.41	0.01	1.25	3.79	0.71	3.37
Pterocarpus sp	5	1.41	0.01	1.25	3.54	0.66	3.32
Borassus aethiopicum	5	1.41	0.01	1.25	0.5	0.09	2.75
Total		100.03	0.45	100	533.29	99.99	300.01

lowest was *Borassus aetheopicum*. It is crystal clear that there is no iota of relationship pin the experimental forests when the observed abundances of different species in terms of importance value index were compared. This could be explained by the fact that the sampled forests are of different orientations, management motives etc (nature reserve, shrine, and community forests).

However, [19] observed that abundance is contrasted with, but typically correlate to incidence, which is the frequency with which the species occur at all in a sample. In his work to determine the abundance of species in the Nature Reserve Wisconsin, he noted that oak tree; Gopherwood and *Virgilia* dominated the forest more than other species, though their quantitative measurements were not given. Barfet et al. [20] have also worked extensively on species abundance on different forest resources and agreed that some species are actually more in abundance than others. They noted that one of the factors that could account for this was probably because majority of the species could not withstand extreme environmental conditions as well as sustainable exploitation of the species. This is in agreement with the finding of this research work in the sense that some of the dominant species have been sustainably exploited especially in the government regulated areas like the Forest Reserves.

Meanwhile, Ogugu-Nza shrine forest has species diversity of (0.949), with 31 plant species. The dominant species are *Newbouldia laevis, Pterocarpus sp, Gambeya albida,* among others (Table 4). Osomari forest Reserve had species diversity of (0.8), with 24 plant species. The dominant species are *Tectona grandis* and *Gmelina aborea* (Table 5). Ukpor community forest had high species diversity (0.976), with 35 number of plant species recorded in the forest. In Ukpor community forest, the dominant species are *Ceiba pentandra, Sarcocephalus latifolius* and *Pentaclethra macrophylla* (Table 6). Comparatively, it is glaring that Ukpor community forest ranked highest in species diversity, followed by Ogugu-Nza Shrine forest. This goes a long way to confirm that species richness of a

Table 3. Species abundance of Ukpor community forest

All Species	F (%)	RF (%)	D (Ind ha^{-1})	RD (%)	Dom	RDom (%)	IVI
Ceiba pentandra	5	5.06	0.07	5	202.61	8.87	18.93
Gambeya albida	3.75	3.8	0.05	3.75	247.4	10.83	18.38
Pentaclethra macrophylla	5	5.06	0.07	5	172.75	7.56	17.62
Adansonia digitata	3.75	3.8	0.05	3.75	167.21	7.32	14.87
Sarcocephalus latifolius	5	5.06	0.07	5	77.54	3.39	13.46
Irvingia gabonensis	3.75	3.8	0.05	3.75	102.31	4.48	12.03
Pterocarpus sp	3.75	3.8	0.05	3.75	97.89	4.28	11.83
Datarium microcarpium	3.75	3.8	0.05	3.75	82.02	3.59	11.14
Hildegardia barteri	3.75	3.8	0.05	3.75	66.14	2.89	10.44
Buchholzia coriaceae	3.75	3.8	0.05	3.75	64.43	2.82	10.37
Myranthus arboreus	3.75	3.8	0.05	3.75	61.99	2.71	10.26
Pointiana regia	3.75	3.8	0.05	3.75	54.8	2.4	9.95
Vitex doniana	3.75	3.8	0.05	3.75	46.97	2.06	9.6
Afzelia Africana	2.5	2.53	0.03	2.5	94.72	4.15	9.18
Tetrapleura tetraptera	2.5	2.53	0.03	2.5	88.2	3.86	8.89
Ficus exasperate	3.75	3.8	0.05	3.75	23.69	1.04	8.58
Prosopis Africana	2.5	2.53	0.05	3.75	37.04	1.62	7.9
Sensepalum dulcificum	2.5	2.53	0.03	2.5	50.78	2.22	7.25
Piptadeniastrum africanum	2.5	2.53	0.03	2.5	48.74	2.13	7.17
Draecena arborea	2.5	2.53	0.03	2.5	44.87	1.96	7
Anthocleista djalonensis	2.5	2.53	0.03	2.5	44.36	1.94	6.97
Milletia thoningii	2.5	2.53	0.03	2.5	33.89	1.48	6.52
Enantia chlorantha	2.5	2.53	0.03	2.5	28.09	1.23	6.26
Newboudia laevis	2.5	2.53	0.03	2.5	28.06	1.23	6.26
Dacroydes edulis	2.5	2.53	0.03	2.5	27.76	1.22	6.25
Syzigium guineense	2.5	2.53	0.03	2.5	25.93	1.14	6.17
Parkia biglobosa	2.5	2.53	0.03	2.5	20.88	0.91	5.95
Melicia excels	1.25	1.27	0.02	1.25	69.72	3.05	5.57
Aubrevillea kerstingii	1.25	1.27	0.02	1.25	48.63	2.13	4.64
Beitschlemeidia manii	1.25	1.27	0.02	1.25	40.01	1.75	4.27
Dialium guineense	1.25	1.27	0.02	1.25	38.16	1.67	4.19
Daniella oliveri	1.25	1.27	0.02	1.25	30.57	1.34	3.85
Spondias mombin	1.25	1.27	0.02	1.25	10.59	0.46	2.98
Borassus aethiopicum	1.25	1.27	0.02	1.25	4.33	0.19	2.71
Rauvolfia vomitoria	1.25	1.27	0.02	1.25	1.51	0.07	2.58
Total		100	1.32	100	2284.6	100	300

Frequency = F, Density = D, Relative Frequency = RF, Relative Density = RD, Dominance = Dom, Relative Dominance = RDom

particular forest ecosystem is also a function of its species diversity. As explained earlier, management, mode of exploitation and environmental factors could actually account for the paucity of plant species as well as the low species diversity as observed in the Osomari forest reserve.

Krebs [21] agreed that the observed species diversity is affected by not only the number of individual but also by the heterogeneity of the sample. He was also of the opinion that increasing the area samples increases observed species diversity both because more individuals get included in the sample and large areas were environmentally more heterogynous than small areas. His observation tallies with the present research work because Point Center Quarter method gives room for large area sampling and virtually all the sampled forests were relatively diverse, even the Osomari Forest Reserve that was the least in the rank of diversity could also be considered relatively diverse (0.800). Over exploitation of the species could actually be a factor to account for this low diversity in relation to other sampled forests. Whicker and Defling [22] has been able to explain much of the variation in woody plant diversity and dominance by some tree species across Sonoran forest landscapes by differences in soil age, frequency of land disturbance caused by soil erosion and soil depth. The key point here is that community forests generally consist of many species that potentially interact in all the ways with one another. Richlefs and Schluter [23] concurred that species diversity increases with environmental complexity or heterogeneity. They however noted that an aspect of environmental structure important to one group of organisms may not have a positive influence on another group. Consequently, one must be acquainted with the ecological requirements of species to predict environmental structure that affects the diversity.

Generally, species diversity is one of the most important indices used to evaluate an ecosystem. A rich ecosystem with high species diversity has a large value (H') while an ecosystem with low value (H') will have low species diversity [24]. The present study sites had relatively high species diversity for tree species. Probably, the high species diversity could be attributed to the many tributaries and streams that empty rich organic content and mineral resources utilized by the species for growth and production as well as the sampling methodology (the Point Center Quarter method). Giliba et al. [25,26,27] reported similar findings on woodland of Bereku Forest Reserve in Tanzania.

Table 4. Species diversity of Ogugu-Nza shrine forest

Species	**n**	**N**	Pi	**In(pi)**	**pi*In(pi)**	**-Σ(pi)*In(pi)**
Adonsonia digitata	2	80	0.025	-3.68888	-0.092221986	H^1=3.22916
Afzelia Africana	4	80	0.05	-2.99573	-0.149786614	
Anthocleista djalonensis	3	80	0.0375	-3.28341	-0.123128038	
Aubrevillea kerstingii	1	80	0.0125	-4.38203	-0.054775333	H_{max}= Ins (In30)
Buchholzia coriaceae	1	80	0.0125	-4.38203	-0.054775333	3.40120
Ceiba pantandra	2	80	0.025	-3.68888	-0.092221986	
Melicia excels	3	80	0.0375	-3.28341	-0.123128038	
Gambeya albida	4	80	0.05	-2.99573	-0.149786614	
Dacroydes edulis	4	80	0.05	-2.99573	-0.149786614	Equitability=
Daniella oliveri	1	80	0.0125	-4.38203	-0.054775333	(H^1/ H_{max})=
Datarium microcarpium	1	80	0.0125	-4.38203	-0.054775333	0.94942
Poitiana regia	2	80	0.025	-3.68888	-0.092221986	
Dialium guineense	1	80	0.0125	-4.38203	-0.054775333	
Draecena arborea	2	80	0.025	-3.68888	-0.092221986	
Elaeis guineensis	1	80	0.0125	-4.38203	-0.054775333	
Enantia chlorantha	3	80	0.0375	-3.28341	-0.123128038	
Ficus capensis	4	80	0.05	-2.99573	-0.149786614	
Hildegardia barteri	3	80	0.0375	-3.28341	-0.123128038	
Irvingia gabonensis	4	80	0.05	-2.99573	-0.149786614	
Myrianthus arboreus	3	80	0.0375	-3.28341	-0.123128038	
Sarcocephalus latifolius	1	80	0.0125	-4.38203	-0.054775333	
Newbouldia laevis	9	80	0.1125	-2.1848	-0.245790231	
Parkia biglobosa	4	80	0.05	-2.99573	-0.149786614	
Pentaclethra macrophylla	2	80	0.025	-3.68888	-0.092221986	
Prosopis Africana	4	80	0.05	-2.99573	-0.149786614	
Pterocarpus sp	4	80	0.05	-2.99573	-0.149786614	
Sensepalum dulcificum	1	80	0.0125	-4.38203	-0.054775333	
Spondias mombin	2	80	0.025	-3.68888	-0.092221986	
Syzigium guineense	3	80	0.0375	-3.28341	-0.123128038	
Tetraplura tetraptera	1	80	0.0125	-4.38203	-0.054775333	
Total					3.229	

N = Number of sampling points; n = Number of species encountered

Table 5. Species diversity of Osomari forest reserve

Species	n	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	4	80	0.05	-2.99573	-0.14979	H^1=2.51078
Afzelia Africana	1	80	0.0125	-4.38203	-0.05478	
Arithocleista djalonensis	1	80	0.0125	-4.38203	-0.05478	H_{max}= Ins (In23)
Aubreillea kerstingii	1	80	0.0125	-4.38203	-0.05478	3.13549
Beistschlemeidia manii	4	80	0.05	-2.99573	-0.14979	
Borassus aethiopicum	1	80	0.0125	-4.38203	-0.05478	
Melicia excels	2	80	0.025	-3.68888	-0.09222	
Daniella oliveri	5	80	0.0625	-2.77259	-0.17329	Equitability=
Datarium macrophylla	3	80	0.0375	-3.28341	-0.12313	(H^1/ H_{max})=
Poitiana regia	1	80	0.0125	-4.38203	-0.05478	0.80076
Draecena arborea	3	80	0.0375	-3.28341	-0.12313	
Enantia chlorantha	2	80	0.025	-3.68888	-0.09222	
Gmelina aborea	24	80	0.3	-1.20397	-0.36119	
Hildagardia barteri	2	80	0.025	-3.68888	-0.09222	
Irvingia gabonensis	1	80	0.0125	-4.38203	-0.05478	
Milletia thoriningii	1	80	0.0125	-4.38203	-0.05478	
Sarcocephalus latifolius	1	80	0.0125	-4.38203	-0.05478	
Parkia biglobosa	3	80	0.0375	-3.28341	-0.12313	
Pentaclethra macrophylla	1	80	0.0125	-4.38203	-0.05478	
Piptadeniastrum africanum	1	80	0.0125	-4.38203	-0.05478	
Pterocarpus sp	1	80	0.0125	-4.38203	-0.05478	
Tectona grandis	14	80	0.175	-1.74297	-0.30502	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					2.510	

Table 6. Species diversity of Ukpor community forest

Species	n	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	3	80	0.0375	-3.28341	-0.12313	H^1=3.47176
Afzelia Africana	2	80	0.025	-3.68888	-0.09222	
Aubrevillea kerstingii	1	80	0.0125	-4.38203	-0.05478	H_{max}= Ins (In35)
Anthocleista djalonensis	2	80	0.025	-3.68888	-0.09222	3.55535
Beitsclemeidia manii	1	80	0.0125	-4.38203	-0.05478	
Borassus aethiopicum	1	80	0.0125	-4.38203	-0.05478	
Buchholzia coriaceae	3	80	0.0375	-3.28341	-0.12313	
Ceiba pentandra	4	80	0.05	-2.99573	-0.14979	Equitability=
Melicia excels	1	80	0.0125	-4.38203	-0.05478	(H^1/H_{max})=
Gambeya albida	3	80	0.0375	-3.28341	-0.12313	0.97649
Dacroydes edulis	2	80	0.025	-3.68888	-0.09222	
Daniella oliveri	1	80	0.0125	-4.38203	-0.05478	
Datarium macrocarpium	3	80	0.0375	-3.28341	-0.12313	
Pointiana regia	3	80	0.0375	-3.28341	-0.12313	
Dialium guineense	1	80	0.0125	-4.38203	-0.05478	
Draecena arborea	2	80	0.025	-3.68888	-0.09222	
Enantia chlorantha	2	80	0.025	-3.68888	-0.09222	
Ficus exasperate	3	80	0.0375	-3.28341	-0.12313	
Hildegardia barteri	3	80	0.0375	-3.28341	-0.12313	
Irvingia gabonensis	3	80	0.0375	-3.28341	-0.12313	
Milletia thorningii	2	80	0.025	-3.68888	-0.09222	
Myranthus arboreus	3	80	0.0375	-3.28341	-0.12313	
Sarcocephalus latifolius	4	80	0.05	-2.99573	-0.14979	
Newboudia laevis	2	80	0.025	-3.68888	-0.09222	

Species	n	N	Pi	ln(pi)	pi*ln(pi)	-Σ(pi)*ln(pi)
Parkia biglobosa	2	80	0.025	-3.68888	-0.09222	
Pentaclethra macrophylla	4	80	0.05	-2.99573	-0.14979	
Piptadeniastrum africanum	2	80	0.025	-3.68888	-0.09222	
Prosopis Africana	3	80	0.0375	-3.28341	-0.12313	
Pterocarpus sp	3	80	0.0375	-3.28341	-0.12313	
Rauvolfia vomitoria	1	80	0.0125	-4.38203	-0.05478	
Sensepalum dulcificum	2	80	0.025	-3.68888	-0.09222	
Spondias mombin	1	80	0.0125	-4.38203	-0.05478	
Syzigium guineense	2	80	0.025	-3.68888	-0.09222	
Tetrapleura tetraptera	2	80	0.025	-3.68888	-0.09222	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					3.471	

5. CONCLUSION

Forests need to be managed so that the risks and impacts of unwanted disturbances are minimized, including wildfires, airborne pollution, storm felling, invasive species, pests, diseases and insects. Such disturbances may impact social and economic as well as environmental dimensions of forestry. Primary forests are often equated with high levels of biodiversity, but [25,28,29] opined that, this is not always the case. In the temperate and boreal zones, for example, they can be poor in terms of number of plant and animal species, while some modified natural or semi-natural forests and forests bordering agricultural areas may provide additional habitats and thus harbor more species. Nevertheless, he noted that, the size of the area of primary forest is one of several important indicators of the state of forest ecosystems. It should also be kept in mind that primary forests fulfill many essential functions other than the conservation of biological diversity soil and water conservation, carbon sequestration and the preservation of aesthetic, cultural and religious values. Forest area provides the first indication of the relative importance of forests in a country or region, while estimates of forest area change over time provide an indication of the demand for land for forestry and other land uses, and may also illustrate the impact of significant environmental disasters and disturbances on forest ecosystems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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