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Evaluating Species Diversity and Ecological Health of Nnamdi Azikiwe University Forest, Awka, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The increasing threats to forest habitats due to natural and anthropogenic factors necessitate a detailed ecological assessment. This study aims to understand the ecological dynamics and biodiversity within the forest ecosystems of Nnamdi Azikiwe University, Awka, in the context of climate change and habitat destruction. Employing a stratified random sampling method and the Point Center Quarter Method, we collected data from 24 designated sample points across a 5000 m² plot. Measurements included species distance from sampling points and diameter at breast height (DBH) of trees. We computed phytosociological parameters such as density, basal area,

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dominance, cover, and frequency, along with relative values to determine species importance and diversity indices. A total of 96 trees comprising 71 species from 33 families were identified. Notably, Malvaceae and Fabaceae were the most represented families. Ficus benjamina had the highest total basal area (113.89 m²/ha) and important value index (25.98), indicating its ecological significance. The Shannon-Wiener index value of 4.13 reflects robust biodiversity, highlighting the ecological richness of the forest. These findings are crucial for informing conservation efforts and sustainable management of forest resources.

Keywords: Ecological assessment; species diversity; forest habitat; point center quarter method (PCQM); biodiversity.

1. INTRODUCTION

Throughout human history, trees have been revered for their numerous contributions, ranging from serving as a means of sustenance in the form of fruits and nuts to providing shelter and raw materials for tools and construction [1]. The ancient civilizations of Nigeria recognized the role of trees in maintaining life and culture, a practice that continues to resonate today. Trees were not only sources of sustenance for the ancient civilizations but also symbols of spiritual significance, embodying beauty and life [2]. Forests are among the most important ecosystems on our planet, playing an essential role in preserving global ecological balance. They provide habitats for numerous species, regulate climate, purify air and water, and provide many resources that support both natural and human societies. A forest is a vibrant and intricate ecosystem, an exquisite web of life in which trees and their associated plants and animals form an interconnected community. Within this ecosystem, a remarkable life cycle unfolds as plants and animals interact and eventually experience the complete range of existence, including aging and death [1,3].

Forests can be found in all places capable of supporting tree growth, at altitudes up to the tree line, except when natural fire frequency or other disturbances are too great, or where the environment has been altered by human activity [4]. Nigeria possesses land spanning 92.4 million hectares, with approximately 9.7 million hectares, constituting around 10% of the nation, designated as forest reserves [5]. The tropical rainforest, a significant component of Nigeria's forested areas, has been recognized as the most biologically diverse terrestrial ecosystem globally [6,1,7,8,9].

In forest ecology, species diversity is an important metric. Forests may have a large number of tree species in a small area (as in tropical rain and temperate deciduous forests) or a small number of species in a large area (as in taiga and arid montane coniferous forests). Tree diversity is critical to tropical forest biodiversity because trees provide homes and resources for a diverse range of plant and animal species. They contribute significantly to forest ecosystem stability, stress resistance, ecological processes (pollination, reproduction and renewal, competition and dependence, growth, and death), and ecosystem services (primary productivity, decomposition, nutrition, energy, and culture) [10,11,12]. As a result, they influence the design and composition of forest communities [13]. This study was carried out to determine the floristic composition and diversity of the study area and to understand how this assessment can lead to biodiversity conservation and sustainable forest management.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study site is located at Nnamdi Azikiwe University Awka forest, in Anambra State, Nigeria established in the Southeastern zone in 1991 with a mean elevation of 136 meters above sea level. The University lies within the geographical location: 6.245° and 6.283° N, 7.115° and 7.1219° E. Anambra State, with a total land area of 4,416 sq. km is situated on a generally low elevation on the eastern side of the River Niger, and shares boundaries with Kogi, Enugu, Imo, Abia, Rivers, Delta and Edo states. It lies within the following geographical locations: 5° 451 N to 6° 451 N and 6° 361 E to 7° 081 E [14]. It is bordered in the West by Delta State, on the North by Kogi State, on the East by Enugu State, and the South by Imo State. Anambra State has a high potential for agricultural development, because of stretches of fertile land on the plains in Ogbaru, Ayamelum, Oyi, Awka, and Orumba Local Government Areas. Anambra State experiences an equatorial tropical rainforest

climate, marked by two primary seasons namely: the rainy (wet) season and the dry season. The rainy season, featuring intense thunderstorms, spans from April to October, while the dry season covers the period from November to March each year [15]. The rainfall is typically intense throughout the rainy season, except for a notable decrease in August, known as the August break. This contributes to the distinctive double maxima of rainfall in this pattern. The rainy season is marked by elevated temperatures ranging from 25°C to 33°C and high relative humidity at 85% [15].

2.2 Data Collection

The initial step in conducting this research involved conducting a preliminary survey of the forest intended for sampling. A plot size of 5000 m² (50 m × 100 m), representing the minimal area, was employed. Once the plots were delineated, pegs were placed at each end to ensure proper demarcation. The forest's species composition was evaluated through floristic assessment, and this was complemented by determining the abundance of each species present at the site. However, the forest area was delineated and divided into random strata. Measurements of tree girth were then taken for trees taller than one meter. Species identification was conducted using Flora of West Tropical Africa [16] and Nigerian Trees [17].

2.2.1 Stratified sampling

This process involves dividing the study area into relatively uniform sections and then sampling each subsection based on its area or other relevant parameter. The plotless method was utilized to estimate the species' density. This approach is also applicable for gathering data on species composition (inventory), growth, and environmental factors. The specific plotless method employed in this study is the Point Center Quarter Method. In the Point Center Quarter Method, four distances instead of one were measured at every sampling point. To establish four quarters at the sampling point, a cross was formed by two lines, one following the compass direction and the other running perpendicular to the compass direction through the sampling point. Alternatively, the cross could be randomly determined by spinning it over each sampling point. The distance to the midpoint of the nearest tree from the sampling point was measured in each quarter. The four distances between several sampling points were averaged and squared to find the mean area occupied by each tree. Cottam and Curtis [18] validated the reliability of this method across various random populations by cross-verifying the results with the plot method. The calculations for the accurate mean area per tree (MA) were observed to be applicable across various sets of mean distances. Hence, there is no necessity for a correction factor when averaging the distances from the four quarters; MA = D2, where D represents the mean distance from four points to the nearest tree, measured in each of the four quarters. The mathematical validation of the effectiveness of this method was provided by Morisita (1954). According to Cottam and Curtis [18], accuracy improves with an increasing number of sampling points, and a minimum of 20 points was recommended. Newsome and Dix [19] pointed out that a limitation of this method for field application is that an individual must be located within each quarter, and the same individual must not be measured twice. Therefore, stands with individuals widely spaced pose a challenge in applying this method.

Following the sampling process, the species diversity was calculated using the data obtained from the forest sampling. The Shannon-Wiener Index of Diversity was employed to analyze and ascertain the species diversity of the sampled site utilizing the formula:

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

$$H_{Max} = \ln S H_{Max}$$

$$E, \text{Equitability} = H'/H_{Max}$$

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

2.3 Data Analysis

The density, frequency, dominance, and important value index (IVI) and their relative values were calculated for each tree species using the following formula:

Density = Total number of individuals of a species / Total area sampled
Relative density = (Density of a species / Sum of densities of all species) x 100

Relative Frequency = (Frequency of a species / Sum of frequencies of all species) x 100
Dominance = Total basal area of a species / Total area sampled
Relative Dominance = (Dominance of a species / Sum of dominance of all species) x 100
Important value index (IVI) = Relative frequency + Relative density + Relative dominance

3. RESULTS

3.1 Ecological Survey of Plants in the Study Area

3.1.1 Forest tree species, composition, diversity, and distribution

A total of 24 sample points numbered A-X were made available using PCQM to identify trees in the study area. The distance of the species closest to the center point per quarter was estimated and the diameter at breast Height (DBH) of the tress was measured.

The species mostly encountered belonged to the Malvaceae family (9 species), followed by the Fabaceae family (8 species), Moraceae family (5 species), Euphorbiaceae family (4 species), Urticaceae family (4 species), Combretaceae, Meliaceae, Rutaceae, and Anarcadiaceae (3 species each), Annonaceae, Lecythidaceae, Sapindaceae, Stilbaceae, Apocynaceae (2 species each), and Arecaceae, Theaceae, Thymelaceae, Bixaceae, Lauraceae, Rubiaceae, Dipterocarpaceae, Salicaceae, Clusiaceae, Myristicaceae, Oleaceae, Magnoliaceae, Bignoniaceae, Phytoloccaceae, Nyctaginaceae, Myrtaceae, Resedaceae, Tetramelaceae, Adoxaceae (each having one species).

When the number of trees belonging to each family was estimated, Fabaceae was the dominant species in the forest with 13 trees, closely followed by Malvaceae having 12 trees, and Moraceae with 11 trees (Table 2).

Table 1. Species Encountered in the sampled Points

Sample Area	Quarter	Species	DBA (cm)	Distance (m)
A	1st	*Combretum illarii* Engl.	4.00	2.50
	2nd	*Magnolia grandiflora* L.	3.00	1.00
	3rd	*Antiaris toxicaria* Lesch	2.50	3.00
	4th	*Ficus trichopoda* Baker	3.50	2.00
B	1st	*Elaeis guineensis* Jacq	2.50	1.70
	2nd	*Flacourtia rukam* Zoll. &Moritzi	3.00	2.90
	3rd	*Ficus benjamina* L.	10.20	2.50
	4th	*Cecropia obtusa* Trecul	5.00	2.50
C	1st	*Trichilia dregeana* Sond.	1.10	3.22
	2nd	*Theobroma cacao* L.	2.90	2.80
	3rd	*Schizolobium parahyba* (Vell.) S. F. Blake	0.30	3.48
	4th	*Duboscia macrocarpa* Bocq.	2.00	3.40
D	1st	*Garcinia gardneriana* (Planch. &Triana) Zapp	2.30	2.15
	2nd	*Hymenea courbaril* L.	0.35	4.50
	3rd	*Cola cordifolia* (Cav.) R. Br.	0.30	2.30
	4th	*Trichilia dregeana* Sond.	2.00	3.40
E	1st	*Nuxia floribunda* Benth.	0.45	2.60
	2nd	*Alchornea glandulosa* Poepp.	0.50	2.40
	3rd	*Petivera alliacea* L.	0.30	2.28
	4th	*Alchornea cordifolia* Müll.Arg.	0.30	1.70
F	1st	*Pterocarpus officinalis* Jacq.	1.20	3.28
	2nd	*Bixa Orellana* L.	1.50	2.58
	3rd	*Hevea brasiliensis* (Willd.ex A. Juss.) Müll.Arg.	0.70	4.00
	4th	*Firmiana simplex* (L.) W.Wight	1.00	2.10

Sample Area	Quarter	Species	DBA (cm)	Distance (m)
G	1st	*Populus alba* L.	2.00	5.00
	2nd	*Coffea liberica* Hiern	1.39	3.69
	3rd	*Hevea brasiliensis* (Willd. ex A. Juss.) Müll.Arg.	0.95	2.38
	4th	*Derris elliptica* (Wall.) Benth.	2.23	1.08
H	1st	*Ficus insipida*Willd.	2.47	6.05
	2nd	*Antiaris toxicaria* Lesch.	1.95	3.40
	3rd	*Couroupita guianensis* Aubl.	0.60	2.14
	4th	*Pterocarpus officinalis* Jacq.	1.56	1.50
I	1st	*Sterculia macrophylla* Vent.	0.80	0.19
	2nd	*Sterculia tragacantha* Lindl.	1.04	2.50
	3rd	*Pterocarpus rohrii* Vahl	2.15	3.30
	4th	*Toxicodendron succedaneum* (L.) Kuntze	2.20	2.10
J	1st	*Mustanga cecropioides*R. Br. ex Tedlie	3.05	6.50
	2nd	*Annona purpurea* Moc. &Sessé ex Dunal	2.30	3.20
	3rd	*Archidendron jiringa* (Jack) I. C. Nielsen	1.07	4.00
	4th	*Pterocarpus officinalis* Jacq.	1.25	2.21
K	1st	*Grewia trichocarpa* Hochst. ex A. Rich.	2.34	4.08
	2nd	*Zanthoxylum rhoifolium* Lam.	2.17	1.49
	3rd	*Guarea guidonia* (L.) Sleumer	1.96	2.72
	4th	*Terminalia arjuna* (Roxb. ex DC.) Wight &Arn.	3.31	2.50
L	1st	*Dimocarpus longan* Lour.	1.26	5.02
	2nd	*Cecropia obtusifolia* Bertol.	2.01	4.20
	3rd	*Aphanamixis polystachya* (Wall.) R. Parker	1.45	0.93
	4th	*Elaeisg uineensis* Jacq.	0.81	2.70
M	1st	*Vibrurnum tinus* L.	2.61	2.07
	2nd	*Tetrameles nudiflora* R.Br.	1.90	1.25
	3rd	*Hura crepitans* L.	2.15	0.79
	4th	*Horsifieldia kingie* (Hook.f.) Warb.	1.52	2.42
N	1st	*Stixis suaveolens* (Roxb.) Pierre	1.70	4.51
	2nd	*Antiaris toxicaria* Lesch.	2.05	3.02
	3rd	*Camellia sinensis* (L.) Kuntze	1.89	3.15
	4th	*Persea Americana* Mill.	2.23	2.90
O	1st	*Jasminum multiflorum* (Burm.f.) Andrews	0.81	2.37
	2nd	*Annona squamosal* L.	0.69	4.10
	3rd	*Combretum erythrophyllum* Sond.	2.30	2.25
	4th	*Psidium cattleianum* Sabine	1.59	1.50
P	1st	*Tabernaemontana pachysiphon* Stapf	2.12	0.62
	2nd	*Vepris trichocarpa* (Engl.) Letouzey	0.96	2.12
	3rd	*Elaeis guineensis* Jacq.	0.82	3.32
	4th	*Ficus sycomorus* L.	2.33	1.82
Q	1st	*Millettia pachycarpa*Benth.	2.02	2.48
	2nd	*Barringtonia racemose* (L.) Spreng.	2.10	2.32
	3rd	*Antiaris toxicaria*Lesch.	2.50	4.10
	4th	*Lannea coromandelica* (Houtt.) Merr.	1.35	0.82
R	1st	*Aquilaria sinensis*(Lour.) Spreng.	2.45	1.49
	2nd	*Dracontomelon duperreanum* Pierre	1.83	3.26
	3rd	*Antiaris toxicaria*Lesch.	2.40	2.52

Sample Area	Quarter	Species	DBA (cm)	Distance (m)
	4th	*Firmiana simplex* (L.) W.Wight	0.60	4.80
S	1st	*Dipterocarpus turbinatus* C.F.Gaertn.	0.62	3.20
	2nd	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. &Timler	1.89	2.90
	3rd	*Harpullia pendula* Planch. ExF.Muell.	2.72	4.30
	4th	*Pterocarpus officinalis* Jacq.	0.32	2.45
T	1st	*Theobroma cacao* L.	0.71	3.63
	2nd	*Cecropia peltata* L.	1.25	2.10
	3rd	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. &Timler	1.41	1.96
	4th	*Saraca indica* L.	1.52	2.85
U	1st	*Persea americana* Mill.	1.32	1.76
	2nd	*Ceiba pentadra* (L.) Gaertn.	0.92	2.45
	3rd	*Pisonia aculeate* L.	1.52	2.70
	4th	*Sterculia tragacantha* Lindl.	2.00	3.10
V	1st	*Combretum illarii* Browicz&Zemanek	1.27	3.50
	2nd	*Cola millenii* K. Schum.	0.42	4.01
	3rd	*Oroxylum indicum* (L.) Kurz	0.56	3.60
	4th	*Terminalia arjuna* (Roxb. ex DC.) Wight &Arn.	2.52	3.70
W	1st	*Ficus insipida*Willd.	0.92	2.10
	2nd	*Schizolobium parahyba* (Vell.) S. F. Blake	0.67	1.97
	3rd	*Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg.	1.52	3.26
	4th	*Zanthoxylum rhoifolium* Lam	1.28	3.00
X	1st	*Antiaris toxicaria* Lesch.	0.86	1.57
	2nd	*Hymenaea courbaril* L.	1.65	2.80
	3rd	*Tabernaemontana donnell - smithii* Rose ex J. D. Sm.	2.24	1.65
	4th	*Elaeis guineensis*Jacq.	1.25	2.40
Total				

Table 2. Family list of the forest, their number of species, and number of trees

Family Name	Scientific Names	No. of Species	Number of Trees
Moraceae	*Antiaris toxicaria* *Ficus insipida* *Ficus benjamina* *Ficus sycomorus* *Ficus trichopoda*	5	11
Arecaceae	*Elaeis guineensis*	1	4
Fabaceae	*Pterocarpus officinalis* *Hymenaea courbaril* *Schizolobium parahyba* *Archidendro njiringa* *Millettia pachycarpa* *Pterocarpus rohrii* *Saraca indica* *Derris elliptica*	8	13
Euphorbiaceae	*Hevea brasiliensis* *Alchornea cordifolia* *Alchornea glandulosa*	4	6

Family Name	Scientific Names	No. of Species	Number of Trees
	Hura crepitans		
Combretaceae	*Combretum illarii*	3	5
	Terminalia arjuna		
	Combretum erythrophyllum		
Malvaceae	*Sterculia tragacantha*	9	12
	Firmiana simplex		
	Theobroma cacao		
	Ceiba pentadra		
	Cola cordifolia		
	Cola millenii		
	Duboscia macrocarpa		
	Grewia trichocarpa		
	Sterculia macrophylla		
Lauraceae	*Persea Americana*	1	2
Meliaceae	*Trichilia dregeana*	3	4
	Aphanamixis polystachya		
	Guarea Guidonia		
Rutaceae	*Zanthoxylum rhoifolium*	3	5
	Zanthoxylum zanthoxyloides		
	Vepris trichocarpa		
Annonaceae	*Annona purpurea*	2	2
	Annona squamosal		
Thymelaeaceae	*Aquilaria sinensis*	1	1
Lecythidaceae	*Barringtonia racemose*	2	2
	Couroupita guianensis		
Bixaceae	*Bixa Orellana*	1	1
Theaceae	*Camellia sinensis*	1	1
Urticaceae	*Cecropia obtuse*	4	4
	Cecropia obtusifolia		
	Cecropia peltata		
	Mustanga cecropioides		
Rubiaceae	*Coffea liberica*	1	1
Sapindaceae	*Dimocarpus longan*	2	2
	Harpullia pendula		
Dipterocarpaceae	*Dipterocarpus turbinatus*	1	1
Anacardiaceae	*Dracontomelon duperreanum*	3	3
	Lannea coromandelica		
	Toxicodendron succedaneum		
Salicaceae	*Flacourtia rukam*	1	1
Clusiaceae	*Garcinia gardneriana*	1	1
Myristicaceae	*Horsifieldia kingie*	1	1
Oleaceae	*Jasminum multiflorum*	1	1
Magnoliaceae	*Magnolia grandiflora*	1	1
Stilbaceae	*Nuxia floribunda*	2	2
Bignoniaceae	*Oroxylum indicum*	1	1
Phytolaccaceae	*Petivera alliacea*	1	1
Nyctaginaceae	*Pisonia aculeate*	1	1
Myrtaceae	*Psidium cattleianum*	1	1
Resedacea	*Stixis suaveolens*		
Apocynaceae	*Tabernaemontana donnell – smithii*	2	2
	Tabernaemontana pachysiphon		
Tetramelaceae	*Tetrameles nudiflora*	1	1
Adoxaceae	*Vibrurnum tinus*	1	1

Table 3. Species abundance of the forest

Species	FREQ	R. F (%)	Density	R.Density (%)	Dominance	R. Dom (%)	IVI
Antiaris toxicaria	6	6.25	0.063	6.25	23.94	5.03	17.53
Elaeis guineensis	4	4.17	0.042	4.20	9.91	2.08	10.45
Pterocarpus officinalis	4	4.17	0.042	4.20	6.31	1.32	9.69
Hevea brasiliensis	3	3.13	0.031	3.10	4.13	0.87	7.10
Combretum illarii	2	2.08	0.021	2.10	19.26	4.04	8.22
Ficus insipida	2	2.08	0.021	2.10	7.71	1.62	5.80
Firmiana simplex	2	2.08	0.021	2.10	1.65	0.35	4.53
Hymenaea courbaril	2	2.08	0.021	2.10	3.90	0.69	4.87
Persea americana	2	2.08	0.021	2.10	7.43	1.56	5.74
Schizolobium parahyba	2	2.08	0.021	2.10	0.83	0.17	4.35
Sterculia tragacantha	2	2.08	0.021	2.10	5.78	1.21	5.39
Terminalia arjuna	2	2.08	0.021	2.10	3.16	3.99	8.17
Theobroma cacao	2	2.08	0.021	2.10	9.91	2.08	6.26
Trichilia dregeana	2	2.08	0.021	2.10	5.78	1.21	5.39
Zanthoxylum rhoifolium	2	2.08	0.021	2.10	6.88	1.44	5.62
Zanthoxylum zanthoxyloides	2	2.08	0.021	2.10	6.05	1.27	5.45
Alchornea cordifolia	1	1.04	0.010	1.04	0.10	0.02	2.10
Alchornea glandulosa	1	1.04	0.010	1.04	0.27	0.06	2.14
Annona purpurea	1	1.04	0.010	1.04	5.79	1.22	3.30
Annona squamosal	1	1.04	0.010	1.04	0.52	0.11	2.19
Aphanamixis polystachya	1	1.04	0.010	1.04	2.30	0.48	2.56
Aquilaria sinensis	1	1.04	0.010	1.04	6.57	1.38	3.46
Archidendron jiringa	1	1.04	0.010	1.04	1.25	0.26	2.34
Barringtonia racemose	1	1.04	0.010	1.04	4.83	1.01	3.09
Bixa Orellana	1	1.04	0.010	1.04	2.46	0.52	2.60
Camellia sinensis	1	1.04	0.010	1.04	3.91	0.82	2.90
Cecropia obtusa	1	1.04	0.010	1.04	27.37	5.74	7.82
Cecropia obtusifolia	1	1.04	0.010	1.04	4.24	0.93	3.01
Cecropia peltata	1	1.04	0.010	1.04	1.71	0.36	2.44
Ceiba pentadra	1	1.04	0.010	1.04	0.93	0.19	2.27
Coffea liberica	1	1.04	0.010	1.04	2.12	0.44	2.52
Cola cordifolia	1	1.04	0.010	1.04	0.10	0.02	2.10

Species	FREQ	R. F (%)	Density	R.Density (%)	Dominance	R. Dom (%)	IVI
Cola millenii	1	1.04	0.010	1.04	0.19	0.04	2.12
Combretum erythrophyllum	1	1.04	0.010	1.04	5.79	1.22	3.30
Couroupita guianensis	1	1.04	0.010	1.04	0.39	0.08	2.16
Derris elliptica	1	1.04	0.010	1.04	5.44	1.14	3.22
Dimocarpus longan	1	1.04	0.010	1.04	1.74	0.36	2.44
Dipterocarpus turbinatus	1	1.04	0.010	1.04	0.42	0.09	2.17
Dracontomelon duperreanum	1	1.04	0.010	1.04	3.67	0.77	2.85
Duboscia macrocarpa	1	1.04	0.010	1.04	4.38	0.92	3.00
Ficus benjamina	1	1.04	0.010	1.04	113.89	23.90	25.98
Ficus sycomorus	1	1.04	0.010	1.04	5.94	1.25	3.33
Ficus trichopoda	1	1.04	0.010	1.04	13.41	2.81	4.89
Flacourtia rukam	1	1.04	0.010	1.04	9.85	2.07	4.15
Garcinia gardneriana	1	1.04	0.010	1.04	5.79	1.22	3.30
Grewia trichocarpa	1	1.04	0.010	1.04	5.99	1.26	3.34
Guarea Guidonia	1	1.04	0.010	1.04	4.21	0.88	2.96
Harpullia pendula	1	1.04	0.010	1.04	8.10	1.70	3.78
Horsifieldia kingii	1	1.04	0.010	1.04	2.53	0.53	2.61
Hura crepitans	1	1.04	0.010	1.04	5.06	1.06	3.14
Jasminum multiflorum	1	1.04	0.010	1.04	0.72	0.15	2.23
Lannea coromandelica	1	1.04	0.010	1.04	2.00	0.42	2.50
Magnolia grandiflora	1	1.04	0.010	1.04	9.85	2.07	4.15
Millettia pachycarpa	1	1.04	0.010	1.04	4.47	0.94	3.02
Mustanga cecropioides	1	1.04	0.010	1.04	10.18	2.14	4.22
Nuxia floribunda	1	1.04	0.010	1.04	0.22	0.05	2.13
Oroxylum indicum	1	1.04	0.010	1.04	0.34	0.07	2.15
Petivera alliacea	1	1.04	0.010	1.04	0.10	1.56	3.64
Pisonia aculeate	1	1.04	0.010	1.04	2.53	0.53	2.61
Populus alba	1	1.04	0.010	1.04	4.38	0.92	3.00
Psidium cattleianum	1	1.04	0.010	1.04	2.77	0.58	2.66
Pterocarpus rohrii	1	1.04	0.010	1.04	5.06	1.32	3.40
Saraca indica	1	1.04	0.010	1.04	2,53	0.53	2.61
Sterculia macrophylla	1	1.04	0.010	1.04	0.83	0.15	2.23
Stixis suaveolens	1	1.04	0.010	1.04	3.16	0.66	2.74
Tabernaemontana donnell – smithii	1	1.04	0.010	1.04	5.49	1.15	3.23

Species	FREQ	R. F (%)	Density	R.Density (%)	Dominance	R. Dom (%)	IVI
Tabernaemontana pachysiphon	1	1.04	0.010	1.04	4.92	1.03	3.11
Tetrameles nudiflora	1	1.04	0.010	1.04	3.95	0.83	2.91
Toxicodendron succedaneum	1	1.04	0.010	1.04	5.30	1.11	3.19
Vepris trichocarpa	1	1.04	0.010	1.04	1.01	0.21	2.29
Vibrurnum tinus	1	1.04	0.010	1.04	7.46	1.57	3.65
Total					476.45		309.1

Table 4. Shannon Weiner Index of Species Diversity

S/N	Species	N	N	Pi	ln(Pi)	pi*ln(pi)	-Σ(pi)*ln(pi)
1	*Antiaris toxicaria*	6	96	0.06250	-2.77259	-0.17329	H^1 =
2	*Elaeis guineensis*	4	96	0.04167	-3.17805	-0.13242	4.12922
3	*Pterocarpus officinalis*	4	96	0.04167	-3.17805	-0.13242	
4	*Hevea brasiliensis*	3	96	0.03125	-3.46574	-0.10830	
5	*Combretum illarii*	2	96	0.02083	-3.87120	-0.08065	
6	*Ficus insipida*	2	96	0.02083	-3.87120	-0.08065	
7	*Firmiana simplex*	2	96	0.02083	-3.87120	-0.08065	
8	*Hymenaea courbaril*	2	96	0.02083	-3.87120	-0.08065	
9	*Persea Americana*	2	96	0.02083	-3.87120	-0.08065	
10	*Schizolobium parahyba*	2	96	0.02083	-3.87120	-0.08065	
11	*Sterculia tragacantha*	2	96	0.02083	-3.87120	-0.08065	
12	*Terminalia arjuna*	2	96	0.02083	-3.87120	-0.08065	
13	*Theobroma cacao*	2	96	0.02083	-3.87120	-0.08065	
14	*Trichilia dregeana*	2	96	0.02083	-3.87120	-0.08065	
15	*Zanthoxylum rhoifolium*	2	96	0.02083	-3.87120	-0.08065	
16	*Zanthoxylum zanthoxyloides*	2	96	0.02083	-3.87120	-0.08065	
17	*Alchornea cordifolia*	1	96	0.01042	-4.56435	-0.04755	
18	*Alchornea glandulosa*	1	96	0.01042	-4.56435	-0.04755	
19	*Annona purpurea*	1	96	0.01042	-4.56435	-0.04755	
20	*Annona squamosal*	1	96	0.01042	-4.56435	-0.04755	
21	*Aphanamixis polystachya*	1	96	0.01042	-4.56435	-0.04755	
22	*Aquilaria sinensis*	1	96	0.01042	-4.56435	-0.04755	
23	*Archidendron jiringa*	1	96	0.01042	-4.56435	-0.04755	
24	*Barringtonia racemosa*	1	96	0.01042	-4.56435	-0.04755	
25	*Bixa Orellana*	1	96	0.01042	-4.56435	-0.04755	
26	*Camellia sinensis*	1	96	0.01042	-4.56435	-0.04755	
27	*Cecropia obtusa*	1	96	0.01042	-4.56435	-0.04755	
28	*Cecropia obtusifolia*	1	96	0.01042	-4.56435	-0.04755	
29	*Cecropia peltata*	1	96	0.01042	-4.56435	-0.04755	
30	*Ceiba pentadra*	1	96	0.01042	-4.56435	-0.04755	
31	*Coffea liberica*	1	96	0.01042	-4.56435	-0.04755	
32	*Cola cordifolia*	1	96	0.01042	-4.56435	-0.04755	
33	*Cola millenii*	1	96	0.01042	-4.56435	-0.04755	
34	*Combretum erythrophyllum*	1	96	0.01042	-4.56435	-0.04755	
35	*Couroupita guianensis*	1	96	0.01042	-4.56435	-0.04755	
36	*Derris elliptica*	1	96	0.01042	-4.56435	-0.04755	
37	*Dimocarpus longan*	1	96	0.01042	-4.56435	-0.04755	
38	*Dipterocarpus turbinatus*	1	96	0.01042	-4.56435	-0.04755	
39	*Dracontomelon duperreanum*	1	96	0.01042	-4.56435	-0.04755	
40	*Duboscia macrocarpa*	1	96	0.01042	-4.56435	-0.04755	
41	*Ficus benjamina*	1	96	0.01042	-4.56435	-0.04755	
42	*Ficus sycomorus*	1	96	0.01042	-4.56435	-0.04755	
43	*Ficus trichopoda*	1	96	0.01042	-4.56435	-0.04755	
44	*Flacourtia rukam*	1	96	0.01042	-4.56435	-0.04755	
45	*Garcinia gardneriana*	1	96	0.01042	-4.56435	-0.04755	
46	*Grewia trichocarpa*	1	96	0.01042	-4.56435	-0.04755	
47	*Guarea Guidonia*	1	96	0.01042	-4.56435	-0.04755	
48	*Harpullia pendula*	1	96	0.01042	-4.56435	-0.04755	
49	*Horsifieldia kingie*	1	96	0.01042	-4.56435	-0.04755	
50	*Hura crepitans*	1	96	0.01042	-4.56435	-0.04755	
51	*Jasminum multiflorum*	1	96	0.01042	-4.56435	-0.04755	

S/N	Species	N	N	Pi	ln(Pi)	pi*ln(pi)	-Σ(pi)*ln(pi)
52	*Lannea coromandelica*	1	96	0.01042	-4.56435	-0.04755	
53	*Magnolia grandiflora*	1	96	0.01042	-4.56435	-0.04755	
54	*Millettia pachycarpa*	1	96	0.01042	-4.56435	-0.04755	
55	*Mustanga cecropioides*	1	96	0.01042	-4.56435	-0.04755	
56	*Nuxia floribunda*	1	96	0.01042	-4.56435	-0.04755	
57	*Oroxylum indicum*	1	96	0.01042	-4.56435	-0.04755	
58	*Petivera alliacea*	1	96	0.01042	-4.56435	-0.04755	
59	*Pisonia aculeate*	1	96	0.01042	-4.56435	-0.04755	
60	*Populus alba*	1	96	0.01042	-4.56435	-0.04755	
61	*Psidium cattleianum*	1	96	0.01042	-4.56435	-0.04755	
62	*Pterocarpus rohrii*	1	96	0.01042	-4.56435	-0.04755	
63	*Saraca indica*	1	96	0.01042	-4.56435	-0.04755	
64	*Sterculia macrophylla*	1	96	0.01042	-4.56435	-0.04755	
65	*Stixis suaveolens*	1	96	0.01042	-4.56435	-0.04755	
66	*Tabernaemontana donnell – smithii*	1	96	0.01042	-4.56435	-0.04755	
67	*Tabernaemontana pachysiphon*	1	96	0.01042	-4.56435	-0.04755	
68	*Tetrameles nudiflora*	1	96	0.01042	-4.56435	-0.04755	
69	*Toxicodendron succedaneum*	1	96	0.01042	-4.56435	-0.04755	
70	*Vepris trichocarpa*	1	96	0.01042	-4.56435	-0.04755	
71	*Vibrurnum tinus*	1	96	0.01042	-4.56435	-0.04755	
	Total					-4.12922	

Equitability = (H^1 /Hmax)
*Where H^1 = Shannon Weiner Diversity Index = -Σ(pi)*ln(pi) = -(- 4.12922) = 4.12922*
Hmax= Ins (ln71) = 4.2627
H^1/Hmax = 4.12922/4.2627
= 0.9686

3.2 Floristic, Species Important Value Indices, and Structural Characteristics of the Forest

The result in Table 3 shows that *Antiaris toxicaria* has the highest frequency (6) succeeded by *Elaeis guineensis,* and *Pterocarpus officinalis* (4 each). In terms of dominance, *Ficus benjamina* had the highest value (113.89 m^2/ha), followed by *Cecropia obtusa* (27.37), and *Antiaris toxicaria* (23.94). *Ficus benjamina* also recorded the highest important value index (25.98), followed by *Antiaris toxicaria* (17.53), *Elaeis guineensis* (10.45), and *Pterocarpus officinalis* (9.69).

3.3 Species Diversity Index (Shannon Weiner Index)

The analysis of the species diversity using the Shannon Weiner index of species diversity proved that the forest has a high diversity of 4.12922 approximately 4.13, and an evenness of 0.97. This showed that the forest has a large number of species that are relatively evenly distributed and almost equally abundant (Table 4).

4. DISCUSSION

This study aimed to conduct a comprehensive ecological assessment of the species diversity and evaluate the physicochemical parameters of the soil within the forest of Nnamdi Azikiwe University, Awka. A total of 96 trees comprising 71 species and 33 families were documented during the study. The high number of species and families recorded in the study area highlights the rich biodiversity of the studied forest which is consistent with research findings that show that tropical rainforests are the most biologically diverse terrestrial ecosystem in the world [1,8].

Among the families observed, Malvaceae and Fabaceae were the most dominant species, having 9 and 8 species respectively, closely followed by Moraceae with 5 species, Euphorbiaceae and Urticaceae with 4 species each, and Combretaceae, Meliaceae, and Rutaceae having 3 species each. This observation suggests that these families play a

vital role in shaping the forest ecosystem. The presence of many species recorded in these families demonstrates their ecological significance in the forest. The species richness of the Malvaceae family observed in this study agrees with the work of Olaoti-Laaro et al. [20] in their study of tree species diversity and distribution in the natural forest of Onigambari Forest Reserve, Oyo State, Nigeria. They observed that Malvaceae was the most abundant among other families. However, regarding the number of individual trees within a family, Fabaceae was more dominant with 13 trees followed by Malvaceae which had 12 trees, Moraceae with 11 trees, Euphorbiaceae with 6 trees, and Combretaceae and Rutaceae having 5 trees each. This may be due to their ability to germinate quickly along with the symbiotic properties that have allowed them to establish in habitats rapidly. This observation was consistent with the work of Deka et al [21] on the vegetative assessment of tree species in Takamanda forest, in Cameroon. Patrick et al [22] in their work on diversity, distribution, and conservation status of forest tree species in cross river state, Nigeria also reported Fabaceae to be the dominant species, but in addition, Malvaceae, Moraceae, Euphorbiaceae, were also among the families observed to be dominant, which is in agreement with the findings of this work. These families may be dominant in the study area because of their ability to adapt to their habitat and suitable environmental conditions that favour their root penetration and nutrient absorption from the subsurface. This is confirmed by Austin et al [23] who discovered that an ecosystem's species richness and establishment can be significantly influenced by edaphic factors such as soil nutrients.

When analyzing the species found in the study area, *Antiaris toxicaria* had the highest frequency of 6, this suggests that *A. toxicaria* is a frequently encountered plant in the study area. This may be due to their ability to grow in diverse habitats, thrive in tropical and subtropical regions across Africa, Asia, and the Pacific Islands, and tolerate a range of soil types and climatic conditions [24]. The large number of seeds produced by *Antiaris toxicaria*, and its rapid growth rate enabling them to reach maturity quickly as reported by Orwa et al [25] may be another reason why it was frequently encountered in this study area. Aside from *A. toxicaria*, other species such as *Elaeis guineensis,* and *Pterocarpus officinalis* with four occurrences each were also recorded. In terms of dominance, *Ficus benjamina* had the highest value (113.89 m^2/ha), followed by *Cecropia obtusa* (27.37 m^2/ha), and *Antiaris toxicaria* (23.94 m^2/ha). Other species like *Combretum illarii, Elaeis guineensis, Theobroma cacao, Ficus trichopoda, and Mustanga cecropioides* had 19.26 m^2/ha, 9.91 m^2/ha, 9.91 m^2/ha, 13.41 m^2/ha, and 10.18 m^2/ha respectively. These values offer insights into the important ecological functioning and structure of the ecosystem and how these species can play vital roles in preserving ecological balance by providing habitats and foods for the various faunas inhabiting the forest. According to Finegan [26], the structural framework of a forest is frequently formed by dominant tree species, which also create a variety of microhabitats on the forest floor, understory, and canopy. Supporting numerous plant and animal species, including birds, animals, insects, and epiphytes. The dominance pattern observed in this study aligns with previous research works on tropical forests. Condit et al [27] in Panama's Barro Colorado Island, demonstrated that a few species exerted more influence on the overall shape and function of the ecosystem. These species with distinct demographic characteristics played a significant role in shaping the demographic space analyzed, indicating that certain species may have a disproportionate impact on the dynamics of the ecosystem compared to others which is in line with the findings of this research. However, the findings of Adekunle et al [28] are in contrast to the observation recorded in this study area. In their work on Forest reserves in Southwestern Nigeria, they observed that different environmental conditions and management regimes have a significant influence on plant species composition and richness, which in turn affects forest growth and yield.

In terms of important value index, *Ficus benjamina* also recorded the highest value of 25.98, followed by *Antiaris toxicaria* (17.53), *Elaeis guineensis* (10.45), and *Pterocarpus officinalis* (9.69). The high IVI value of *Ficus benjamina* indicates that it is a species exerting an influence on the structure of the forest availability of habitats and distribution of resources. Its prominent presence signifies its importance in maintaining balance and fostering biodiversity [28].

The Importance Value Index (IVI) is vital in ecological research as it offers valuable insights into a species' overall significance within a specific ecosystem. IVI is calculated by summing the values of relative frequency, relative density,

and relative dominance of species making it an indispensable tool for understanding the ecological roles of species and their impact on forest structure and dynamics.

The species diversity index employed in this research is the Shannon-Weiner Diversity index (H'). Since the Shannon-Weiner diversity index considers both species richness and evenness in a community, it has been widely used by researchers to study ecosystem diversity [28,29,30,31,32]. Species diversity is typically one of the most significant indices used to assess an ecosystem. An ecosystem with a low value (H') will have low species diversity, whereas an ecosystem with great species diversity and richness has a significant value (H') [33]. This present study has a high species diversity of 4.13, this may be due to the limited or low exploitation of the species in the forest habitat and the species' ability to withstand unfavorable environmental variables that are common in the forest. Patrick et al [22] recorded a much higher species diversity in the Okwangwo Division of Cross River National Park, and in the Oban Division of Cross River National Park (4.75 and 4.68 respectively). The diversity indices of this study were higher than those reported for protected rainforests in Nigeria [1,34,35,36].

Bush et al [37] and Richlefs and Schluter [38] found that environmental complexity or heterogeneity leads to increased species diversity. Their study found that environmental factors that benefit a specific group of organisms may not benefit another. Therefore, to predict the impact of environmental structure on biodiversity, it is important to understand the ecological requirements of species.

5. CONCLUSION

The results from this study reveal that the forest of Nnamdi Azikiwe University, Awka has high species diversity. Some families of trees were more dominant than others, and these families include Malvaceae, Fabaceae, and Moraceae. The abundance of these families is probably a result of their ability to cope with prevalent environmental conditions in the study site. The abundance of trees in the study site demonstrated that the vegetation is relatively natural playing an important role in shaping the forest ecosystem. Some of the dominant species found in the study site include: *Antiaris toxicaria, Elaeis guineensis, Pterocarpus officinalis, Hevea brasiliensis, Combretum illarii, Ficus insipida, Firmiana simplex, Hymenaea courbaril. Ficus insipida, Firmiana simplex,* while some of the least encountered plant species during the study include: *Alchornea cordifolia, Alchornea glandulosa, Annona purpurea, Annona squamosal, Aphanamixis polystachya, Aquilaria sinensis, Archidendron jiringa, Ficus benjamina.*

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that AI technologies such as Natural Language Processors, etc was used to proofread the manuscripts for grammatical correctness.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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