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Full Length Research Article

Assessment of Species Richness and Diversity in the Nnamdi Azikiwe University Conservation Forest, Awka

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ABSTRACT

Biodiversity assessment, particularly plant species richness and diversity, is essential for understanding ecosystem stability and resilience, yet many tropical forest studies underrepresent total plant diversity by focusing mainly on canopy species. This limitation is especially evident in secondary and institutional forests, where understory vegetation plays a critical but often overlooked ecological role. This study assessed plant species richness, diversity, and vegetation structure in the Nnamdi Azikiwe University Conservation Forest, Awka, Nigeria, using an integrated approach that captured both woody and understory vegetation. A stratified ecological survey design was employed. The Point-Centered Quarter Method (PCQM) was used to sample trees and shrubs, while 1 m² quadrats assessed understory vegetation, including herbs, grasses, climbers, and creepers. Eighteen systematically distributed sampling points were established along a central transect, and 72 quadrats were analyzed. Species diversity was quantified using the Shannon–Wiener index (H′), Simpson's dominance index (D), and evenness (E). The study recorded high species richness across vegetation layers, confirming the forest's status as a biologically diverse secondary ecosystem. Shannon–Wiener diversity values were high for woody (H′ = 3.672) and understory vegetation (H′ = 3.089). Evenness values were also high (E = 0.949 and 0.849), indicating balanced species distribution. However, low Simpson's dominance values (D = 0.033 and 0.064) revealed dominance by a few species, particularly disturbance-tolerant taxa such as *Chromolaena odorata* and *Alchornea cordifolia*. Vegetation structure analysis showed a heterogeneous, multi-layered forest with active regeneration and an intermediate successional stage. These findings demonstrate that integrating understory vegetation improves biodiversity assessment and provides baseline ecological data for long-term monitoring and conservation.

Keywords: species richness, plant diversity, Shannon–Wiener index, PCQM, quadrat sampling, secondary forest, institutional forest, Nnamdi Azikiwe University, Nigeria.

Introduction

The concept of biodiversity, encompassing the variety and variability of all living organisms at

multiple levels of biological organization, is central to ecological science. Species richness which is the number of species within a defined area, remains one of the most fundamental measures of biodiversity in plant ecology; while species diversity incorporates both richness and the relative abundance of species, providing deeper insight into community organization (Magurran, 2004)

Forest ecosystems, covering more than four billion hectares globally, support a substantial proportion of terrestrial biodiversity and play key roles in regulating biogeochemical cycles, particularly through carbon storage and nutrient dynamics (FAO and UNEP, 2020). In tropical regions, plant communities are characterized by extraordinary species richness, complex vertical stratification, and diverse ecological roles across multiple strata, from canopy trees to understory herbs and grasses. However, biodiversity assessments in many tropical institutional and secondary forests remain incomplete because they focus predominantly on canopy species, neglecting the fact that understory vegetation contributes substantially to total species richness, phylogenetic diversity, and forest ecological processes. (Perea *et al.*, 2022; Onyekwelu *et al.*, 2026).

The Nnamdi Azikiwe University (UNIZIK) Conservation Forest, Awka, Anambra State, represents one of the few remaining semi-natural forest fragments within an increasingly urbanized setting in southeastern Nigeria. The university hosts multiple forested conservation areas. Earlier studies identified the Botanical Garden Forest and the forest behind the Faculty of Law as major secondary forest units within the campus (Ekwealor *et al*., 2020a). The present study was conducted in the conservation forest described by Iroka *et al*. (2025) as the Nnamdi Azikiwe University Conservation Forest, located within the university's conservation zone. Previous studies have documented considerable floristic diversity within other forest units across the university ecosystem, including a Shannon–Wiener index of 4.13 for tree species (Okoronkwo *et al*., 2024), and have highlighted ecologically important species such as *Elaeis guineensis* and *Ficus benjamina* (Ekwealor *et al*., 2020b). However, these studies primarily emphasize canopy species, with insufficient consideration of the understory vegetation layer.

Secondary forests, which dominate much of Nigeria's contemporary forest landscape, retain substantial biodiversity potential despite shifts in species composition toward pioneer and disturbance-tolerant taxa (FAO and UNEP, 2020; Poorter *et al.*, 2024). Institutional forests situated within university campuses have been shown to function as important biodiversity refuges, supporting high plant diversity even within human-dominated landscapes (Liu *et al.*, 2021b). Understanding their full vegetation structure, across both woody and understory layers, is therefore essential for comprehensive biodiversity assessment and long-term conservation planning.

This study aimed to assess the species richness and diversity of the Nnamdi Azikiwe University Conservation Forest using an integrated sampling approach that captures multiple vegetation strata. Specific objectives were to: identify and document plant species present in the forest, quantify species richness and compute diversity indices, classify species into life forms; and assess species dominance, vegetation structure, and regeneration patterns.

Materials and Methods

Study Area

The study was conducted at the Nnamdi Azikiwe University Conservation Forest

(approximately 6.25°N, 7.11°E; elevation ~136 m asl) located within UNIZIK, Awka, in Awka South Local Government Area, Anambra State, southeastern Nigeria (Okeke *et al*., 2022). The conservation forest covers approximately 6.527 hectares, extending about 364.15 m from its northern to southern boundary (Iroka *et al.*, 2025). The climate is tropical, with a rainy season from April to October and a dry season from November to March. Mean annual rainfall ranges between 1,800 mm and 2,000 mm, with mean annual temperatures averaging 26–27 °C. The soils are predominantly sandy loams (~70% to 90% sand) and loamy sands (~50% to 70% sand), characteristic of the Anambra Basin sedimentary formations.

The forest vegetation is characteristic of a tropical lowland secondary forest ecosystem, comprising multiple vertical strata including trees, shrubs, herbs, and grasses. Its protected status within the university landscape makes it ecologically significant as a refuge for plant biodiversity within an urbanizing environment.

Research Design and Sampling Techniques

A stratified ecological survey design was employed. Stratification was based on vegetation layers: the woody layer (trees and shrubs) and the understory layer (herbs, grasses, climbers, and creepers). The Point-Centered Quarter Method (PCQM) was used to sample woody vegetation, while 1 m × 1 m quadrats were used for understory vegetation. Sampling points were arranged along a single central transect of approximately 360 m, with 18 systematically distributed points at 20-metre intervals. At each sampling point, four quadrats were diagonally placed within each quarter, resulting in 72 quadrats across the study area shown in Figure 1.

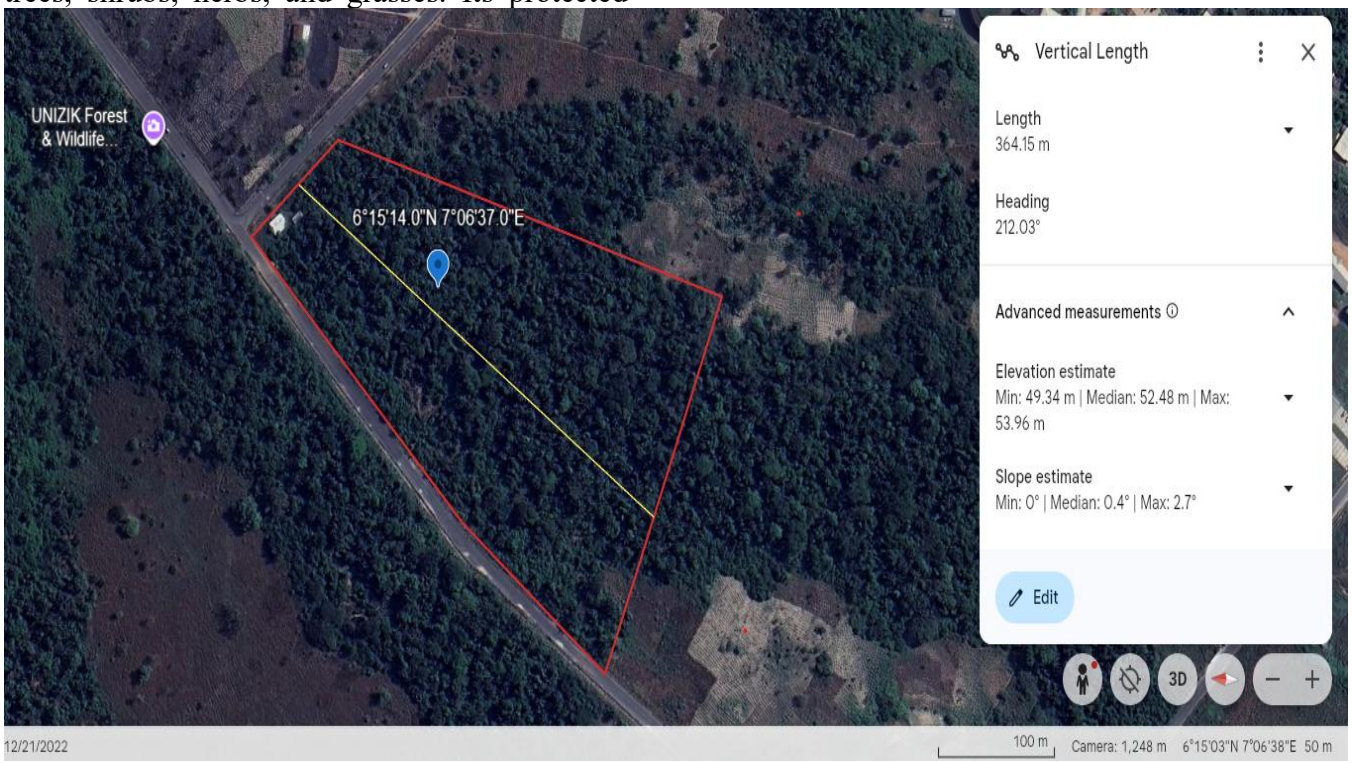


Figure 1: *Aerial map of the Nnamdi Azikiwe University Conservation Forest showing the study area boundary, and a 364.15 m vertical length measurement (Source: Google Earth, 2025).*

Point-Centered Quarter Method (PCQM) for Assessing Woody Vegetations

Following Mitchell (2007), the nearest woody individual with a circumference at chest height (CCH) ≥ 4 cm was identified in each of the four quarters at every sampling point. Species name, distance from point to the woody species, and circumference at 1.3 m above ground (C130) were recorded. Data were used to compute absolute density, relative density, frequency, basal area, relative cover, and the Importance Value Index (IVI = Relative Density + Relative Frequency + Relative Cover).

Quadrat Sampling for Understory Vegetation

Within each 1 m² quadrat, all plant species were identified and the number of individuals per species was recorded. Parameters computed included abundance, relative abundance, frequency, relative frequency, cover, and Importance Value for understory species.

Plant Identification

Plant species were identified in situ using the Flora Incognita mobile application, with all identifications subsequently validated by a taxonomist in the Department of Botany, Nnamdi Azikiwe University, Awka. Scientific names were standardized following accepted botanical nomenclature.

Data Analysis

Data were analyzed using Python (pandas, NumPy, Matplotlib) in a Jupyter Notebook

environment, with Microsoft Excel for preliminary cross-checking. Species diversity was quantified using: the Shannon–Wiener Diversity Index ($H' = -\Sigma\ p_i \ln p_i$), Simpson's Dominance Index ($D = \Sigma\ p_i^2$), and Evenness ($E = H' / \ln S$), where p_i is the proportion of individuals of species 'i' and S is species richness.

Results

Woody Species Density and Relative Density

Alchornea cordifolia recorded the highest absolute density (42.540 trees/ha) and relative density (9.7%), making it the most dominant woody species in the forest. *Elaeis guineensis* ranked second (30.386 trees/ha; 6.9%), followed by *Newbouldia laevis* (24.309 trees/ha; 5.6%). Forty-eight woody species were recorded in total, with the majority (36 species) occurring at the minimum density class of 6.077 trees/ha (1.4% relative density), reflecting high species richness alongside dominance by a few species.

Table 1: Absolute and Relative Woody Density of Selected Species (PCQM)

S/N	Species	Life Form	Absolute Density (trees/ha)	Relative Density (%)
1	*Alchornea cordifolia*	Shrub	42.540	9.7
2	*Elaeis guineensis*	Tree (palm)	30.386	6.9
3	*Newbouldia laevis*	Tree	24.309	5.6
4	*Ricinodendron heudelotii*	Tree	18.231	4.2
5	*Funtumia elastic*	Tree	18.231	4.2
6	*Carapa procera*	Tree	12.154	2.8
7	*Cola cordifolia*	Tree	12.154	2.8
8	*Nauclea latifolia*	Tree	12.154	2.8
9	*Dacryodes edulis*	Tree	12.154	2.8
10	*Musanga cecropioides*	Tree	12.154	2.8

11	*Vitex doniana*	Shrub	12.154	2.8
12	*Trema orientalis*	Tree	12.154	2.8
13–48	*Remaining 36 species*	Trees and Shrubs	6.077 each	1.4 each

Full species list provided in Appendix A1

Basal Area, Cover, and Frequency of Woody Species

Elaeis guineensis contributed the highest absolute cover (2.932 m²/ha; relative cover 8.1%) with a high absolute frequency (27.8%). Large-statured emergent trees including *Ceiba pentandra* (mean basal area 3851.55 cm²) and *Milicia excelsa* (3509.37 cm²) contributed substantially to total basal area despite low densities. *Alchornea cordifolia* exhibited the highest absolute frequency (38.9%) and relative frequency (10.0%), reflecting widespread distribution across the forest.

Table 2: Basal Area, Cover, and Frequency of Selected Woody Species (PCQM)

S/N	Species	Life Form	Mean BA (cm²)	Abs. Cover (m²/ha)	Rel. Cover (%)	Abs. Freq. (%)	Rel. Freq. (%)
1	*Elaeis guineensis*	Tree (palm)	964.877	2.932	8.1	27.8	7.1
2	*Ceiba pentandra*	Tree	3851.550	2.341	6.5	5.6	1.4
3	*Carapa procera*	Tree	1851.171	2.250	6.2	11.1	2.9
4	*Milicia excels*	Tree	3509.366	2.133	5.9	5.6	1.4
5	*Ricinodendron heudelotii*	Tree	1093.527	1.994	5.5	11.1	2.9
6	*Parkia biglobosa*	Tree	3183.099	1.934	5.3	5.6	1.4
7	*Alchornea cordifolia*	Shrub	245.224	1.043	2.9	38.9	10.0
8	*Newbouldia laevis*	Tree	363.072	0.883	2.4	16.7	4.3
9	*Funtumia elastic*	Tree	390.301	0.712	2.0	16.7	4.3
10	*Nauclea latifolia*	Shrub	720.176	0.875	2.4	11.1	2.9

Full data for all 48 species provided in Appendix A2

The Importance Value Index (IVI) showed clear differences in the ecological significance of woody species within the UNIZIK Conservation Forest. *Alchornea cordifolia* and *Elaeis guineensis* emerged as the most ecologically important species, reflecting their combined dominance in terms of density, frequency, and cover. Other relatively important species included *Ricinodendron heudelotii*, *Newbouldia laevis*, *Carapa procera*, and *Funtumia elastica*, whereas the majority of species exhibited comparatively low IVI values (Figure 2).

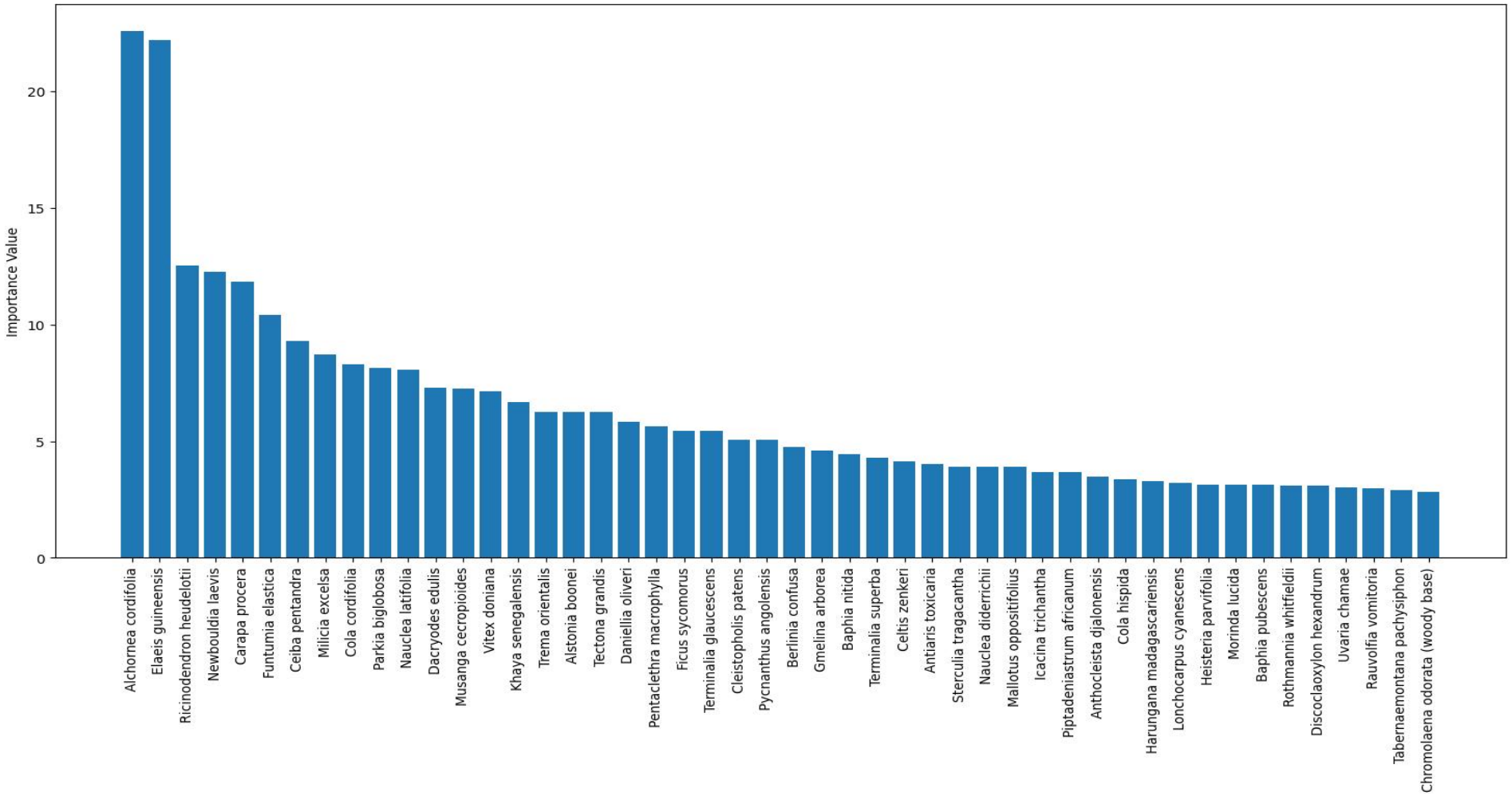


Figure 2: *Importance Value Index (IVI) of the woody species in the UNIZIK Conservation Forest showing the relative ecological significance of dominant tree and shrub species.*

Understory Species Abundance and Density (Quadrat Sampling)

A total of 38 understory species were recorded. *Chromolaena odorata* recorded the highest total count (61 individuals) and density (15.25 ind/quadrat; relative density 14.6%), followed by *Ageratum conyzoides* (10.5%) and *Peperomia pellucida* (8.4%). The life-form composition revealed a structurally diverse understory dominated by herbs, with climbers, grasses, shrub seedlings, and tree saplings also represented.

Table 3: Abundance and Density of Understory Species from Quadrat Sampling

S/N	Species	Growth Form	Total Count	Density (ind/quadrat)	Rel. Density (%)
1	*Chromolaena odorata*	Herb	61	15.25	14.6
2	*Ageratum conyzoides*	Herb	44	11.00	10.5
3	*Peperomia pellucida*	Herb	35	8.75	8.4
4	*Aspilia Africana*	Herb	29	7.25	6.9
5	*Dioscorea spp.*	Climber	27	6.75	6.4
6	*Centrosema pubescens*	Creeper	25	6.25	6.0
7	*Elaeis guineensis (sapling)*	Tree sapling	24	6.00	5.7
8	*Mikania cordata*	Climber	19	4.75	4.5
9	*Sida acuta*	Herb	15	3.75	3.6
10	*Axonopus compressus*	Grass	14	3.50	3.3
11	*Tridax procumbens*	Herb	13	3.25	3.1
12	*Ipomoea involucrate*	Climber	12	3.00	2.9
13	*Panicum maximum*	Grass	10	2.50	2.4
14–38	*Remaining 25 species*	Herbs, Climbers, grasses, Tree saplings, Shrub seedlings	≤ 8 each	≤ 2.00 each	≤ 1.9 each

Full species list provided in Appendix B1

Understory Vegetation Cover and Frequency

Chromolaena odorata recorded the highest total cover (475 m²; mean 118.75 m²; occurring in 13 quadrats). *Ageratum conyzoides* followed with 395 m² total cover and presence in 16 quadrats. *Dioscorea* spp. (270 m²; 14 quadrats) and *Axonopus compressus* (210 m²; 14 quadrats) also contributed substantially to understory ground cover. Herbaceous species dominated both cover and frequency metrics, reinforcing their structural importance in the ground layer.

Table 4: Cover, Frequency, and Importance Value of Selected Understory Species (Quadrat Sampling)

S/N	Species	Growth Form	Total Cover (m²)	Mean Cover (m²)	Rel. Cover (%)	Freq. (quadrats)	Abs. Freq. (%)	Rel. Freq. (%)
1	*Chromolaena odorata*	Herb	475	118.75	12.1	13	325.0	6.8
2	*Ageratum conyzoides*	Herb	395	98.75	10.0	16	400.0	8.4
3	*Elaeis guineensis (sapling)*	Tree sapling	340	85.00	8.6	11	275.0	5.8
4	*Dioscorea spp.*	Climber	270	67.50	6.9	14	350.0	7.4
5	*Peperomia pellucida*	Herb	225	56.25	5.7	10	250.0	5.3
6	*Aspilia Africana*	Herb	210	52.50	5.3	9	225.0	4.7
7	*Axonopus compressus*	Grass	210	52.50	5.3	14	350.0	7.4
8	*Centrosema pubescens*	Creeper	185	46.25	4.7	12	300.0	6.3
9	*Mikania cordata*	Climber	160	40.00	4.1	9	225.0	4.7
10	*Alchornea cordifolia (seedling)*	Shrub seedling	140	35.00	3.6	7	175.0	3.7

Full data for all 38 understory species provided in Appendix B2

The distribution of understory growth forms revealed a clear predominance of herbaceous species, which constituted the largest proportion of species richness within therr forest understory. Climbers and grasses also contributed substantially to the understory flora, whereas tree saplings, shrub seedlings, and creepers were comparatively less represented (Figure 3).

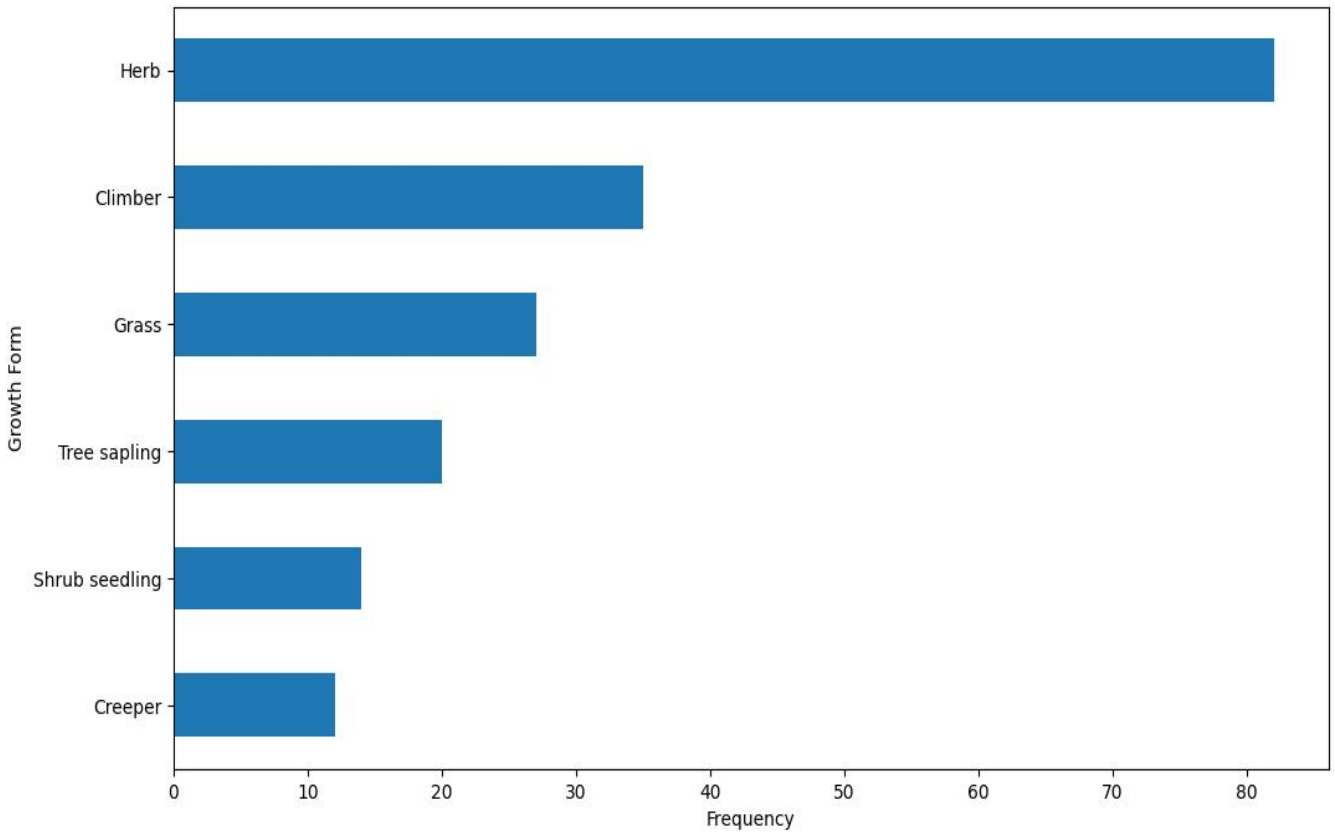


Figure 3: *Relative contribution of understory growth forms to species richness within the UNIZIK Conservation Forest.*

Diversity Indices

Diversity indices are summarized in Table 5. Shannon–Wiener diversity values were high for both woody (H′ = 3.672) and understory (H′ = 3.089) vegetation, indicating substantial species heterogeneity. Evenness values were also high (PCQM: E = 0.949; Quadrat: E = 0.849), suggesting relatively balanced species distribution. Low Simpson's dominance values (D = 0.033 and 0.064) indicate that despite the presence of dominant pioneer species, overall community structure is not excessively skewed.

Table 5: Diversity Indices Summary

Method	H′ (Shannon)	E (Evenness)	D (Simpson)
PCQM (Woody)	3.672	0.949	0.033
Quadrat (Understory)	3.089	0.849	0.064

Discussion

This study demonstrates that the Nnamdi Azikiwe University Conservation Forest is a biologically diverse secondary forest ecosystem characterized by high species richness across multiple vegetation strata. The 48 woody species and 38 understory species recorded confirm its status as an ecologically significant institutional forest, consistent with empirical findings from southeastern Nigeria where protected institutional forests retain substantial plant diversity (Okeke *et al.*, 2021; Onyekwelu *et al.*, 2026).

The high Shannon–Wiener diversity values (H′ = 3.672 for PCQM; H′ = 3.089 for quadrat) indicate substantial species heterogeneity within the forest. These values align with those reported by Okoronkwo *et al.* (2024), who recorded an H′ of 4.13 for tree species in the same forest system, and are comparable to values reported for secondary forests across southeastern Nigeria. High evenness values (E = 0.949 and 0.849) further confirm that individuals are relatively uniformly distributed among species, particularly within the woody layer.

The dominance of *Alchornea cordifolia* (highest density: 42.540 trees/ha; frequency: 38.9%) and *Elaeis guineensis* in the woody layer reflects patterns typical of regenerating tropical secondary forests, where pioneer and disturbance-tolerant species proliferate rapidly following disturbance (Jakovac *et al.*, 2021; Poorter *et al.*, 2024). Large-statured emergent trees such as *Ceiba pentandra* and *Milicia excelsa*, despite low densities, contributed disproportionately to basal area, echoing Okoronkwo *et al.* (2024) who found that structurally dominant species can exert strong ecological influence even at low abundance.

In the understory, *Chromolaena odorata* dominated with the highest density (14.6% relative density) and cover area equal to 475 m², consistent with its known ecology as an aggressive pioneer herb in disturbed tropical forests. Its dominance, alongside *Ageratum conyzoides* and *Peperomia pellucida*, mirrors findings by Onyekwelu and Olusola (2021) that disturbance-tolerant species often dominate understory layers in secondary institutional forests. However, the low Simpson's dominance values (D = 0.033 and 0.064) indicate that this

dominance does not excessively simplify overall community structure.

This study extends previous assessments by explicitly incorporating understory vegetation alongside woody species. The 38 understory species documented would have been missed by tree-only surveys, demonstrating the assertion by Perea *et al.* (2022) and Onyekwelu *et al.* (2026) that herbs, grasses, and climbers contribute substantially to total forest species richness. The combined use of PCQM and quadrat sampling proved effective in capturing vegetation patterns across strata, supporting recommendations by Magurran (2004) and Liu *et al.* (2021a) for integrating plotless and plot-based approaches.

Vegetation structural attributes, including heterogeneous stem distributions, varied diameter classes, and the simultaneous presence of pioneer species and economically important trees, indicate that the forest occupies an intermediate successional stage. This is consistent with Poorter *et al.* (2024), who noted that structural recovery often outpaces compositional recovery in secondary tropical forests. The presence of active regeneration, as evidenced by *Alchornea cordifolia* and *Newbouldia laevis* seedlings in the understory, reinforces the forest's ongoing ecological development.

These findings reinforce arguments by Liu *et al.* (2021b) that institutional and university forests can function as important biodiversity reservoirs. Despite proximity to human activity, the UNIZIK Conservation Forest supports high species richness, structural complexity, and active regeneration, underscoring its ecological value within an urbanizing landscape. The dominance of disturbance-tolerant species such as *Chromolaena odorata*, however, highlights potential long-term ecological risks if anthropogenic pressures increase, warranting targeted conservation management.

Conclusion

This study confirms that the Nnamdi Azikiwe University Conservation Forest is a biologically diverse secondary forest characterized by high species richness, substantial diversity, and structurally complex multi-layered vegetation. By integrating PCQM for woody species and quadrat sampling for understory vegetation, the study provides a more comprehensive assessment of plant diversity than studies focused solely on canopy species. The high Shannon–Wiener diversity values ($H' = 3.672$ and 3.089) and high evenness indices confirm ecological stability, while low Simpson's dominance values indicate that pioneer dominance does not critically simplify community structure. These findings demonstrate that secondary institutional forests can play a significant role in biodiversity conservation and ecological resilience, particularly within rapidly urbanizing environments. The study provides baseline ecological data for long-term monitoring and highlights the importance of considering all vegetation layers in forest management and sustainability planning.

Recommendations

Long-term monitoring: Repeated vegetation surveys should be conducted to track successional change, dominance shifts, and species turnover.

Conservation management: Targeted management should address aggressive understory species such as *Chromolaena odorata* while maintaining natural regeneration processes.

Integrated biodiversity assessment: Future studies should incorporate fauna and soil analyses to align with ecosystem-level biodiversity frameworks.

Methodological advancement: Establishment of permanent sample points and integration with remote sensing would enhance long-term ecological inference.

Educational and research use: The forest should be actively utilized for teaching and applied ecological research, reinforcing its institutional and conservation value.

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Conflict of Interest
The author declares that there is no conflict of interest regarding the publication of this manuscript.

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Author's contribution
Okoye, E. P. conceived the study, conducted the fieldwork, collected and analyzed the data, interpreted the results, and prepared the original manuscript. Okereke, C. N. and Eze, H. N. supervised the study, contributed to the study design, critically reviewed the manuscript, and approved the final version for publication. All authors read and approved the final manuscript.

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Appendix

Appendix A1: Complete Woody Species Density Data (PCQM) — All 48 Species

S/N	Species	Life Form	Absolute Density (trees/ha)	Relative Density (%)
1	*Alchornea cordifolia*	Shrub	42.540	9.7
2	*Elaeis guineensis*	Tree (palm)	30.386	6.9
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7	*Cola cordifolia*	Tree	12.154	2.8
8	*Nauclea latifolia*	Tree	12.154	2.8
9	*Dacryodes edulis*	Tree	12.154	2.8
10	*Musanga cecropioides*	Tree	12.154	2.8
11	*Vitex doniana*	Shrub	12.154	2.8
12	*Trema orientalis*	Tree	12.154	2.8
13	*Ceiba pentandra*	Tree	6.077	1.4
14	*Milicia excels*	Tree	6.077	1.4
15	*Parkia biglobosa*	Tree	6.077	1.4
16	*Khaya senegalensis*	Tree	6.077	1.4
17	*Alstonia boonei*	Tree	6.077	1.4
18	*Tectona grandis*	Tree	6.077	1.4
19	*Daniellia oliveri*	Tree	6.077	1.4
20	*Pentaclethra macrophylla*	Tree	6.077	1.4
21	*Ficus sycomorus*	Tree	6.077	1.4
22	*Terminalia glaucescens*	Tree	6.077	1.4
23	*Cleistopholis patens*	Tree	6.077	1.4
24	*Pycnanthus angolensis*	Tree	6.077	1.4
25	*Berlinia confusa*	Tree	6.077	1.4
26	*Gmelina arborea*	Tree	6.077	1.4
27	*Baphia nitida*	Shrub	6.077	1.4
28	*Terminalia superba*	Tree	6.077	1.4
29	*Celtis zenkeri*	Tree	6.077	1.4
30	*Antiaris toxicaria*	Tree	6.077	1.4
31	*Sterculia tragacantha*	Tree	6.077	1.4
32	*Nauclea diderrichii*	Tree	6.077	1.4
33	*Mallotus oppositifolius*	Shrub	6.077	1.4
34	*Icacina trichantha*	Shrub	6.077	1.4
35	*Piptadeniastrum africanum*	Tree	6.077	1.4
36	*Anthocleista djalonensis*	Tree	6.077	1.4

37	*Cola hispida*	Shrub	6.077	1.4
38	*Harungana madagascariensis*	Shrub	6.077	1.4
39	*Lonchocarpus cyanescens*	Shrub	6.077	1.4
40	*Heisteria parvifolia*	Tree	6.077	1.4
41	*Morinda lucida*	Tree	6.077	1.4
42	*Baphia pubescens*	Shrub	6.077	1.4
43	*Rothmannia whitfieldii*	Tree	6.077	1.4
44	*Discoclaoxylon hexandrum*	Tree	6.077	1.4
45	*Uvaria chamae*	Shrub	6.077	1.4
46	*Rauvolfia vomitoria*	Shrub	6.077	1.4
47	*Tabernaemontana pachysiphon*	Shrub	6.077	1.4
48	*Chromolaena odorata (woody base)*	Shrub (woody base)	6.077	1.4

Appendix A2: Complete Woody Species Basal Area, Cover, and Frequency Data (PCQM) — All 48 Species

S/N	Species	Life Form	Mean BA (cm²)	Abs. Cover (m²/ha)	Rel. Cover (%)	Abs. Freq. (%)	Rel. Freq. (%)
1	*Elaeis guineensis*	Tree (palm)	964.877	2.932	8.1	27.8	7.1
2	*Ceiba pentandra*	Tree	3851.550	2.341	6.5	5.6	1.4
3	*Carapa procera*	Tree	1851.171	2.250	6.2	11.1	2.9
4	*Milicia excelsa*	Tree	3509.366	2.133	5.9	5.6	1.4
5	*Ricinodendron heudelotii*	Tree	1093.527	1.994	5.5	11.1	2.9
6	*Parkia biglobosa*	Tree	3183.099	1.934	5.3	5.6	1.4
7	*Khaya senegalensis*	Tree	2299.789	1.398	3.9	5.6	1.4
8	*Alstonia boonei*	Tree	2037.183	1.238	3.4	5.6	1.4
9	*Tectona grandis*	Tree	2037.183	1.238	3.4	5.6	1.4
10	*Daniellia oliveri*	Tree	1790.493	1.088	3.0	5.6	1.4
11	*Alchornea cordifolia*	Shrub	245.224	1.043	2.9	38.9	10.0
12	*Pentaclethra macrophylla*	Tree	1673.116	1.017	2.8	5.6	1.4
13	*Cola cordifolia*	Tree	795.775	0.967	2.7	11.1	2.9
14	*Ficus sycomorus*	Tree	1559.718	0.948	2.6	5.6	1.4
15	*Terminalia glaucescens*	Tree	1559.718	0.948	2.6	5.6	1.4
16	*Newbouldia laevis*	Tree	363.072	0.883	2.4	16.7	4.3
17	*Nauclea latifolia*	Tree	720.176	0.875	2.4	11.1	2.9
18	*Cleistopholis patens*	Tree	1344.859	0.817	2.3	5.6	1.4
19	*Pycnanthus angolensis*	Tree	1344.859	0.817	2.3	5.6	1.4
20	*Funtumia elastica*	Tree	390.301	0.712	2.0	16.7	4.3
21	*Berlinia confusa*	Tree	1145.916	0.696	1.9	5.6	1.4
22	*Gmelina arborea*	Tree	1052.412	0.640	1.8	5.6	1.4
23	*Dacryodes edulis*	Tree	490.396	0.596	1.6	11.1	2.9
24	*Musanga cecropioides*	Tree	482.438	0.586	1.6	11.1	2.9
25	*Baphia nitida*	Shrub	962.887	0.585	1.6	5.6	1.4

26	*Vitex doniana*	Shrub	447.623	0.544	1.5	11.1	2.9
27	*Terminalia superba*	Tree	877.342	0.533	1.5	5.6	1.4
28	*Celtis zenkeri*	Tree	795.775	0.484	1.3	5.6	1.4
29	*Antiaris toxicaria*	Tree	718.187	0.436	1.2	5.6	1.4
30	*Sterculia tragacantha*	Tree	644.578	0.392	1.1	5.6	1.4
31	*Nauclea diderrichii*	Tree	644.578	0.392	1.1	5.6	1.4
32	*Mallotus oppositifolius*	Shrub	644.578	0.392	1.1	5.6	1.4
33	*Icacina trichantha*	Shrub	509.296	0.310	0.9	5.6	1.4
34	*Piptadeniastrum africanum*	Tree	509.296	0.310	0.9	5.6	1.4
35	*Anthocleista djalonensis*	Tree	389.930	0.237	0.7	5.6	1.4
36	*Trema orientalis*	Tree	184.023	0.224	0.6	11.1	2.9
37	*Cola hispida*	Shrub	336.215	0.204	0.6	5.6	1.4
38	*Harungana madagascariensis*	Shrub	286.479	0.174	0.5	5.6	1.4
39	*Lonchocarpus cyanescens*	Shrub	240.722	0.146	0.4	5.6	1.4
40	*Heisteria parvifolia*	Tree	198.944	0.121	0.3	5.6	1.4
41	*Morinda lucida*	Tree	198.944	0.121	0.3	5.6	1.4
42	*Baphia pubescens*	Shrub	183.346	0.111	0.3	5.6	1.4
43	*Rothmannia whitfieldii*	Tree	161.144	0.098	0.3	5.6	1.4
44	*Discoclaoxylon hexandrum*	Tree	161.144	0.098	0.3	5.6	1.4
45	*Uvaria chamae*	Shrub	114.910	0.070	0.2	5.6	1.4
46	*Rauvolfia vomitoria*	Shrub	97.482	0.059	0.2	5.6	1.4
47	*Tabernaemontana pachysiphon*	Shrub	62.389	0.038	0.1	5.6	1.4
48	*Chromolaena odorata (woody base)*	Shrub (woody base)	17.905	0.011	0.0	5.6	1.4

Appendix B1: Complete Understory Species Density Data (Quadrat Sampling) — All 38 Species

S/N	Species	Growth Form	Total Count	Density (ind/quadrat)	Rel. Density (%)
1	*Chromolaena odorata*	Herb	61	15.25	14.6
2	*Ageratum conyzoides*	Herb	44	11.00	10.5
3	*Peperomia pellucida*	Herb	35	8.75	8.4
4	*Aspilia africana*	Herb	29	7.25	6.9
5	*Dioscorea spp.*	Climber	27	6.75	6.4
6	*Centrosema pubescens*	Creeper	25	6.25	6.0
7	*Elaeis guineensis (sapling)*	Tree sapling	24	6.00	5.7
8	*Mikania cordata*	Climber	19	4.75	4.5
9	*Sida acuta*	Herb	15	3.75	3.6
10	*Axonopus compressus*	Grass	14	3.50	3.3
11	*Tridax procumbens*	Herb	13	3.25	3.1
12	*Ipomoea involucrata*	Climber	12	3.00	2.9
13	*Panicum maximum*	Grass	10	2.50	2.4

14	*Oldenlandia corymbosa*	Herb	8	2.00	1.9
15	*Alchornea cordifolia (seedling)*	Shrub seedling	7	1.75	1.7
16	*Commelina benghalensis*	Herb	7	1.75	1.7
17	*Newbouldia laevis (sapling)*	Tree sapling	6	1.50	1.4
18	*Dracaena surculosa*	Shrub seedling	6	1.50	1.4
19	*Laportea aestuans*	Herb	6	1.50	1.4
20	*Synsepalum dulcificum*	Shrub seedling	4	1.00	1.0
21	*Costus afer*	Climber	4	1.00	1.0
22	*Palisota hirsuta*	Herb	4	1.00	1.0
23	*Mikania micrantha*	Climber	4	1.00	1.0
24	*Nephrolepis biserrata*	Herb	4	1.00	1.0
25	*Aneilema beniniense*	Herb	4	1.00	1.0
26	*Selaginella myosurus*	Herb	4	1.00	1.0
27	*Borreria ocymoides*	Herb	3	0.75	0.7
28	*Colocasia esculenta (wild)*	Herb	2	0.50	0.5
29	*Piper umbellatum*	Herb	2	0.50	0.5
30	*Mallotus oppositifolius (seedling)*	Shrub seedling	2	0.50	0.5
31	*Baphia nitida (sapling)*	Tree sapling	2	0.50	0.5
32	*Rinorea dentata*	Herb	2	0.50	0.5
33	*Psychotria vogeliana*	Herb	2	0.50	0.5
34	*Cissus aralioides*	Climber	2	0.50	0.5
35	*Paspalum conjugatum*	Grass	2	0.50	0.5
36	*Piper guineense*	Herb	2	0.50	0.5
37	*Oplismenus burmannii*	Grass	1	0.25	0.2
38	*Icacina trichantha (sapling)*	Tree sapling	1	0.25	0.2

Appendix B2: Complete Understory Species Cover, Frequency, and Importance Value Data (Quadrat Sampling) — All 38 Species

S/N	Species	Growth Form	Total Cover (m²)	Mean Cover (m²)	Rel. Cover (%)	Freq. (quadrats)	Abs. Freq. (%)	Rel. Freq. (%)
1	*Chromolaena odorata*	Herb	475	118.75	12.1	13	325.0	6.8
2	*Ageratum conyzoides*	Herb	395	98.75	10.0	16	400.0	8.4
3	*Elaeis guineensis (sapling)*	Tree sapling	340	85.00	8.6	11	275.0	5.8
4	*Dioscorea spp.*	Climber	270	67.50	6.9	14	350.0	7.4
5	*Peperomia pellucida*	Herb	225	56.25	5.7	10	250.0	5.3
6	*Aspilia africana*	Herb	210	52.50	5.3	9	225.0	4.7
7	*Axonopus compressus*	Grass	210	52.50	5.3	14	350.0	7.4
8	*Centrosema pubescens*	Creeper	185	46.25	4.7	12	300.0	6.3
9	*Mikania cordata*	Climber	160	40.00	4.1	9	225.0	4.7
10	*Alchornea cordifolia (seedling)*	Shrub seedling	140	35.00	3.6	7	175.0	3.7

11	*Newbouldia laevis (sapling)*	Tree sapling	140	35.00	3.6	6	150.0	3.2
12	*Tridax procumbens*	Herb	130	32.50	3.3	4	100.0	2.1
13	*Sida acuta*	Herb	110	27.50	2.8	5	125.0	2.6
14	*Ipomoea involucrata*	Climber	110	27.50	2.8	6	150.0	3.2
15	*Panicum maximum*	Grass	100	25.00	2.5	10	250.0	5.3
16	*Dracaena surculosa*	Shrub seedling	70	17.50	1.8	3	75.0	1.6
17	*Synsepalum dulcificum*	Shrub seedling	60	15.00	1.5	2	50.0	1.1
18	*Oldenlandia corymbosa*	Herb	50	12.50	1.3	2	50.0	1.1
19	*Costus afer*	Climber	50	12.50	1.3	2	50.0	1.1
20	*Commelina benghalensis*	Herb	45	11.25	1.1	2	50.0	1.1
21	*Laportea aestuans*	Herb	44	11.00	1.1	2	50.0	1.1
22	*Colocasia esculenta (wild)*	Herb	40	10.00	1.0	2	50.0	1.1
23	*Palisota hirsuta*	Herb	36	9.00	0.9	2	50.0	1.1
24	*Mikania micrantha*	Climber	35	8.75	0.9	2	50.0	1.1
25	*Nephrolepis biserrata*	Herb	32	8.00	0.8	2	50.0	1.1
26	*Piper umbellatum*	Herb	30	7.50	0.8	2	50.0	1.1
27	*Mallotus oppositifolius (seedling)*	Shrub seedling	28	7.00	0.7	2	50.0	1.1
28	*Aneilema beniniense*	Herb	26	6.50	0.7	2	50.0	1.1
29	*Baphia nitida (sapling)*	Tree sapling	24	6.00	0.6	2	50.0	1.1
30	*Rinorea dentata*	Herb	24	6.00	0.6	2	50.0	1.1
31	*Selaginella myosurus*	Herb	22	5.50	0.6	2	50.0	1.1
32	*Borreria ocymoides*	Herb	20	5.00	0.5	1	25.0	0.5
33	*Psychotria vogeliana*	Herb	20	5.00	0.5	2	50.0	1.1
34	*Cissus aralioides*	Climber	20	5.00	0.5	2	50.0	1.1
35	*Paspalum conjugatum*	Grass	20	5.00	0.5	2	50.0	1.1
36	*Piper guineense*	Herb	16	4.00	0.4	2	50.0	1.1
37	*Oplismenus burmannii*	Grass	10	2.50	0.3	1	25.0	0.5
38	*Icacina trichantha (sapling)*	Tree sapling	9	2.25	0.2	1	25.0	0.5