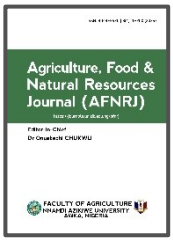
Agr. Foo. Nat. Res. J. Volume 4, Issue 2, Page 220 - 227

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj



Original Article

Diversity and composition of tree species in University of Benin, Benin City, Nigeria

OPEN ACCESS

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DOI: https://www.doi.org/10.5281/zenodo.17227189

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *June 30, 2025*
Accepted: *August 20, 2025*
Available online: *September 30, 2025*

Peer-review: *Externally peer-reviewed*

Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *The authors declared that this study has received no financial support.*

ABSTRACT

This study assessed the diversity and composition of tree species of the University of Benin (UNIBEN) in Benin City, Nigeria. Tree characteristics such as diameter at breast height (Dbh) and height measurement were obtained during the field inventory. A complete inventory was carried out in five different sample plots at the University of Benin. Data collected were analysed using biodiversity indices such as Shannon-Wiener diversity index, important value index, dominance index, species evenness, and results were presented in means, percentages, charts, and tables. A total population of 666 trees distributed among 18 families and 41 species was identified, with Fabaceae (14.63%) and Meliaceae (14.63%) being the most dominant families and Tectona grandis being the most occurring tree species with a relative density of 61.11%. However, the diversity index 1.79 > 1 is an indication of moderate diversity. Also, the tree species dominance index of 0.39 was recorded. Hence, urban forests are rich in tree diversity and can provide diverse ecosystem services to their communities. To manage sustainably, an urban forest inventory should be regularly carried out.

KEYWORDS: *Biodiversity, Diversity index, Inventory, Species richness*

INTRODUCTION

Trees in urban areas are of immense benefit to man. They provide important ecological, economic, social, and cultural services for the well-being of society (Ogwu *et al*., 2016). These include conservation of species, habitat provision/preservation for plant and animal species, provision of raw materials for industries, provision of food, air quality improvement, noise reduction, erosion control, carbon storage and sequestration, and recreation (Agbelade *et al*., 2016; Oladele *et al*., 2020).

The diversity of tree species, which is determined by the abundance and distribution of species, is an important feature of urban forest ecosystems (Kacholi, 2019). The abundance of tree species increases the number of ecological habitats and their associated species (Ogwu *et al*., 2016; Agbelade *et al*., 2016; Jeje *et al*., 2021). In addition, the value of the species diversity index helps to determine the sustainability and stability of forests. Some abiotic factors that influence species diversity include climate, soil, topography, and geographical characteristics of a community (Kacholi, 2019). Assessing tree species diversity and richness is an essential aspect of urban

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forest management that addresses the biodiversity conservation value and regeneration capacity of forests (Kacholi *et al*., 2015; Oladele *et al*., 2020). Many urban centres, despite having the capacity to support high tree species diversity, still have low and decreasing diversity due to overexploitation and poor management. Even those with high species abundance are dominated by a few species, which is a known global economic and environmental problem. Thus, it is necessary to place more emphasis on species diversity in urban forest design, conservation strategies, planning, and management (Morgenroth *et al*., 2016; Ogwu *et al*., 2016). For effective protection of urban forests, it is necessary to evaluate the state of species composition, diversity, and richness. This will help in their management and enhance our knowledge of tree species identification. Also, biodiversity conservation is evaluated based on an understanding of the tree structural characteristics, species richness, and ecological features of the forest community (Oladele *et al*., 2020).

The land area of plantation forests has increased over the years and is still increasing owing to their economic benefits, and they are mainly established with exotic species (MacDicken, 2015; Vroh *et al*., 2021). Urban forests have been grouped into different types based on their use, and they are urban plantation/woodland, community/sacred forests, parks and gardens, agroforest, avenue/street trees, and reserve forest (Yilmaz *et al*., 2008; Marziliano *et al*., 2013; Schnell *et al*., 2015; Taylor & Lovell, 2021). This study considers the plantation/woodland type of urban forest.

University of Benin, Ugbowo Campus, harbours some urban plantation forests that provide education and research benefits to people around, among others. This study examined the tree species composition, richness, diversity, and growth characteristics of urban forest plantations in the University of Benin.

MATERIALS AND METHOD

Study Area

This study was carried out in the University of Benin, Ugbowo Campus, a higher educational institution located between latitude 6^0 20′ 22″N and 6^0 24′ 62″N and longitude 5^0 36′ 9″E and 5^0 38′ 36″E in Ovia North East Local Government Area (LGA) of Benin City, Edo State (Figure 1). Benin City has an average annual rainfall and temperature of 2679mm and 25.7°C, respectively (Dania-Ogbe *et al*., 1992; Ogwu *et al*., 2016).

Data Collection

The study sites were purposively selected based on the urban forest type, which is the urban plantation/woodland. A complete inventory of tree species distribution was carried out in five (05) different urban forests in the Ugbowo Campus of the University of Benin (Table 1). Tree species with a diameter at breast height (Dbh) equal to or greater than 10cm were sampled.

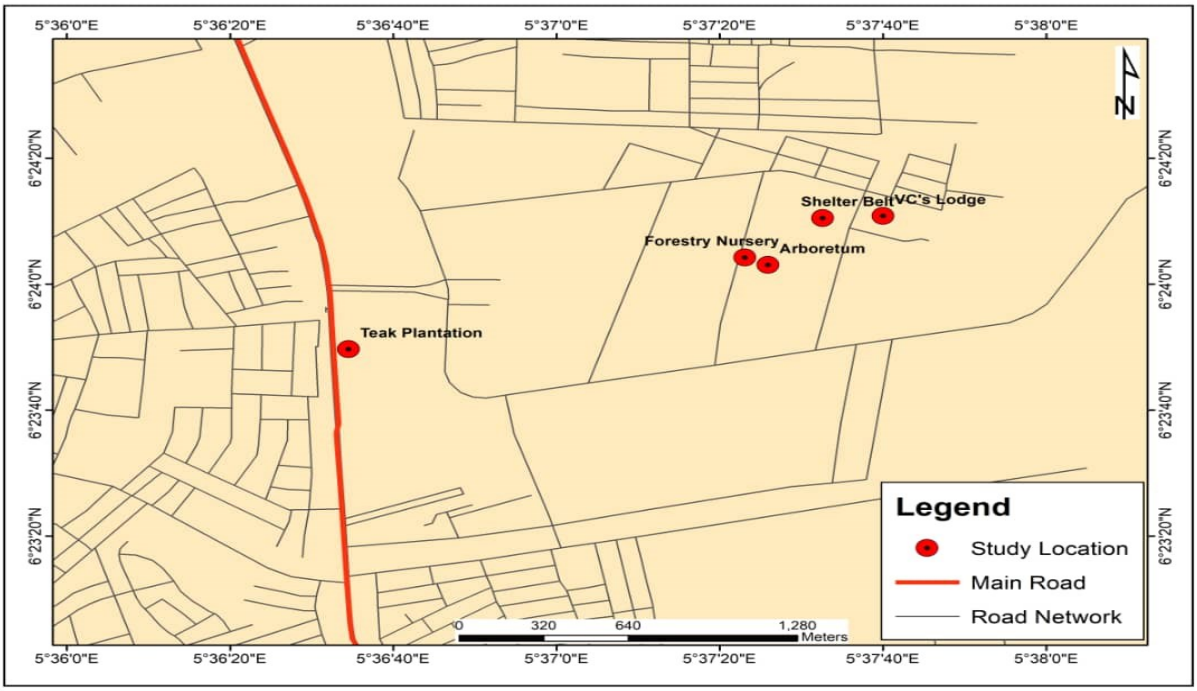

Figure 1. Map of the University of Benin showing the Study Locations

Table 1. Sampling Locations in the University of Benin

Sampling Sites	Description	Area of Site (ha)	Latitude and Longitude
a. Department of Forest Resources & Wildlife Nursery	Mixed forest plantation	0.15	$6^0$24.050′N $5^0$37.388′E
b. Teak Plantation beside VC's Lodge	Monoculture (Teak) forest plantation	1.48	$6^0$24.052′N $5^0$37.581′E
c. Shelter belt beside UNIBEN Health Centre	Mixed forest plantation	0.56	$6^0$24.150′N $5^0$37.598′E
d. Teak plantation beside the school gate	Monoculture (Teak) forest plantation	0.89	$6^0$23.887′N $5^0$36.551′E
e. Department Forest Resources & Wildlife Arboretum	Mixed forest plantation	0.17	$6^0$24.051′N $5^0$37.410′E

Data Analysis

The following growth and biodiversity variables were calculated;

(i) Basal Area: this was calculated with the formula below;

$$BA = \frac{\pi D^2}{4} \quad (1)$$

Where: BA = Basal area (m^2), D = Diameter at breast height, π = Pie (3.142)

(ii) Species Relative Dominance: This shows the relative space occupancy of a particular tree species. This was assessed with the formula (Aidar *et al*., 2001) below;

$$RDo = \frac{(\sum Ba_i \times 100)}{\sum Ba_n} \quad (2)$$

Where; Ba_i = Basal area of a particular tree species, Ba_n = Basal area of all trees in the community

(iii) Relative Density: this is defined by the formula below (Oduwaiye *et al*., 2002);

$$\text{Relative density} = \frac{n_i}{N} \times 100 \quad (3)$$

Where; ni = Number of individual species I, N = Total number of individuals in the entire population

(iv) Importance Value Index (IVI): This helps to evaluate the conservation and ecological status of tree species (Gopal *et al*., 2015). It is expressed as;

$$\text{Importance value index} = \frac{RD+RDo}{2} \quad (4)$$

Where; RD = Relative density, RDo = Relative dominance

(v) Species diversity index: this was assessed using the Shannon-Weiner index (Kent & Coker, 1992), defined as;

$$H' = -\sum_{i=1}^{k} pi\ In\ pi \quad (5)$$

Where; k = Number of tree species, p_i = Proportional abundance of the ith species, In = Natural logarithm

(vi) Shannon's Maximum Diversity Index: This is defined with the formula shown below (Guo *et al.*, 2003);

$$H_{max} = \ln(S) \quad (6)$$

Where= H_{max} = Shannon's maximum diversity index, S = Total number of species in the community

(vii) Species Evenness: this will be calculated using Shannon-Weiner's equitability (Kent & Coker, 1992) in equation 7;

$$EH = \frac{H'}{H_{max}} = \frac{\sum P_i\, In(P_i)}{In(S)} \quad (7)$$

Where H′, H_{max}, P_i, In, and S are the same as previously defined

(viii) Margalef's Index of Species Richness: This was calculated with equation 8 below (Margalef, 1958);

$$M = \left(\frac{S-1}{\ln N}\right) \quad (8)$$

Where; S = Number of a particular species, N = Total number of all individual species

(ix) Dominance Index: This was calculated with the equation below (Odum, 1971):

$$C = \sum \left(\frac{ni}{N}\right)^2 \quad (9)$$

Where; ni = Number of individuals of each species, N = Total number of individuals

RESULTS AND DISCUSSION

Results

Family Distribution of Tree Species

A total of 18 families were identified at the University of Benin. The dominant families represented were Fabaceae (14.63%), Meliaceae (14.63%), Malvaceae (12.20%), Moraceae (9.76%), and Verbenaceae (7.30%) (Table 2).

Table 2. Tree Families Distribution of Urban Forest Plantations at UNIBEN

S/N	Tree Families	No. of species	%
1	Anacardiaceae	1	2.44
2	Annonaceae	2	4.88
4	Bignoniaceae	1	2.44
5	Boraginaceae	1	2.44
6	Burseraceae	2	4.88
7	Clusiaceae	1	2.44
8	Combretaceae	2	4.88
9	Fabaceae	6	14.63
10	Irvingiaceae	2	4.88
11	Lauraceae	1	2.44
12	Malvaceae	5	12.20
13	Meliaceae	6	14.63
14	Moraceae	4	9.76
15	Myristicaceae	1	2.44
16	Rubiaceae	1	2.44
17	Sapindaceae	1	2.44
18	Sapotaceae	1	2.44
19	Verbenaceae	3	7.30
	Total	41	100

Urban Plantation Tree Species Richness and Diversity

The urban plantation forests at the University of Benin harbour a total tree population of 666, which were distributed into thirty-seven (37) genera and forty-one (41) different tree species (Table 3). The most dominant tree species was *Tectona grandis* (62.49%). *Tectona grandis*, an exotic tree species, had the highest relative density, importance value index, and Margalef's species richness of 61.11%, 61.80, and 62.62, respectively. Tree species with the least relative density of 0.15% and Margalef's species richness of zero (0) were *Antiaris toxicaria, Artocarpus altilis, Azadirachta indica, Blighia sapida, Ceiba pentandra, Cleistopholis patens, Distemonanthus benthamianus, Monodora myristica, Pentaclethra macrophylla, Persea americana, Spathodea campanulata, Spondias mombin*, and *Treculia africana*. However, *Cedrela odorata* had the highest mean Dbh of 0.74 m. *Antiaris toxicaria* and *Irvingia wombolu* had the least relative dominance of 0.01%, while *Gmelina arborea* had the least mean Dbh of 0.04 m. Furthermore, *Cleistopholis patens* had the highest mean height of 29.80 m, while *Monodora myristica* and *Spathodea campanulata* had the lowest height of 8.40 m (Table 2).

Population Structure of Urban Plantation Forests

The diameter distribution graph presented in Figure 2 shows that tree species at the University of Benin urban plantation forests comprised mostly small-diameter tree species that fall within the diameter range of 10-59cm. The maximum population percentage of 28.1% was found in the size class of 20-29 cm. There were only about four tree species that were in the diameter range of 90-129 cm.

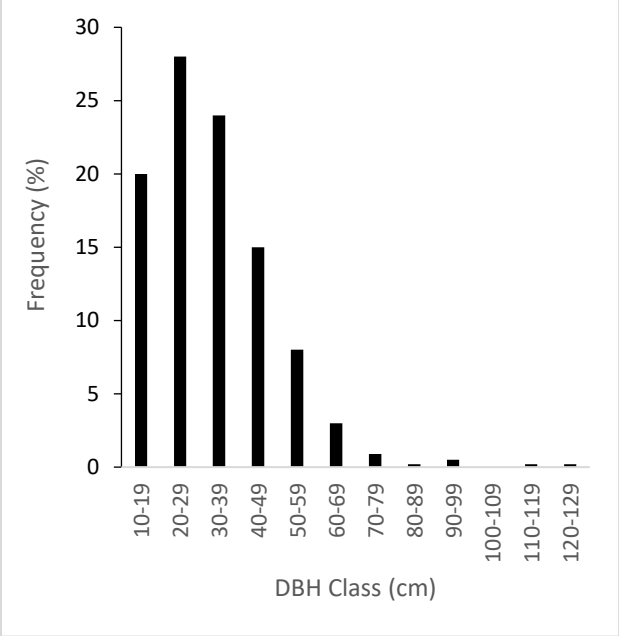

Figure 2. Diameter Distribution Graph of Tree Species at the University of Benin

Figure 3 is a graphical representation of the height distribution of trees at the University of Benin. The urban trees were mostly within the height range of 6 to 25 m. The dominant height range was 11-15m

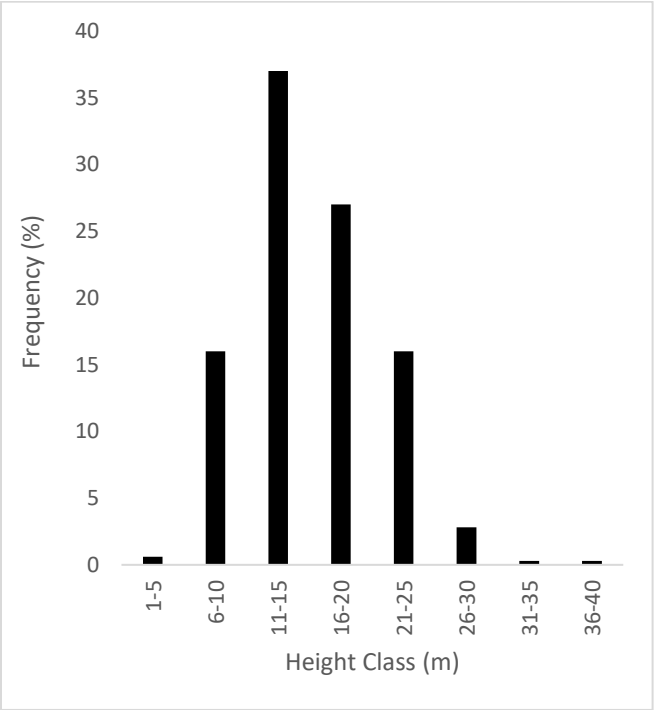

Figure 3. Height Distribution of Trees at the University of Benin

Table 2. Tree Growth Parameters at University of Benin, Benin City, Edo State

Family	Tree Species	Freq.	Mean DBH (m)	Mean Basal Area (m^2)	Mean Total Ht (m)	RDo (%)	RD (%)	IVI	M
Anacardiaceae	*Spondias mombin*	1	0.25	0.05	17.6	0.07	0.15	0.11	0.00
Annonaceae	*Cleistopholis patens*	1	0.61	0.29	29.8	0.43	0.15	0.29	0.00
	Monodora myristica	1	0.13	0.01	8.40	0.02	0.15	0.08	0.00
Bignoniaceae	*Spathodea campanulate*	1	0.15	0.02	8.40	0.03	0.15	0.09	0.00
Boraginaceae	*Cordia millenii*	3	0.23	0.05	17.85	0.22	0.45	0.34	0.31
Burseraceae	*Canarium schweinfurthii*	4	0.22	0.05	14.99	0.28	0.60	0.44	0.46
	Dacryodes edulis	3	0.15	0.02	12.90	0.09	0.45	0.27	0.31
Clusiaceae	*Garcinia kola*	4	0.18	0.03	9.36	0.16	0.60	0.38	0.46
Combretaceae	*Terminalia ivorensis*	33	0.33	0.09	17.30	4.32	4.95	4.64	4.92
	Terminalia superba	2	0.40	0.13	19.03	0.38	0.30	0.34	0.15
Fabaceae	*Albizia lebbeck*	7	0.15	0.02	10.52	0.24	1.05	0.64	0.92
	Dialium guineense	6	0.19	0.03	9.89	0.27	0.90	0.58	0.77
	Leuceana leucocephala	4	0.15	0.02	8.60	0.10	0.60	0.35	0.46
	Distemonanthus benthamianus	1	0.19	0.03	17.4	0.04	0.15	0.10	0.00
	Pentaclethra macrophylla	1	0.17	0.02	14.9	0.03	0.15	0.09	0.00
	Senna alata	2	0.18	0.03	6.60	0.07	0.30	0.19	0.15
Irvingiaceae	*Irvingia wombolu*	1	0.11	0.01	8.00	0.01	0.15	0.08	0.00
	Irvingia gabonensis	2	0.13	0.01	10.3	0.04	0.30	0.17	0.15
Lauraceae	*Persea americana*	1	0.38	0.11	14.00	0.17	0.15	0.16	0.00
Malvaceae	*Bombax buonopozense*	10	0.32	0.09	16.48	1.36	1.50	1.43	1.38
	Ochroma pyramidale	3	0.48	0.23	24.03	1.05	0.45	0.75	0.31
	Triplochiton scleroxylon	10	0.41	0.22	17.03	3.20	1.50	2.35	1.38
	Ceiba pentandra	1	0.20	0.03	14.55	0.05	0.15	0.10	0.00
	Mansonia altissima	2	0.27	0.06	18.20	0.18	0.30	0.24	0.15
Meliaceae	*Khaya grandifololia*	28	0.30	0.08	16.04	3.36	4.20	3.78	4.15
	Khaya ivorensis	3	0.17	0.02	10.77	0.10	0.45	0.28	0.31
	Entandrophragma angolense	2	0.22	0.04	19.70	0.12	0.30	0.21	0.15
	Entandrophragma cylindricum	17	0.24	0.06	14.76	1.45	2.55	2.00	2.46
	Cedrela odorata	7	0.74	0.50	26.44	5.14	1.05	3.09	0.92
	Azadirachta indica	1	0.34	0.09	18.00	0.13	0.15	0.14	0.00
Moraceae	*Antiaris toxicaria*	1	0.11	0.01	9.00	0.01	0.15	0.08	0.00
	Milicia excelsa	1	0.46	0.17	12.70	0.25	0.15	0.20	0.00
	Treculia Africana	1	0.49	0.19	15.50	0.28	0.15	0.22	0.00
	Artocarpus altilis	1	0.16	0.02	9.50	0.03	0.15	0.09	0.00
Myristicaceae	*Pycnanthus angolensis*	2	0.45	0.16	22.35	0.46	0.30	0.38	0.15
Rubiaceae	*Nauclea diderrchii*	52	0.34	0.10	18.30	7.34	7.81	7.57	7.84
Sapotaceae	*Chrysophyllum albidum*	14	0.30	0.09	16.27	1.76	2.10	1.93	2.00
Sapindaceae	*Blighia sapida*	1	0.25	0.05	13.70	0.07	0.15	0.11	0.00
Verbenaceae	*Gmelina arborea*	22	0.04	0.12	15.73	4.01	3.30	3.66	3.23
	Tectona grandis	407	0.33	0.10	15.91	62.49	61.11	61.80	62.45
	Vitex doniana	2	0.25	0.06	14.50	0.16	0.30	0.23	0.15
	Total	666							

M = Margalef's Index of Species Richness; IVI = Importance Value Index; RD = Relative Density; RDo = Relative Dominance; Ht = Height; Freq. = Frequency

Table 4 shows that Tree species in UNIBEN forest plantations have a mean DBH of 32.51cm, a maximum DBH of 126.40cm, a mean height of 16.03m, a maximum height of 39.00m, a Maximum Diversity Index of 6.50, Species Evenness of 0.28, and a difference between H' & H_{max} of 4.71.

Table 4. Summary of Tree Parameters and Biodiversity Indices Obtained from Urban Forest Plantations

Parameters	Value
Number of Species	41
Number of Families	18
Number of Trees	666
Mean DBH (cm)	32.51
Maximum DBH (cm)	126.40
Mean Height (m)	16.03
Maximum Height (m)	39.00
Shannon Diversity Index	1.79
Maximum Diversity	6.50
Diff. Btw. H′ & H_{max}	4.71
Species Evenness	0.28
Dominance index	0.39

H' = Shannon-Wiener's Diversity Index; Hmax = Shannon's Maximum Diversity Index, Diff. Btw. H' & Hmax = difference between H' and Hmax

Discussion

Urban forests are home to diverse species of trees, including rare species and those with high conservation value and benefit (Shrestha, 2016). The University of Benin urban plantation forests were mostly rich in *Tectona grandis*, an exotic tree species, and were dominated by the tree families Fabaceae and Meliaceae. A similar study carried out by Ilaide & Opeyemi (2023) surveyed another type of urban forest use known as avenue trees in the University of Benin, and identified a total number of 1,591 avenue trees belonging to 61 species. *Tectona grandis* was also the most dominant avenue tree with a relative frequency of 14.02% and the family Fabaceae was the most dominant family among the families encountered in the study. Ogwu *et al*. (2016) also assessed urban forests in the University of Benin, but did not specify the urban forest type of use assessed in their study. The study recorded a total population of 214 trees distributed among 20 species and 12 families. *Elaeis guineensis* was reported as the most abundant tree species with a relative density of 22.07. The tree families Arecaceae and Fabaceae were the most dominant. Erhabor *et al.* (2020) carried out a complete survey of every tree in the University of Benin Teaching Hospital and identified a total of 224 trees/shrubs belonging to 27 species, 26 genera, and 19 families. *Terminalia mantaly*, an exotic tree species, was the most occurring tree species with an Important Value Index of 12.51. This further reveal that urban forests are dominated by exotic tree species in Benin City (Erhabor *et al*., 2020). Also, urban forests help in the conservation of both indigenous and exotic tree species (Erhabor *et al*., 2020). It comprises of trees species like *Tectona grandis*, *Terminalia mentaly*, *Delonix regia*, *Nauclea diderrichii*, *Terminalia catappa*, *Khaya grandifoliola*, *Mansonia altissima*, *Nauclea diderichii, Citrus sinensis* and *Terminalia ivorensis* (Erhabor *et al*., 2020; Iliade & Opeyemi, 2023). Moreover, the moist southern part of the lowland rainforests' vegetation belt in Nigeria, where Benin City is found, has been reported to comprise mainly of tree species belonging to the family Fabaceae (such as *Piptadeniastrum africanum, Cylicodiscus gabunensis, Brachystegia spp*.), and family Meliaceae (consisting of *Khaya ivorensis, Entandrophragma spp, Guarea spp., Lovoa trichilioides*) (World Wildlife Fund 'WWF', 2025).

The population structure of these forests, according to the diameter class distribution graph, showed that a higher population of trees was found in the lower diameter class, and as the diameter size class increases, the population decreases. This is in tandem with the characteristics of tropical forests, which include complex tree species diversity, high tree population density, and competition for soil water, nutrients, space, and sunlight. This is the reason for its high concentration of lower diameter size of tree species, which is supported by the report of Aderounmu *et al*. (2017). In an assessment of growth characteristics, diversity, and structure of tree species in Opara Forest Reserve, Oyo State, Nigeria, Ogidan *et al*. (2023) observed that trees with a height range of 6-10m dominated the reserve. Also, the diameter class distribution of trees showed a normal distribution pattern with the highest population concentrating in the middle diameter class, while few trees were found at the highest and lowest classes. Also, in Nongeni Forest Reserve in Morogoro Region of Tanzania, Kacholi (2019) reported that the diameter class distribution of trees in the forest had a reverse J-shaped curve, and about 81.8% of the trees were found under the first size class range of 0.0-10.0cm.

Furthermore, UNIBEN had diversity indices > 1, which according to Daniel *et al*. (2015) indicates richness in diversity. Also, according to Maisyaroh *et al*. (2021), a diversity index ≤ 0.50 means low diversity, a diversity index of 0.50-0.75 is moderate diversity, and 0.75-1 indicates high diversity (Odum, 1971). The result of species evenness at UNIBEN had a value close to zero. Thus, this implies that most of the tree species in UNIBEN plantation forests are of the same species, which is in line with the report of Ogidan *et al*. (2023). The dominance index of tree species in UNIBEN, according to the dominance index classification of Maisyaroh *et al*. (2021), falls below 0.50, indicating that no species dominated the urban forest. Maisyaroh *et al*. (2021) classified the dominance index of less than 0.50 as no species is dominant, index of 0.50-0.75 as moderate dominance, and 0.75-1 as high dominance. Similar studies (Arabomen *et al*., 2020; Erhabor *et al*., 2020) carried out in Benin City reported a higher species diversity and evenness indices. Arabomen *et al*. (2020) recorded Shannon-Wiener diversity, maximum diversity, and evenness indices of 4.15, 4.58, and 0.91 for Benin City, while Erhabor *et al*. (2020) reported Shannon-Wiener and maximum diversity indices of 2.66 and 3.30 for the tree population in the University of Benin Teaching Hospital. Hence, urban forest plantations are rich in tree species and diverse as their composition and distribution

vary from one ecosystem to another. It has the capacity to provide numerous ecosystem services, which include the conservation of diverse plant and animal species.

CONCLUSION AND RECOMMENDATIONS

The study observed that forest plantations were rich in tree species composition and diversity. Its population was dominated by trees of smaller diameter size classes, while fewer trees were in higher diameter size classes. Its rich biodiversity can provide numerous ecosystem services for the growth and development of its community. Though dominated by exotic tree species, these plantations have promoted the conservation of rare and endangered economic tree species such as *Khaya grandifololia, Mansonia altissima, Milicia excelsa,* and *Nauclea diderrichii*. Therefore, forest inventory should be carried out regularly to promote its sustainable management, and indigenous tree species should be considered more during tree planting exercises.

Acknowledgements

The authors acknowledge the University of Benin for granting access to their facilities. The authors also acknowledge the academic staff of the Department of Forestry and Wood Technology, Federal University of Technology, Akure for providing constructive criticism, which improved the quality of the research.

Authors' Contributions

ENA, OVO, SAA & JAO conceptualized the study and designed the experiment. ENA collected data, performed data analysis, and wrote the first draft of the manuscript. OVO, SAA & JAO performed literature searches and reviewed the first draft of the manuscript. All authors read and approved the final draft of the manuscript.

Ethical Statement

Not applicable

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