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Climate change mitigation and adaptation capabilities of avenue tree species at the University of Port Harcourt, Nigeria

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ABSTRACT

The capacity of trees to contribute to climate change mitigation and adaptation in urban areas will depend, to a large extent, on their abundance, diversity and the possession of appropriate structural characteristics. This study evaluated the climate change adaptation and mitigation capabilities of avenue tree species in three campuses – Choba, Delta, and Abuja, of the University of Port Harcourt by examining their abundance, alpha and beta diversity, diameter at breast height, total height, crown diameter, and basal area. Species relative abundance was highest for Elaeis guineensis (41.10%), Polyalthia longifolia (15.29), and Terminalia mantaly (25.00%) in Abuja, Choba, and Delta Campuses respectively. Avenue tree species richness for Abuja, Choba, and Delta Campuses, was 8, 12, and 16, respectively. No significant difference (p > 0.05) was observed in mean values of diameter at breat height, total height and crown diameter, for Azadirachta indica, Dacryodes edulis, Elaeis guineensis, and Terminalia catappa, in the campuses where they occurred. Avenue tree species diversity was slightly higher in Delta campus (H = 2.3950) than Choba Campus (H = 2.3300) when Shannon index was used, but slightly higher in Choba Campus (Simpson 1 –D = 0.8891) than Delta Campus (Simpson 1 –D = 0.8731) when Simpson index was used. Abuja Campus (H = 1.5670; Simpson 1 –D = 0.7295) was the least diverse of the three campuses. The highest similarity in avenue tree species (42.11%) was observed between Choba Campus and Delta Campus, while the least similarity (17.65%) was observed between Choba Campus and Abuja Campus. Delonix regia, Eucalyptus camaldulensis, Gmelina arborea, Mangifera indica, Azadirachta indica, Albizia lebbeck, Irvingia gabonensis, Terminalia catappa, Pinus caribaea, and Tectona grandis with better growth attributes and high capacity for climate change mitigation and adaptation, were represented by few individuals in all the campuses. Low tree species diversity especially in the permanent site (Abuja Campus) and low relative abundance of species with high capacity to address climate change indicate that the university is not making the best use of trees in confronting the menace of climate change. Tree planting in urban institutions should consider climate change mitigation and adaptation capabilities of tree species.

Key words: Urban forestry, climate change, global warming, tree growth, carbon sink

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INTRODUCTION

The current trend in climate change has become a global challenge and a source of great concern to the international community. According to [11] current projections indicate that concentrations of greenhouse gases will continue to increase into the indefinite future, entailing a process of continued global warming. Hence, efforts are being made at the international level to address the present climate change problems through climate change mitigation and adaptation. Climate change mitigation efforts are geared towards preventing or reducing emission of the greenhouse gases – Carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, etc., which are hugely responsible for climate change. Efforts at climate change mitigation at the international level include reduction of emission levels, tree planting, the use of biofuels, general changes in lifestyle, etc. Climate change adaptation on the other hand, advocates for and encourages strategies to cope with the effects of climate change that are being felt already. Arguments in favour of climate change adaptation posit that the effects of climate change being experienced at the moment will linger even if the emission of the greenhouse gases ceases at the moment; hence the need for adaptive strategies.

In addition to their roles in climate change mitigation, forests, trees, and their genetic diversity are also useful in climate change adaptation, which focuses on the reduction of the impacts of climate change on ecosystems and societies. They provide ecosystem services that facilitate the adaptation of local people to climate change and adaptation of wider sectors of the economy and society; hence, they are key components of ecosystem based adaptation [4].

Trees in urban areas provide shade against intense solar radiation, and protect buildings and humans against the damaging effects of strong winds and torrential rains associated with climate change. According to [7], the conservation, restoration and sustainable management of ecosystems can help reduce vulnerability to climatic hazards such as hurricanes, rising sea levels, floods and droughts. Hence, the global advocacy for greening the Earth by planting trees in urban areas and centres like churches, schools, hospitals, recreation centres, markets, to mention a few. Since tree species vary in their attributes, the effectiveness of trees in urban areas to achieve this goal will depend to a large extent on the planting of tree species that have the desired growth and structural attributes capable of enhancing climate change adaption and mitigation.

This study evaluated the climate change mitigation and adaptation capabilities of avenue tree species at the three campuses of the University of Port Harcourt by examining their abundance, diversity, total height, diameter at breast height, basal area, and crown diameter.

MATERIALS AND METHODS

The study area

This study was conducted at the three campuses of the University of Port Harcourt, Choba, Rivers State, Nigeria. The University of Port Harcourt is located on latitude 4^{o} 53' 14" N through 4^{o} 54' 42" N and longitude 6^{o} 54' 00" E through 6^{o} 55' 50" E. It has three campuses - Abuja, Delta and Choba. These three campuses are separated by road networks, although, Abuja and Delta Campuses are closer to each other than to Choba Campus which is on the other side of the popular East-West Road. Figure 1 is the map of University of Port Harcourt showing the three campuses and their landmarks.

Data collection

Tree enumeration

Avenue trees were enumerated along major roads, and walkways covering a distance of one kilometer in each of the three campuses. Each of the tree species encountered was identified to species level and the number of individuals counted and recorded. Only trees ≥ 5m in height were enumerated. Thereafter, equal number of individuals for each species was selected in each campus for the measurement of total height, diameter at breast height, and crown diameter.

Measurement of total height

Total height of the tree is the vertical distance between ground level and the tip of the tree**.** The total height for each tree was measured using a pole graduated in meters. Each tree was measured from the ground level up to a point considered to be half of the tree height, and the value was multiplied by two to get the total height.

Diameter at breast height (Dbh)

The diameter at breast height for each sampled tree was estimated by first measuring the girth of the tree at 1.3m from the ground level using a measuring tape graduated in meters. The girth was converted to diameter following [17] using the formula below:

$$Dbh = \frac{c}{\pi} \qquad \text{eqn. 1}$$

Where: c= circumference

π= 3.1416

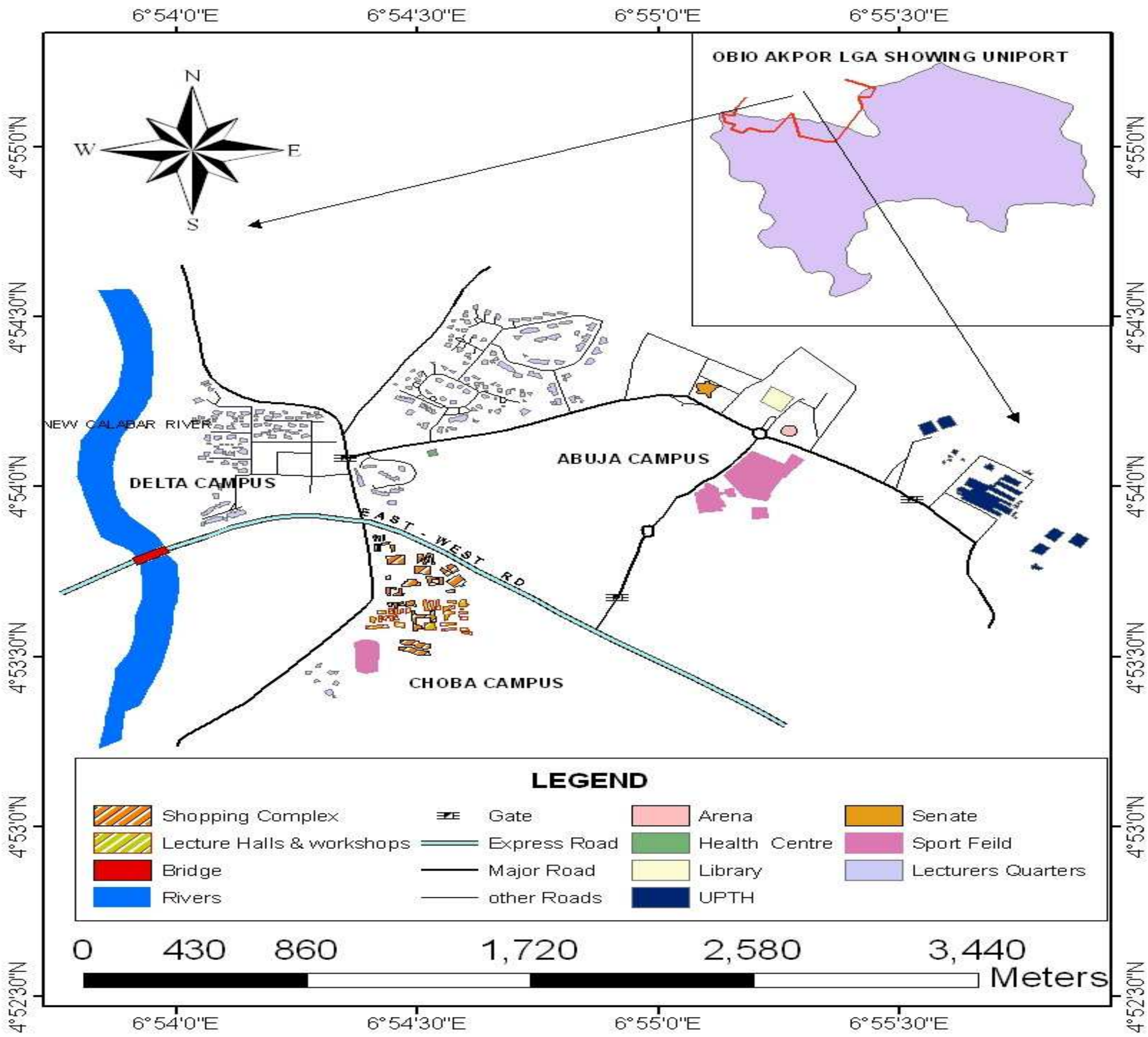

Figure 1: Map of University of Port Harcourt showing the three campuses
Source: Department of Geography and Environmental Management, University of Port Harcourt

Basal area
The basal area (BA) for each tree species was computed after [17]. The average stem diameter of the tree species was first divided by 2 to get the radius. The radius was thereafter squared and multiplied by π to get the basal area.

Crown Diameter
The crown diameter is the distance between the tips of the crown. The crown diameter was gotten by taking the measurement of the distance between the tips of the crown of each tree from north to south and from east to west, using a measuring tape, and the average of the measurements taken.

Data analyses
Species relative abundance
Species relative abundance was computed for each tree species in each of the three campuses using the formula below:

$$\text{Relative abundance} = \frac{\text{Number of individuals of a tree species}}{\text{Total number of individuals for all tree species}} \times 100 \qquad \text{eqn. 2}$$

Percentage population of each tree species present in each campus
The percentage population of avenue tree species in a campus was computed using the formula below:

Tree species population (%) in a campus =

$$\frac{\text{Population a tree species in a campus}}{\text{Population of the tree species in all campuses}} \times 100 \qquad \text{eqn. 3}$$

Analysis of variance

One-way analysis of variance was used to test for significant differences in total height, diameter at breast height, and crown diameter, among avenue trees of the same species growing at the different campuses. Fisher's Least Significant Difference (LSD) test was used for mean separation where significant difference was observed. Analysis of variance and LSD test were performed using Statistical Package for Social Sciences (SPSS). The linear model for one-way analysis of variance is as stated below:

$$Yij = \mu + Tj + Eij \qquad \text{eqn. 4}$$

Where Yij = individual observation
μ = general mean
Tj = effect of the jth treatment
Eij = experimental error containing all uncontrolled sources of variation

Measurement of tree diversity

Alpha (within-community) avenue tree species diversity was computed for each of the campuses using both Simpson diversity index [13] and Shannon-Wiener diversity index [8]

Simpson's diversity index (D) = $\dfrac{\Sigma ni(ni-1)}{N(N-1)}$ eqn. 5

Where: ni = the number of individuals of an avenue tree species in a campus
N = the total number of individuals for all avenue tree species in a campus.

Simpson diversity index (D) as expressed in the formula above has an indirect relationship with diversity (i.e. the lower the index, the higher the diversity). Therefore, avenue tree species diversity for each of the campuses was subtracted from 1 as shown in equation 6 below to allow for a direct relationship.

Simpson (1 – D) = 1 - $\dfrac{\Sigma ni(ni-1)}{N(N-1)}$ eqn. 6

Shannon-Wiener's diversity index (H) $= -\sum_{i=1}^{s} \text{pi} \log \text{pi}$ eqn. 7

Where: pi = the proportion of individuals of a particular avenue tree species in a campus.
s = the total number of avenue tree species enumerated in a campus.

Sorensen's similarity index [16] was used to ascertain the extent of similarity in avenue tree species between campuses. Other workers like [2], [9], and [10] have employed Sorensen similarity index to measure similarity in tree species composition between communities. Sorensen index (SI) is expressed as:

SI = $\dfrac{a}{a+b+c} \times 100$ eqn. 8

Where: a = number of avenue tree species present in both campuses.
b = number of avenue tree species present in Campus 1 but absent in Campus 2.
c = number of avenue tree species present in Campus 2 but absent in Campus 1.

RESULTS AND DISCUSSION

Population Structure of Avenue Tree Species at the Campuses

The population, relative abundance, total height, diameter at breast height, and crown diameter of the avenue tree species are shown in Tables 1, 2, and 3 while the basal area is presented in Figures 2, 3, and 4, for Abuja, Choba, and Delta Campuses, respectively. At the Abuja Campus, a total of 8 avenue tree species were recorded. *E.*

guineensis had the highest relative abundance, followed by *A. Indica*, and *C. nucifera/S. elegans*, respectively. The relative abundance of avenue tree species with better growth attributes like *G. arborea*, *M. indica*, *P. caribaea*; and *T. grandis* known for its durable wood and good mechanical properties, put together, was less than 10%. Avenue tree species richness for Choba campus was 12. *P. longifolia* was the most abundant avenue tree species in Choba Campus, followed by *T. catappa* and *C. pulcherrima*, respectively. Tree species like *D. regia*, *E. camaldulensis*, *G. arborea*, and *M. indica*, with better growth attributes in terms of height, diameter at breast height, crown diameter, and basal area, were represented by few individuals in Choba Campus. In Delta Campus, 16 avenue tree species were encountered. Species relative abundance was highest for *T. mantaly*, followed by *P. caribaea*, and *C. nucifera*, respectively. Large trees with good growth attributes and mechanical properties like *A. indica*, *A. lebbeck*, *D. regia*, *I. gabonensis*, *M. indica*, and *T. catappa*, were also few in Delta Campus.

Table 1: Population structure of avenue tree species in Abuja Campus

S/No.	Species	Population	Relative abundance (%)	Total height (m)		Dbh (m)		Crown diameter (m)	
				Range	Average	Range	Average	Range	Average
1.	*Azadirachta indica*	37	25.34	10.50 – 13.50	11.83	0.70 – 1.11	0.90	9.12 – 19.21	13.11
2.	*Cocus nucifera*	16	10.96	5.00 – 9.00	6.40	0.27 – 0.40	0.35	4.20 – 7.50	5.80
3.	*Elaeis guineensis*	60	41.10	9.00 – 12.00	10.50	0.46 – 0.80	0.66	6.75 – 8.27	7.63
4.	*Gmelina arborea*	4	2.74	16.00 – 17.25	16.58	0.71 – 0.75	0.73	9.44 – 9.75	9.55
5.	*Mangifera indica*	4	2.74	10.50 – 13.50	12.25	0.80 – 1.12	0.97	13.50 – 19.05	16.31
6.	*Pinus caribaea*	3	2.05	10.50 – 12.75	11.75	0.68 – 0.93	0.80	9.50 16.50	13.88
7.	*Seaforthia elegans*	16	10.96	6.00 – 10.50	8.00	0.71 – 0.99	0.83	3.75 – 7.68	5.81
8.	*Tectona grandis*	3	2.05	7.60 – 10.50	9.10	0.35 – 0.50	0.43	6.80 – 8.00	7.32

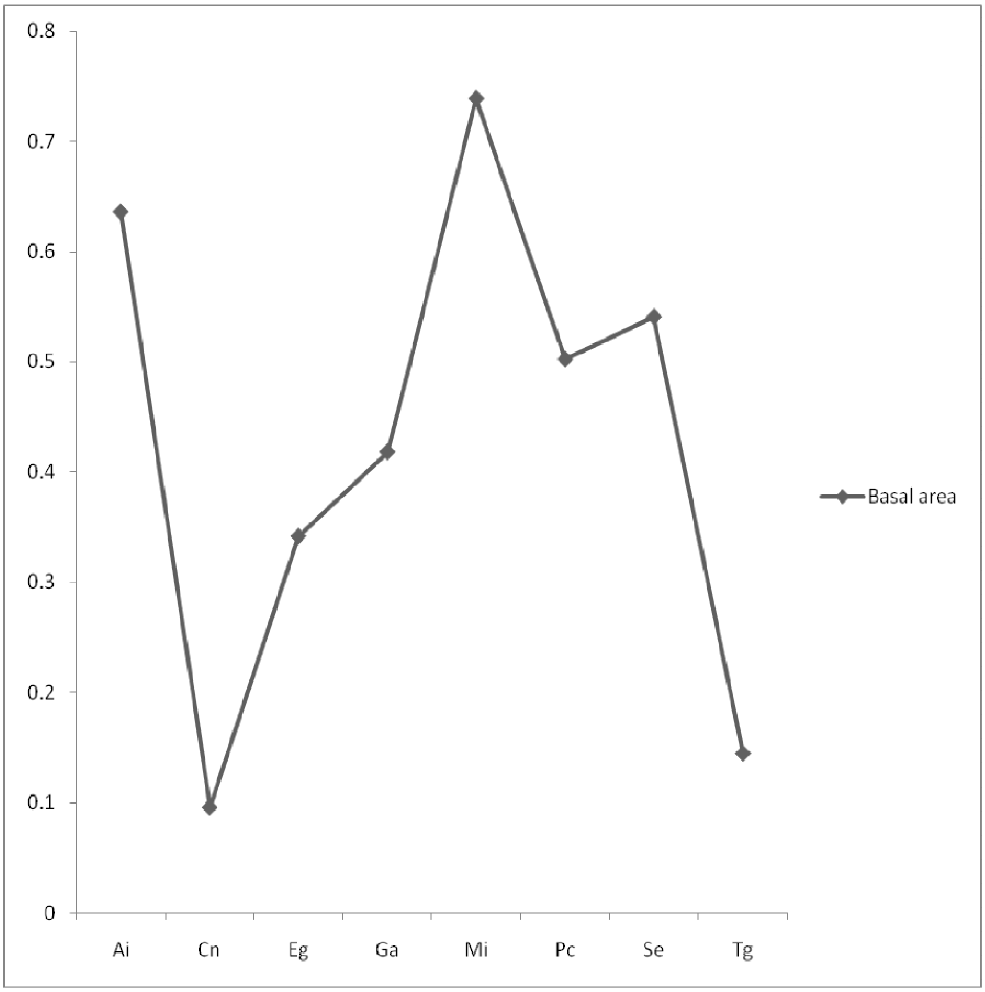

Figure 2: Mean basal area (m^2) of avenue tree species in Abuja Campus
Ai = Azadiractha indica; Cn = Cocus nucifera; Eg = Elaeis guineensis; Ga = Gmelina arborea; Mi = Mangifera indica; Pc = Pinus caribaea; Se = Seaforthia elegans; Tg = Tectona grandis.

Table 2: Population structure of avenue tree species in Choba Campus

S/No.	Species	Species abundance	Relative abundance (%)	Total height (m)		Dbh (m)		Crown diameter (m)	
				Range	Average	Range	Average	Range	Average
1.	*Caesalpinia pulcherrima*	9	10.59	5.70 – 8.00	6.63	0.52 – 0.68	0.59	4.80 – 9.50	7.27
2.	*Casuarina equisetifolia*	8	9.41	15.00 – 18.50	16.50	0.52 – 0.64	0.58	7.00 – 11.40	9.47
3.	*Citrus sinensis*	3	3.53	5.00 – 5.50	5.17	0.10 – 0.28	0.18	2.77 – 4.50	3.62
4.	*Cocos nucifera*	3	3.53	8.10 – 10.00	9.07	0.30 – 0.48	0.39	5.80 – 8.60	6.97
5.	*Dacryodes edulis*	3	3.53	6.10 – 11.20	8.60	0.28 – 0.58	0.42	5.00 – 7.80	6.67
6.	*Delonix regia*	6	7.06	6.50 – 12.50	9.93	0.61 – 1.24	0.99	15.00 – 20.00	17.87
7.	*Eucalyptus camaldulensis*	6	7.06	17.00 – 18.40	17.80	0.68 – 1.00	0.83	12.60 – 15.10	14.17
8.	*Gmelina arborea*	3	3.53	10.90 – 13.40	11.93	0.61 – 0.75	0.67	9.61 – 11.6	10.80
9.	*Mangifera indica*	3	3.53	11.20 – 12.60	12.03	0.55 – 0.75	0.65	7.90 – 9.10	8.60
10.	*Polyalthia longifolia*	13	15.29	11.00 – 13.40	12.53	0.27 – 0.42	0.34	2.70 – 3.50	3.03
11.	*Psidium guajava*	4	4.71	5.10 – 9.50	7.10	0.17 – 0.29	0.23	3.60 – 7.70	5.90
12.	*Terminalia catappa*	12	14.12	17.20 – 22.60	20.53	0.65 – 1.24	0.93	16.50 – 20.70	18.70

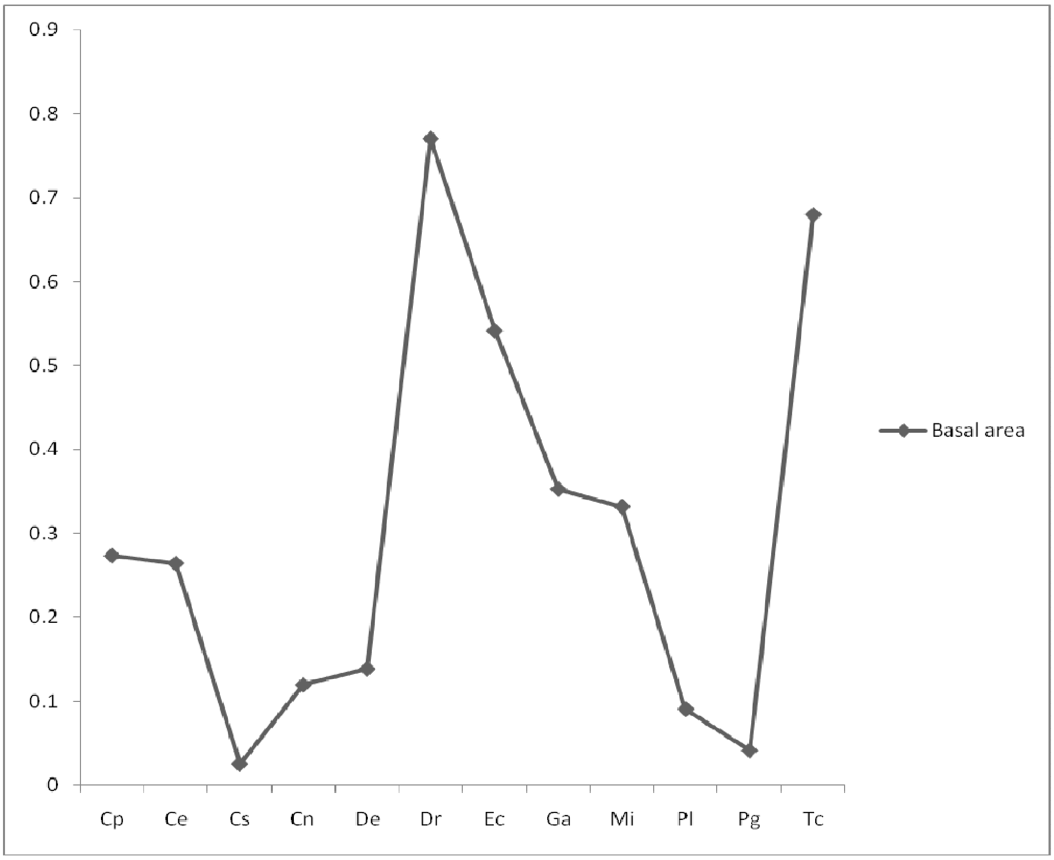

Figure 3: Mean basal area (m^2) of avenue tree species in Choba Campus

CP = Caesalpinia pulcherrima; Ce = Casuarina equisetifolia; Cs = Citrus sinensis; Cn = Cocus nucifera; De = Dacryodes edulis; Dr = Delonix regia; Ec = Eucalyptus camaldulensis; Ga = Gmelina arborea; Mi = Mangifera indica; Pl = Polyalthia longifolia; Pg = Psidium guajava; Tc = Terminalia catappa.

The current global temperature trends and weather patterns are quite worrisome. The present rate of global climate change has been described as unprecedented [15]. Concentration of atmospheric CO_2 has increased over the past four decades by 10% [13]; with a mean global temperature increase of about 0.5^{o}C over the same period [6]. The beehives of activities that take place in urban areas in addition to the wanton deforestation associated with urbanization exacerbate global climatic trends through the release of CO_2 and other greenhouse gases. Consequently, global efforts toward climate change mitigation and adaptation include advocacy and support for tree planting in urban areas due to the ability of trees to sequester carbon, provide shade, act as windbreak, and provide shelter for building and people in vulnerable areas, against extreme weather events driven by climate change. However, the very low relative abundance of tree species with large crown cover, basal area, and good mechanical strength, as observed in this study, shows that the university is not making the best use of trees in addressing the problem of climate change. For instance, [17] observed that the basal area is used to determine the relative importance of a species. Basal area is also indicative of the wood volume of a tree; thus, the quantity of carbon it can hold. Hence, tree species that have large basal area, large crown diameter, and good mechanical strength for wind resistance, should be considered for planting in urban institutions, for them to contribute meaningfully to climate change mitigation and adaptation.

Table 3: Population structure of avenue tree species in Delta Campus

S/No.	Species	Population	Relative abundance (%)	Total height		Dbh (m)		Crown diameter (m)	
				Range	Average	Range	Average	Range	Average
1.	*Azidarachta indica*	3	2.42	11.00 – 13.00	12.00	0.98 – 1.13	1.05	15.40 – 19.31	17.60
2.	*Albizia lebbeck*	3	2.42	12.00 – 15.00	13.67	0.69 – 1.13	0.97	16.00 – 19.50	17.83
3.	*Anacardium occidentale*	3	2.42	6.00 – 7.00	6.33	0.44 – 0.66	0.59	4.48 – 14.85	9.59
4.	*Citrus sinensis*	10	8.06	6.00 – 6.50	6.17	0.44 – 0.53	0.48	6.07 – 6.89	6.57
5.	*Cocos nucifera*	13	10.48	13.00 – 13.50	13.17	0.62 – 0.66	0.65	7.90 – 8.20	8.01
6.	*Dacroydes edulis*	3	2.42	5.00 – 5.50	5.17	0.13 – 0.22	0.18	2.49 – 3.11	2.77
7.	*Delonix regia*	3	2.42	10.00 – 12.00	10.67	1.22 – 1.36	1.29	16.92 – 24.00	19.47
8.	*Elaeis guineensis*	4	3.23	10.00 – 13.00	11.33	0.43 – 0.55	0.49	8.10 – 10.80	9.68
9.	*Irvingia gabonensis*	3	2.42	8.00 – 11.00	9.33	0.66 – 1.12	0.92	6.08 – 18.90	11.16
10.	*Mangifera indica*	7	5.65	9.00 – 12.00	10.67	0.90 – 1.43	1.11	12.55 – 18.40	15.58
11.	*Persea americana*	3	2.42	7.00 – 8.00	7.50	0.44 – 0.51	0.48	6.79 – 8.10	7.40
12.	*Pinus caribaea*	20	16.13	18.00 – 22.00	20.00	0.70 – 1.10	0.86	8.10 – 14.91	8.10
13.	*Polyalthia longifolia*	6	4.84	9.00 – 10.00	9.67	0.29 – 0.35	0.32	1.35 – 1.80	1.55
14.	*Psidium guajava*	3	2.42	5.00 – 6.00	5.33	0.44 – 0.61	0.51	6.23 – 7.30	6.78
15.	*Terminalia catappa*	5	4.03	10.00 – 18.00	14.33	0.77 – 1.21	1.00	12.42 – 22.00	16.04
16.	*Terminalia mantaly*	31	25.00	13.00 – 15.00	14.00	0.73 – 1.03	0.87	17.00 – 20.00	18.00

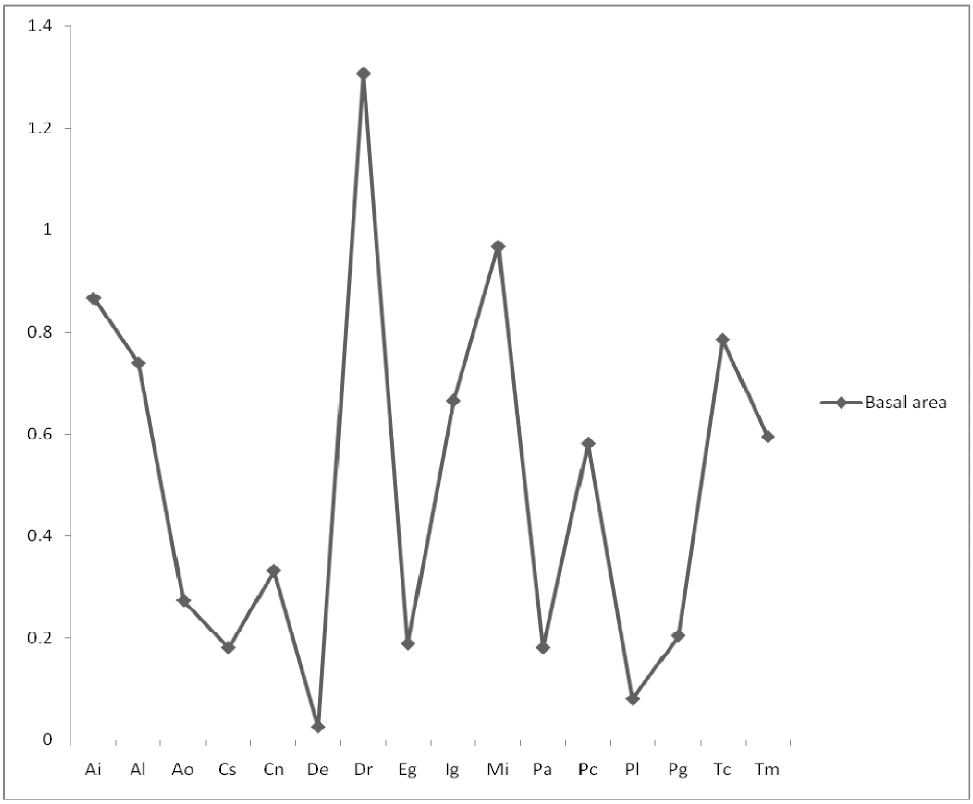

Figure 4: Mean basal area (m^2) of avenue tree species in Delta Campus

Ai = Azadiractha indica; Al = Albizia lebbeck; Ao = Anarcadium occidentale; Cs = Citrus sinensis; Cn = Cocos nucifera; De = Dacryodes edulis; Dr = Delonix regia; Eg = Elaeis guineensis; Ig = Irvingia gabaonensis; Mi = Mangifera indica; Pa = Persea americana; Pc = Pinus caribaea; Pl = Polyalthia longifolia; Pg = Psidium guajava; Tc = Terminalia catappa; Tm = Terminalia mantaly.

Distribution of Avenue Tree Species Populations among Campuses

The percentage distribution of avenue tree species populations in the three campuses is shown in Table 4. Great disparity was observed, with some campuses accounting for 90 to 100 % of the populations of some species, while the percentage population of some species was zero for some campuses. For instance, *Azadirachta indica* which is a popular tree species for shelterbelt in Nigeria due to its ability to resist wind was not observed in Choba Campus with 92.50 % of the observed population found in Abuja Campus. Similarly, *Delonix regia* with about the largest basal area was not encountered in Abuja Campus which is the permanent site of the university. Effective use of trees in addressing present global climate change should ensure equitable, proper and balanced distribution of tree species with capabilities for climate change mitigation and adaptation, in urban areas and institutions.

Table 4: Distribution and Percentage populations of avenue tree species in the campuses

Tree species	Total population enumerated in all Campuses	% in Abuja Campus	% in Choba Campus	% in Delta Campus
Azidarachta indica	40	92.50	0.00	7.50
Albizia lebbeck	03	0.00	0.00	100.00
Anacardium occidentale	03	0.00	0.00	100.00
Caesalpinia pulcherrima	09	0.00	100.00	0.00
Casuarina equisetifolia	08	0.00	100.00	0.00
Citrus sinensis	13	0.00	23.08	76.92
Cocos nucifera	32	50.00	9.38	40.62
Dacroydes edulis	06	0.00	50.00	50.00
Delonix regia	09	0.00	66.67	33.33
Elaeis guineensis	64	93.75	0.00	6.25
Eucalyptus cameldulensis	06	0.00	100.00	0.00
Gmelina arborea	07	57.14	42.86	0.00
Irvingia gabonensis	03	0.00	0.00	100.00
Mangifera indica	14	28.57	21.43	50.00
Persea americana	03	0.00	0.00	100.00
Pinus caribaea	23	13.04	0.00	86.96
Polyalthia longifolia	19	0.00	68.42	31.58
Psidium guajava	07	0.00	57.14	42.86
Seaforthia elegans	16	100.00	0.00	0.00
Tectona grandis	03	100.00	0.00	0.00
Terminalia catappa	17	0.00	70.59	29.41
Terminalia mantaly	31	0.00	0.00	100.00

Extent of variation in Growth Attributes of Avenue Tree Species in different Campuses

Mean separation for total height, diameter at breast height, and crown diameter for the three campuses, is shown in Table 5. No significant difference ($p > 0.05$) was observed in mean values of these growth attributes for *A. indica*, *D. edulis*, *E. guineensis*, and *T. catappa*, in the campuses where they occurred. However, significant differences occurred between campuses in some of the measured attributes in other species. Lack of significant differences and significant differences in mean values of growth characteristics of some species among the campuses could be attributed to similarity and dissimilarity in growth conditions as well as planting periods (age), level of competition, disturbance, and genetic variations.

Table 5: Mean separation for measured growth attributes of avenue tree species common to campuses

Species	Total height			Diameter at breast height			Crown diameter		
	AC	CC	DC	AC	CC	DC	AC	CC	DC
Azidarachta indica	11.83a	-	12.00a	0.90b	-	1.05b	13.11c	-	17.60c
Citrus sinensis	-	5.17a	6.17b	-	0.18b	0.48c	-	3.62c	6.57d
Cocos nucifera	6.40a	9.07ab	13.17c	0.35a	0.39ab	0.66c	5.80c	6.97c	8.01c
Dacroydes edulis	-	8.60a	5.17a	-	0.42b	0.18b	-	6.67c	2.77d
Delonix regia	-	9.93a	10.67a	-	1.00b	1.30b	-	17.87c	19.47c
Elaeis guineensis	100.50a	-	11.33a	0.67b	-	0.49b	7.63a	-	9.68a
Gmelina arborea	16.58a	11.93b	-	0.73b	0.67b	-	9.55c	10.80c	-
Mangifera indica	12.25a	12.03a	10.67a	1.00bcd	0.65bc	1.11d	16.31c	8.60d	15.58c
Pinus caribaea	11.75a	-	20.00b	0.80b	-	0.86b	13.88c	-	11.31c
Polyalthia longifolia	-	13.87a	9.67b	-	0.34b	0.32b	-	3.03c	1.55d
Psidium guajava	-	7.10a	5.33a	-	0.23b	0.51c	-	5.90c	6.78c
Terminalia catappa	-	20.53a	14.33a	-	0.93b	1.00b	-	18.70c	18.04c

Means with the same alphabet on the same row for each growth attribute are not significantly different (p> 0.05). Student's t-test was used to test for significant difference in means where a particular species occurred in two campuses alone while Analysis of Variance was used where a species occurred in the three campuses. None of these analyses was performed when a species occurred only in one campus.
AC = Abuja Campus; CC = Choba Campus; DC = Delta Campus

Avenue Tree species Diversity at the Campuses

The diversity indices of avenue tree species are shown in Table 6 for the three campuses. Avenue tree species richness was highest in Delta Campus, followed by Choba Campus, and Abuja Campus, respectively. Avenue tree species diversity was slightly higher in Delta Campus than Choba Campus when Shannon index was used, but slightly higher in Choba Campus than Delta Campus when Simpson index was used. The Shannon-Wiener index is based on the relative frequencies of species in the population [1], and takes into account both species richness and evenness while Simpson's index is weighted towards the abundance of the most common species in a sample rather than providing a measure of species richness. It has been observed by [5] that Shannon-Wiener index is most strongly related to species richness while Simpson index is less sensitive to species richness. This probably explains why Delta Campus (with higher species richness) had a slightly higher diversity index than Choba Campus when Shannon-Wiener index was used.

Abuja Campus was the least diverse of the three campuses. The low avenue tree species diversity especially in Abuja Campus (the university's permanent site) should be addressed by planting more tree species with the potential and capacity for climate change mitigation and adaptation. Tree diversity has been found to have positive correlation with above-ground biomass. Following their discovery that diversity enhances carbon storage in tropical forests, [12] recommended that biodiversity conservation should be a key component of the UN Reducing Emissions from Deforestation and Degradation (REDD+) strategy.

Table 6: Avenue tree species diversity indices for the three campuses

Index	Abuja Campus	Choba Campus	Delta Campus
No. of species	8	12	16
Number of individuals	143	73	120
Shannon-Wiener H	1.5670	2.3300	2.3950
Simpson 1 – D	0.7295	0.8891	0.8731

Similarity in Avenue Tree Species Composition between Campuses

The level of similarity in avenue tree species composition between campuses is shown in Table 7. The highest similarity was observed between Choba Campus and Delta Campus, while the least similarity was observed between Choba Campus and Abuja Campus. This simply implies that more avenue tree species were common to Choba and Delta Campuses, than with Abuja Campus. A similar trend in tree species similarity among the campuses has been reported by [3]. There is need to introduce some of the avenue tree species that are not present in Abuja Campus, especially those that have the potential and capacity for climate change mitigation and adaptation.

Table 7: Sorensen's similarity indices for the three campuses based on their avenue tree species composition

	Choba Campus	Delta Campus	Abuja Campus
Choba Campus	*	42.11	17.65
Delta Campus		*	26.32
Abuja Campus			*

CONCLUSION

Avenue tree species diversity in the university was found to be low especially in the permanent site (Abuja Campus). The relative abundance of avenue tree species with better growth attributes and high capacity and potential for climate change mitigation and adaptation was very low in all the campuses. These results indicate that the university is not making the best use of trees in confronting the global threat posed by climate change. The need for tree planting in urban institutions to consider climate change mitigation and adaptation capabilities of tree species is emphasized.

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