TREE SPECIES DIVERSITY AND CARBON SEQUESTRATION POTENTIALS OF THE TREES IN THE THREE ONDO STATE OWNED UNIVERSITY CAMPUSES, SOUTHWEST, NIGERIA

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Abstract
This study assessed carbon sequestration potentials and compared the tree species diversity of the three Ondo State owned University campuses. All trees within developed areas of the university campuses with ≥10 cm diameter breast height (Dbh) were identified by forest taxonomist and their Dbh as well as diameter at the base (Db) were measured using girth tape. The diameter at the middle (Dm), diameter at the top (Dt) and the total height were measured with Relaskop for volume estimation. Density of each tree species was obtained from literatures to estimate the tree biomass and carbon. A total number of 220 individual trees were encountered in Adekunle Ajasin University, Akungba Akoko (AAUA) with 22 tree species and 14 families. A total carbon stock of 208,480.40 kg was estimated. In Olusegun Agagu University of Science and Technology, Okikitupa (OAUSTECH), a total number of 40 individual trees were encountered with 8 tree species and 6 families with a total carbon stock of 2,391.70 kg. In addition, 10 individual trees were enumerated in University of Medical Sciences (UNIMED) campus with 3 tree species and 3 families with a total carbon of 1,226.70 kg. The AAUA campus gave the highest in Shannon-Weiner and Margalef indices while UNIMED had the highest value in Evenness diversity index. The result of tree species diversity indices varied amongst the three university campuses but not significantly different at P<0.05. The universities campuses are encouraged to adopt conservation policy to increase tree species diversity which will in turn intensify ecosystem services within the universities.

Keywords: *Benefits, Margalef, erratic, drought, Shannon, species diversity*

Introduction

The environmental benefits of trees in campus ecosystems are numerous and well acknowledged in forestry benefit account. Campus trees improve air quality, cool local air temperatures, filter and retain storm water, phytoremediation and sequester carbon, among others (Nowak *et al*., 2008). It improved social, cultural and physical health as well as enhance mental health, reduces mortality and provide oxygen amongst its benefits (Nowak *et al*., 2008). It does also contribute to healthier and more beautiful cities (Nowak *et al*., 2008). In addition, trees provide numerous benefits to humans as well as provide essential habitat and food sources to wildlife in and around the fragmented landscape of urban forest ecosystems (Nowak *et al*., 2008). Even single urban tree provide significant resting point for local and migrating birds (Rega *et al*., 2015). Trees on streets and in the university campuses are now recognized as more than just enjoyable features with associated maintenance costs; this ecosystem serve as the pillar of urban forestry. According to Berto, (2005) exposure to nature and restorative environments increases sustained attentive capacity for learners, e.g. students. Easy access to green outdoor environments from workplaces has been found to significantly reduce work stress (Lottrup *et al*., 2013). More importantly, academic institutions and hospitals have noted that nature and trees results in quantifiably positive impacts on students and patients wellbeing (Alvarsson *et al*., 2014). Also, the benefits of urban trees are not only well recognized by the academic community but by municipalities and other institutions around the world such as health facilities (Bassett, 2015).

Trees as well as green plants are imperative for life sustenance and healthy state of the planet earth but these entities are disappearing at a terrifying rate. The forest resources are fast becoming degraded in most natural forests as a result of deforestation due to anthropogenic activities such as urbanization; overexploitation as well as poor regeneration mechanism which do not guarantee sustainability. It has been noted that development as well as change in climate aggravates the disappearing of many indigenous and exotic tree species (Olajuyigbe *et al*., 2013). The climatic variability of the present earth limits the ability of trees to adapt to the changing climate (Olajuyigbe *et al*., 2013). Many tree species are threatened by climate change effects and some trees are more vulnerable than others. Though, there is a broad gap in the knowledge of the genetic diversity of tree species owing to lack of up-to-date documentation of plant genetic resources (Olajuyigbe *et al*., 2013). Similarly, tree species diversity is decreasing due to the rate of habitat destruction and over-exploitation which are far greater than the rate of genetic diversity collection and conservation (Olajuyigbe *et al*., 2013). The presence of many indigenous and exotic tree species on university campuses as well as urban forests enhance conservation of these trees species that are scarce in most natural forests ecosystems (Olajuyigbe *et al*., 2013). Therefore, urban forests as well as university campuses are important as live gene bank (Olajuyigbe *et al*., 2013). Consequently, there is need

to document information on the tree taxonomy, diversity and growth features of the trees on university campuses. This information is very important for the conservation and sustainable management of these tree species (Olajuyigbe *et al*., 2013). Simply planting or retaining trees on the university campus without considering their species, health, and status will limit their benefits. As such, this study aimed at identified and enumerated the tree species in the campuses of the three Ondo State owned universities. But the primary aim of this study was to assess carbon sequestration potentials and compared the tree species diversity of Ondo State owned University campuses, Southwest Nigeria.

Study area

This study was conducted in the three Ondo State owned university campuses namely: Adekunle Ajasin University, located in Akungba Akoko, North Senatorial District, established in year 2000, Olusegun Agagu Univeristy of Science and Technology located in Okitipupa, South Senatorial District, established in 2008 and the University of Medical Sciences located Ondo town, Central Senatorial District, established in 2015. Ondo State is one of the seven states created on February 3, 1976. It was carved out of the former Western Region of Nigeria. The state is made of eighteen Local Government Areas and three senatorial districts (Fig 1). Ondo State land area was estimated to be 15,500 km^2 (Omonijo and Matzarakis, 2011). The State is situated on latitude 5°45′ N to 8°15′ N and longitude 4°45′ E to 6°00 ′ E in the Southwestern humid area of Nigeria. It has the tropical wet-and-dry climate with mean annual rainfall of about 1,500 mm and 2,000 mm in the derived savannah and humid forest zones respectively (Omonijo and Matzarakis, 2011). The State is bounded in the North-West by Ekiti State, West-Central by Osun State, South-West by Ogun State, South-East by Delta State and in the South by Atlantic Ocean (Omonijo and Matzarakis, 2011).

The State has texture of topsoil with mainly sandy-loam in the south and the vegetation belongs to tropical rainforest with species such as *Melicia excelsa, Terminalia superba* and *Triplochiton scleroxylon* (Onyekwelu *et al*., 2008). In the north, the shallow valleys and cracks of rocks accommodate small trees and shrubs while the gentler slopes form substrates for various families of grass. Some areas of the north have big and tall trees e.g. *Alstonia congensis*, *Baphia nitida* and *Diospyros monbuttensis* etc. These tree species take the opportunity of using the deep soil directly from weathering of the base rocks (Olugbenga *et al*., 2011).

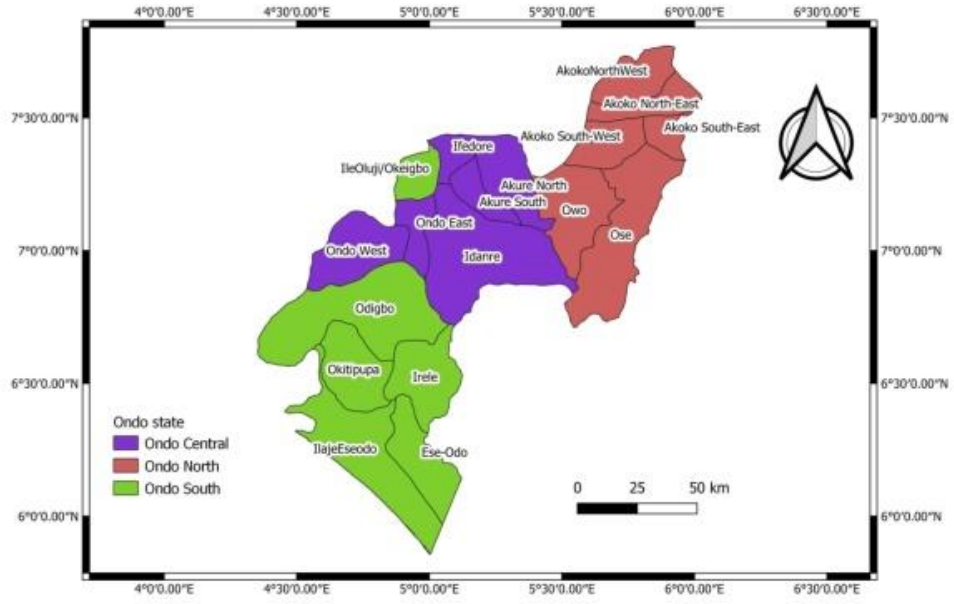

Fig. 1: Map of Ondo State showing the Senatorial districts with Local Government Areas

Data collection

The developed areas of the three university campuses were used for this study. All trees found around the developed facilities (buildings, lawns, parks and playing grounds) with diameters at breast height (Dbh) ≥10 cm were identified by forest taxonomist and their Dbh as well as diameter at the base (Db) were measured using girth tape. The diameter at the middle (Dm), diameter at the top (Dt) and the total height of trees were measured using Spiegel Relaskop for volume estimation. Density of each tree species was obtained from literature to estimate the tree biomass and carbon. Data collected were entered into Microsoft excel sheet, screened and stored.

Data Analysis

Stem of living trees grows both horizontally and vertically. Biomass accumulation also occurs in trees in both directions. The horizontal growth was measured by the diameters and the vertical growth was measured by the tree height. Newton's formula was used to estimate the tree volumes for this study (Equation 1).

$$Volume = \frac{\pi h}{24}(D_b^2 + 4D_m^2 + D_t^2) \quad \text{Equation 1}$$

Where:

Volume is Volume of the stem, π is 3.142, h is Tree total Height, D_b is Diameter at the base, D_m is Diameter at the middle, D_t is Diameter at the top.

Estimation of biomass

Biomass is the volume multiplied by a wood dry mass (density) (Oke *et al*., 2020). Biomass of each tree was estimated using the volume and density as obtained from respective tree and Equation 2 was employed.

$$Biomass = Density \times Volume \quad \text{Equation 2}$$

Estimation of Carbon

Tree biomass obtained in Equation 2 was used to estimate carbon stock for each tree. The standard factor of 50 % was used for conversion of biomass to carbon (Equation 3) (Losi *et al*., 2003).

$$Carbon = 0.5 \times Biomas \quad \text{Equation 3}$$

Species Diversity

The data collected were imported into PAST (4.03) software for diversity analysis. The output of species diversity; Shannon-Weiner, Evenness and Margalef indices were compared using analysis of variance in R-Studio/Script software. The species diversity estimates include species richness and evenness as well as Shannon-Wiener Diversity Index (Brashears *et al*., 2017). The species richness refers to the total number of species recorded in the inventory forest. The Shannon Diversity Index was estimated with Equation 4.

$$H = -\Sigma p_i ln(p_i) \quad \text{Equation 4}$$

The Shannon Diversity Index (H), p_i is the number of individual of species in a given area (plot) divided by the total number of individuals in the area, ln is the natural logarithm, and Σ is the sum of the calculation. The evenness in species abundance was assessed using Equation 5 according to Buzas and Gibson's Evenness Index (Yang *et al*., 2008).

$$E = \frac{ln(H)}{S} \quad \text{Equation 5}$$

The Buzas and Gibson's Evenness Index (E), H is the Shannon Diversity Index and S is the total number of species.

Margalef Index

Margalef Index (M): Margalef index which is a measure of the number of different species represented in the forest area (species richness) was computed as adopted in (Margalef, 1982) and Equation 6 was used.

$$M = \frac{S-1}{lnN} \quad \text{Equation 6}$$

Where; Margalef Index (M), S = total number of species; N = total number of individual in the site

Results and Discussion

In AAUA a total of 220 individual trees were encountered comprising of 22 different species (Table 1). *Terminalia mantaly* had highest number of individual with 37 stems representing 17 % of the trees enumerated followed by *Acacia auriculiformis*, *Eucalyptus camaldulensis* and *Tectona grandis* with 31, 30, and 30 stems each respectively representing 14 % each of the population (Table 1). The result of this study is consistent with findings of Ajayi, (2021) that the AAUA campus is dominated by *Terminalia mantaly* and *Acacia auriculiformis* tree species. Also, in OAUTECH a total of 40 individual trees with 8 tree species were encountered. *Gmelina arborea* (Verbenaceae) is the most abundant in OAUSTECH with 9 individual trees, followed by *Delonix regia* with 7 trees and *polyanthia longifolia* with 7 trees (Table 2). Again, in UNIMED, the total of 10 individual trees was enumerated composed of 3 tree species. The *Swietenia macrophylla* species had the highest occurrence with 5 individual trees, followed by *Tectona grandis* with 3 trees and *Azadirachta indica* with 2 individual trees (Table 3). Tree assessment and documentation of tree species taxonomy, diversity and growth features of the trees on university campuses provide information for the conservation and sustainable management of these tree species (Nowak *et al*., 2008).

Table 1: Mean height, Biomass and Carbon Sequestered by Tree species in AAUA

S/N	Scientific Name	Family	Freq	M-Height (m)	Biomass (Kg/m^3)	Carbon (Kg/m^3)
1	*Acacia auriculiformis*	Fabaceae	31	41.1	39,557.50	19,778.70
2	*Albizia lebbeck*	Fabaceae	4	34.5	5,852.90	2,926.40
3	*Azadirachta indica*	Meliaceae	17	33.9	27,441.00	13,720.50
4	*Bauhinia forficate*	Fabaceae	2	38.6	3,399.80	1,699.90
5	*Blighia sapida*	Sapindaceae	1	37.5	917.30	458.60
6	*Cassia siamea*	Caesalpinoideae	2	31.5	2,756.20	1,378.10
7	*Delonix regia*	Fabaceae	6	35.0	1,734.30	8,671.10
8	*Eucalyptus camaldulensis*	Myrtaceae	31	43.7	52,009.80	26,004.90
9	*Ficus exasperate*	Moraceae	1	23.5	2,044.50	1,022.20
10	*Ficus benjamina*	Moraceae	6	37.0	7,190.40	3,595.20
11	*Gmelina arborea*	Verbenaceae	15	51.7	117,823.80	58,911.90
12	*Hildergardia barteri*	Malvaceae	13	24.6	13,382.40	6,691.20
13	*Hura crepitans*	Euphorbiaceae	1	39.0	6,513.10	3,256.50
14	*Khaya senegalensis*	Meliaceae	2	38.6	2,294.90	1,147.40
15	*Leucaena leucocephala*	Fabaceae	7	37.8	5,971.60	2,985.80
16	*Pinus caribaea*	Pinaceae	1	53.3	640.40	320.20
17	*Polyalthia longifolia*	Annonaceae	6	49.8	3,524.30	1,762.10
18	*Pterocarpus osun*	Papilionoideae	1	45.0	2,556.50	1,278.20
19	*Spondias mombin*	Anarcardiaceae	1	22.5	424.70	212.30
20	*Tectona grandis*	Verbenaceae	30	51.1	49,453.70	24,726.80
21	*Terminalia catappa*	Combretaceae	5	43.6	11,451.10	5,725.50
22	*Terminalia mentally*	Combretaceae	37	32.1	44,113.80	22,206.90
	Total		**220**		**401,054.00**	**208,480.40**

Table 2: Mean height, Biomass and Carbon Sequestered by Tree species in OAUSTECH

S/N	Scientific Name	Family	Freq	M-Height (m)	Biomass (Kg/m^3)	Carbon (Kg/m^3)
1	*Bauhinia purpurea*	Fabaceae	3	6.2	153.80	76.90
2	*Delonix regia*	Fabaceae	7	7.9	1,631.00	815.50
3	*Gmelina arborea*	Verbenaceae	9	9.8	606.00	303.00
4	*Hura crepitans*	Euphorbiaceae	4	11.5	789.00	394.50
5	*Moringa oleifera*	Moringaceae	1	8.5	104.80	52.40
6	*Polyalthia longifolia*	Annonaceae	7	10.4	776.30	388.10
7	*Terminalia catappa*	Combretaceae	6	9.4	195.30	97.60
8	*Terminalia mantaly*	Combretaceae	3	15.8	527.40	263.70
	Total		**40**		**4,783.60**	**2,391.70**

Table 3: Mean height, Biomass and Carbon Sequestered by Tree species in UNIMED

S/N	Scientific Name	Family	Freq	M-Height (m)	Biomass (Kg/m^3)	Carbon (Kg/m^3)
1	*Swietenia macrophylla*	Meliaceae	5	13.4	896.10	448.00
2	*Tectona grandis*	Verbenaceae	3	10.3	155.30	77.60
3	*Azadirachta indica*	Meliaceae	2	19.5	1,402.00	701.10
	Total		**10**		**2,453.40**	**1,226.70**

Species Diversity

The Shannon-Weiner index of 2.46 was recorded for AAUA followed by OAUSTECH with 1.85 and 0.93 was recorded for UNIMED (Table 4). Evenness index highest value for this study was recorded for UNIMED campus with 0.84 followed by OAUSTECH with 0.80 while AAUA campus had 0.53 evenness value amongst these university campuses. The results of Margalef's index of species diversity recorded the highest in AAUA with 3.89 followed OAUSTECH with 1.90 and the lowest was recorded from UNIMED with 0.87 for the index (Table 4). The Shannon-Weiner index obtained in this study was lower than the findings of Ogundele *et al*., (2021), and Akindele, (2013) who reported 3.37 and 3.74 Shannon-Weiner values in their articles respectively. Pielou's evenness index obtained from UNIMED and OAUSTECH as 0.8445 and 0.7980 were higher than 0.68 reported by Ogundele *et al*., (2021). But AAUA Pielou's evenness of 0.53 was lower than the value reported by Akindele, (2013). Again, Margalef's index obtained in this study for the three university campuses were lower than the values reported in Ogundele *et al*., (2021). The report of Akindele, (2013) on "tree species diversity and structure of a Nigerian strict nature reserve had 64.72 Margalef's index of species diversity which is far higher than the values obtained for this study. The Shannon-Weiner and Margalef's diversity indices with high values revealed forest ecosystem with diverse tree species and abundance. The Shannon-Weiner and Evenness indices obtained for this study are higher than the values reported by Rajkumar and Parthasarathy, (2008) who reported 0.18 evenness species diversity index in the article published on "tree diversity and structure of Andaman Giant Evergreen Forests, India". The evenness index ranges from 0 to 1, with result of 1 indicating that all species have the same abundance (Kanieski *et al*., 2010). In addition, Shannon index as reported by Durán *et al*., (2006) ranges between 2.69 and 3.33 and this is also higher than the result of this study. This indicated that there is less diversity of species in these campuses but offered varied ecosystem services. The result of comparison of the species diversity indices was not significantly different from one another at $P < 0.05$ (Table 5). But AAUA offered higher tree species diversity as evident from the result. It is encouraged that diverse tree species be planted or retained in and around university campuses for maximum benefit.

Table 4: Tree species diversity of AAUA, UNIMED and OAUSTECH

Diversity indices	AAUA	UNIMED	OAUSTECH
Shannon-Weiner	2.4630	0.9297	1.8540
Evenness	0.5335	0.8445	0.7980
Margalef	3.8930	0.8686	1.8980

Table 5: ANOVA result for comparison of species diversity indices values

Source of Variation	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Diversity Indices	2.0	3.016	1.508	1.400	0.317 *ns*
Residuals	6.0	6.464	1.077		

ns means not significantly different (P < .05)

Conclusions and Recommendations

The presence of many indigenous and exotic tree species on university campuses enhances carbon sequestration and encourages conservation of these trees species that are scarce in most natural forests ecosystems. Therefore, the university campuses are regarded as live gene bank of tree species. The AAUA campus holds more tree species than the other two campuses considered for this study. Also, the diversity indices are higher in AAUA compare to UNIMED and OAUSTECH except the evenness index where

UNIMED provide the lead but the results of the diversity indices were not significantly different. The tree species benefits will be higher in AAUA campus due to more individual and tree species present. Consequently, it is recommended that diverse tree species should be planted or retained in and around university campuses for maximum benefit.

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