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Diversity, Importance Value Indices and Carbon Credit Assessment of Parks in Joseph Sarwuan Tarka University, Makurdi, Nigeria

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Abstract

The research was undertaken to investigate diversity, important value indices (IVI) and carbon storage of trees located in various parks of Joseph Sarwuan Tarka University Makurdi, Nigeria between 2019 and 2020. Species diversity was determined using Shanon index while tree biomass was determined using the allometric model (AGB = exp (−2.977 + Ln (ρD2H)) = 0.0509 × ρD2H). Total sequestered carbon in trees was determined as 50% of tree biomass. Results revealed a total of 298 trees, belonging to 30 species and 16 families in the study area, with *Daniellia oliveri* having the highest number of plants (76) and percentage occurrence (26%). Plant height and DBH varied among the species with *Daniellia oliveri* recording the highest values (19.77 m and 240.80 cm) respectively. The species Height and, Diameter at Breast Height (DBH) was grouped with class >11 m to 15 m (13) and class >51 cm to 100 cm (12) dominating the parks. The species diversity (Shannon Index) in the individual parks varied, with Food Science and Technology, and Nubess parks having the highest (2.138) and lowest (0.652) diversity indices, respectively. Frequency, basal area, relative frequency (RF), relative density (RDe), cover value index (CVI) and IVI varied with species. *Daniella oliveri* had the highest frequency (76), *Delonix regia* had the highest basal area (4.55), RF (143.33), RDe (14.43) and RDo (9.90). Family value index (FVI), was highest in the family Fabaceae (684.39). Above ground biomass (AGB) ranged from (24021.48) in Delonix regia to 238.47 in *Psidium guajava*, while below-ground biomass (BGB) ranged from 4804.30 in *D. regia* to 47.69 in *P. guajava*. Total Plant biomass (AGB + BGB) varied between Delonix regia (28825.78) and *P. guajava* (286.17), respectively. Carbon storage varied with species and parks, with Veterinary Park having the highest total sequestered carbon (105.65 tonnes) and sequestered carbon dioxide equivalent (387.74 tonnes). *D. regia* had the highest total sequestered carbon (14412.89 tonnes/tree) followed by *Daniella oliveri* (1148.24 tonnes/tree), with *B. ferruginea* (201.16) and *P. guajava* (143.08) having the least total sequestered carbon. *D. regia* had the highest sequestered CO_2 equivalent (SCO_2E) (52.90) followed by *D. oliveri* (42.09) and *P. africana* (34.60), while *P. guajava*, *B. ferruginea* and *Terminalia mentalis* had the least SCO_2E (0.53, 0.74 and 1.2), respectively. Moreover, Plant height correlated moderately with AGB (R = 0.597; p = 0.000) and DBH (R = 0.529; p = 0.003), with a positive relationship between AGB and DBH (R = 0.859; p = 0.000), suggesting that AGB increases with increasing DBH and plant height. Extensive assessment of urban parks and garden for carbon storage is hereby advocated.

Keywords: Species diversity; Importance value indices; Carbon sequestration; Total biomass

Introduction

Species composition and structure are valuable parameters for vegetation monitoring [1] and provide a more reliable index on rate of mortality, under-storey development and spread of disturbances within an ecosystem [2-4]. Species richness and diversity are fundamental to total forest biodiversity, because trees provide resources and habitat for almost all wildlife species [5,6] and potential carbon sinks. Changes in density and composition of flora and fauna in natural ecosystems due to intensive anthropogenic pressures have become a global problem in the 21st century, with tropical forests disappearing at alarming rates annually, by about 4% of their current area, worldwide [7,8]. Land use changes especially conversions to agriculture and poor land management practices have been the major contributors to increase in Greenhouse Gases (GHG) [9].

Baseline information on tree species diversity, composition and distribution patterns within the Joseph Sarwuan Tarka University, Makurdi campus have been provided by various researchers [3,10,11], and have elucidated the richness of the vegetation in the study area.

It has been suggested that global warming may be limited within 1.5°C [12] by keeping GHG emissions under check through internationally binding instruments [13] including carbon quota, clean development mechanism (CDM). As a signatory to the Kyoto protocol, Nigeria needs accurate estimations of existing carbon stocks throughout the country to implement carbon trading and climate change mitigation policies [14]. Achievement of full carbon mitigation potential requires estimation of country-level carbon stocks through statistically validated methods [15]. The determination of carbon stocks through biomass estimation has been widely used in assessing the carbon credit of trees in different ecosystems [16,17].

The quantification of forest biomass has a long history and has received renewed attention in the last decades because forest biomass represents about 44% of the global forest carbon pool [18] and therefore plays a crucial role in climate change mitigation. This highlights the need to precisely determine the amount of carbon stored and CO_2 sequestrated in the trees of different ecosystems [19]. Previous studies have also suggested that quantifying carbon storage in urban areas are necessary to support urban landscape planning and management that is focused on ecosystem services and human wellbeing [20].

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Justification of the Study

Carbon storage by green infrastructures is an important ecosystem service in forests, urban parks [21,22]. This is particularly important now that anthropogenic activities have greatly increased carbon dioxide concentration in the atmosphere. In Nigeria, for instance there is limited accurate data on flora composition. Thus, species currently perceived as abundant might actually be endangered while those previously perceived as endangered might be nearing extinction. However, urban green spaces (parks and gardens) have often been disregarded hence, their specific contributions to the global carbon credit system are not well quantified [23-25]. The reliable quantification of carbon sequestration by vegetation will help policymakers, researchers, and entrepreneurs in Nigeria to sell certified emission reduction to developed countries [26,27] in global carbon markets under reduction of emissions through degradation and deforestation (REDD+) and CDM.

Aim and objectives of the study

This study therefore focuses on assessing the carbon credit potentials of the trees in the various parks, in Joseph Sarwuan Tarka University, Makurdi, Nigeria with a view to evaluating their role in climate change mitigation. Specific objectives included estimation of species relative density, dominance and important value indices, above ground and below ground biomass, sequestered carbon and CO_2 equivalence of the trees sampled in the various parks.

Materials and Methods

Study area

Joseph Sarwuan Tarka University Makurdi is located in North-central Nigeria (longitude 8°32’00” and latitude 7°44’00”) was the study area. The ecology is a tropical, with distinct wet and dry seasons. The wet season starts from April and lasts till October; while the dry season starts in November and lasts till March. Rainfall ranges from 775 millimeters to 1792 millimeters, with a mean annual value of 1190 millimeters. Mean Monthly Relative Humidity varies between 43% in January to 81% in July-August period. Makurdi falls within the Guinea Savanna belt of Southern Nigeria from the true savannah of the North. It is characterized by a mixture of tall grasses and tress of average height. Most of the trees are deciduous and shed their leaves during dry season [28].

Data collection

Data was collected from all parks and garden in both North and South cores of Joseph Sarwuan Tarka University Makurdi. The parks include: Veterinary (Vet) Park, Science Park, Science Extension Park, Student Union (SU) Park, Nubess Park, Engineering Park, Forestry Park, Animal Science Park, Food Science and Technology (FST) Park and Fisheries Park. At each park, all tree species were identified, coordinates taken and the total number of species available recorded.

Data analysis

The Shannon-Weiner Diversity Index, which specifies the comparative occurrence of many species, was used to associate species abundance and relative richness amongst species [29,30]. The cover value indices (CVI) of parks [31] was used to evaluate the importance of woody species within the parks. CVI was calculated by adding relative density (RDe) and relative dominance (RDo) of species [31]. The importance value index (IVI) was calculated by adding CVI and relative frequency (RF) [32].

CVI = RDe + RDo

IVI = CVI + RF

RF, RDe and RDo were obtained using the following equations:

$$\text{Relative frequency (RF)} = \frac{\text{number of individual of species A}}{\text{Total number of individual}} \times 100$$

$$\text{Relative density (RDe)} = \frac{\text{number of individual of species A}}{\text{Total number of individual}} \times 100$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Total basal area of species A}}{\text{Total basal area of all species}} \times 100$$

Where Basal Area (BA) = $0.0001 \times \pi \times \left(\frac{DBH}{2}\right)^2$

Family importance value index

The family importance value (FIV) = CVI + RDi.

Where, RDi (relative diversity) = $\frac{\text{Number of species in family species A}}{\text{Total number of species}} \times 100$

Biomass determination

Data was collected on Plant Height (m), Diameter at Breast Height, DBH (cm), while species above ground biomass (AGB) was estimated non-destructively using the equation [33]:

$AGB = \exp(-2.977 + \text{Ln}(\rho D^2H)) = 0.0509 \times \rho D^2H$.

Where AGB is Aboveground biomass, D is diameter at breast height, H is total height and ρ is wood density (wood specific gravity). $\rho = 0.56$, $D^2 = (DBH)^2$ and H = Height

Dry Above Ground Biomass (DAGB) = 65% of AGB

Below Ground Biomass, (BGB) = 20% of AGB

Dry Below Ground Biomass (DBGB) = 65% of BGB

Total Biomass (TB) = DAGB + DBGB

Total sequestered carbon (TSC)

TSC/Tree = 50% of TB

Sequestered Carbon dioxide Equivalent, SCO_2E (kg) = TSC X 3.67

SCO_2E (Tonnes/Tree) = SCO_2E (kg) x 0.001

Results

Species distribution

A total of 298 trees, belonging to 30 species and 16 families Table 1 were recorded in the study area. *D. oliveri* had the highest number of plants (76), representing 26% (Figure 1) of total plant species. Plant height and DBH varied among the species with *D. oliveri* recording the highest values (19.77 m, 240.80 cm), respectively Table 1. Table 2 shows the species Height (m) and DBH (cm) classes and their frequency of occurrence. The Height class >11 m to 15 m (13) and DBH class >51 cm to 100 cm (12) were predominant in the study area.

Species diversity indices and family value indices

Figure 2A shows the species diversity indices (Shannon Index) of the individual parks on campus, with FST and Nubess parks having the highest (2.138) and lowest (0.652) diversity indices, respectively. Figure 2B shows the FVI, with family Fabaceae having the highest FVI (684.39).

Table 1: Species Richness, Frequency of Occurrence, Height and DBH.

S/N	Species	Family	Total Number of Trees	Height (m)	DBH (cm)
1	*Acacia nilotica*	Fabaceae	1	10	187
2	*Albizia zygia*	Fabaceae	33	14.74	107.17
3	*Anogeissus leiocarpus*	Combretaceae	1	13.5	160
4	*Azadirachta indica*	Meliaceae	18	12.89	82.6
5	*Bridelia ferruginea*	Phyllanthaceae	1	6.2	54
6	*Daniellia oliveri*	Fabaceae	76	19.77	204
7	*Delonix regia*	Fabaceae	43	12.25	240.8
8	*Detarium microcarpum*	Fabaceae	1	11	202
9	*Eucalyptus camaldulensis*	Myrtaceae	3	11.5	215.5
10	*Eucalyptus spp*	Myrtaceae	2	14	118
11	*Ficus sycomorus*	Moraceae	1	10	194
12	*Ficus thonningii*	Moraceae	1	7	75
13	*Gmelina arborea*	Verbenaceae	11	15.53	158.5
14	*Hura crepitans*	Euphorbiaceae	7	10	145
15	*Khaya senegalensis*	Meliaceae	46	17.39	116.5
16	*Leucaena seamis*	Fabaceae	1	16	135
17	*Mangifera indica*	Anacardiaceae	1	7	90
18	*Parkia biglobosa*	Fabaceae	2	16.5	131
19	*Polyalthia longifolia*	Annonaceae	5	10.07	62.33
20	*Prosopis Africana*	Fabaceae	6	18.5	208.33
21	*Psidium guajava*	Myrtaceae	2	7.65	41
22	*Pterocarpus erinnaceus*	Fabaceae	1	11	89
23	*Sarcocephalus latifolius*	Rubiacea	1	12	80
24	*Semia seamis*	Cicadidae	3	17.7	213
25	*Stereospermum kuathianum*	Bignoniaceae	1	8	70
26	*Terminalia avicennioides*	Combretaceae	1	9.2	75
27	*Terminalia mentalis*	Combretaceae	6	8.13	61.25
28	*Unknown spp*	Unknown	14	13	99
29	*Vitellaria paradoxa*	Sapotaceae	4	13.88	120.5
30	*Vitex doniana*	Lamiaceae	5	12.92	98

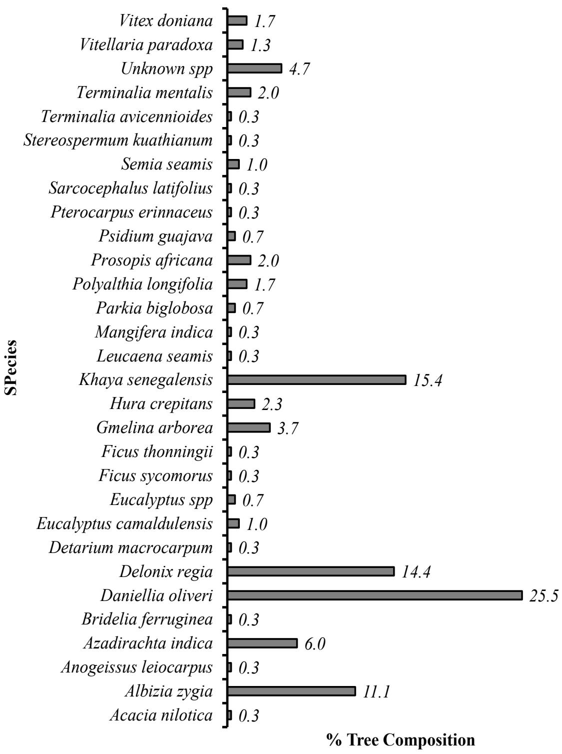

Figure 1: Percentage Occurrence of Trees Species.

Species frequency, RF, RDe, RDo, CVI and IVI

Table 3 shows species frequency, Basal Area, RF, RDe, CVI, IVI. *D. oliveri* had the highest frequency (76), *Delonix regia* had the highest Basal Area (4.55), RF (143.33), RDe (14.43) and RDo (9.90). Furthermore, *D. oliveri* had the highest IVI (285.94) while *Acacia nilotica, Anogeissus leiocarpus, Bridelia ferruginea, Detarium macrocapum, Ficus sycomorus, Ficus thonningii, Leucaena seamis, Mangifera, indica,* and *Pterocarpus erinnaceus* all had the lowest frequency (1), RF (3.33) and RDe (0.34), respectively. *Psidium guajava* had the lowest RDo, while *Bridellia ferruginea* had the lowest CVI and IVI (0.83, 4.17) respectively.

Plant Biomass and Total Sequestered Carbon

Above and below ground biomass estimation

The result shows that the maximum and minimum above ground biomass of the plant species ranged from (24021.48) in *Delonix regia* to (238.47) in *P. guajava*. Additionally, the maximum and minimum below-ground biomass of the plant ranged from (4804.30) in *Delonix regia* to (47.69) in *Psidium guajava* (Table 4).

Total plant biomass estimation

Delonix regia had the highest total biomass (28825.78) while *P. guajava* had the lowest (286.17) (Table 4).

Sequestered carbon and CO_2 equivalent estimation

Carbon storage varied with species and parks (Table 4). *D. regia* had the highest total sequestered carbon (14412.89) followed by *D. oliveri* (1148.24). The least total sequestered carbon was in *Psidium guajava* (143.08) followed by *B. ferrginea* (201.16). Furthermore, the sequestered carbon equivalent (SCO_2E) was highest in *D. regia* (52.90) followed by *D. oliveri* (42.09) and *P. africana* (34.60), while *Psidium guajava*, *B. ferruginea* and *Terminalia mentalis* had the least (0.53, 0.74 and 1.2), respectively (Table 4). Also, Veterinary Park had the highest total sequestered carbon (105.65 tonnes) and sequestered carbon dioxide equivalent (387.74 tonnes) (Figure 3A).

Correlation and regression analyses

Correlations between plant height and AGB, plant height and DBH, and DBH and AGB are shown in Figure 3. Plant height correlated moderately with AGB (Figure 3B; R = 0.597, R^2 = 0.356, p = 0.000) and DBH (Figure 3C; R = 0.529, R^2 = 0.280, p = 0.003), correspondingly. Furthermore, there was high positive correlation between DBH and AGB (Figure 3D; R = 0.859, R^2 = 0.738, p = 0.000). All correlations were statistically significant at 99% confidence interval ($p<0.01$).

Table 2: Height and DBH Class Distribution of Species.

Height Class (m)	Frequency	DBH Class (cm)	Frequency
0 to 5	0	0 to 50	1
6 to 10	10	51 to 100	12
11 to 15	13	101 to 150	7
16 to 20	7	151 to 200	4
		201 to 250	6

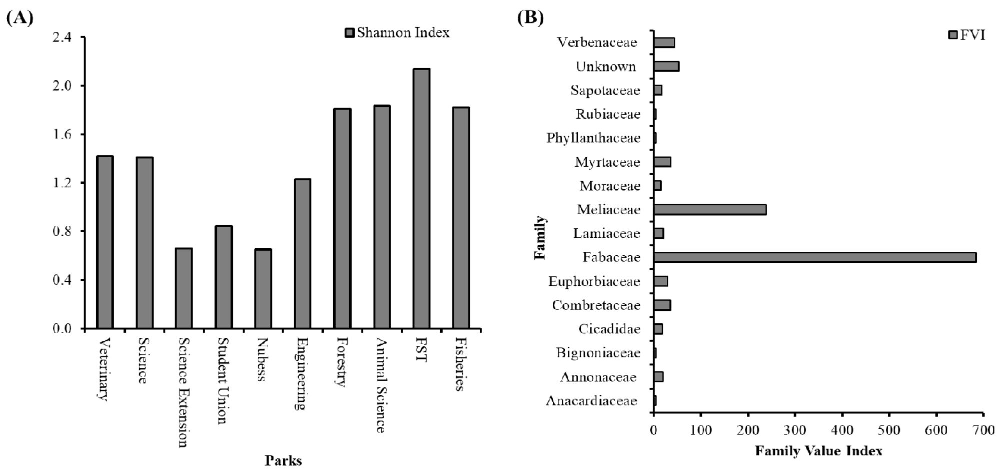

Figure 2: Species Diversity (Shannon) Index and Family Value Index of the study area. (A) Shannon Index of the various parks (B) Family Value Index of the sampled plant families.

Table 3: Species Frequency, RF, RDe, RDo, CVI and IVI.

S/N	Species	Frequency	Basal Area (m2/hectare)	RF	RDe	RDo	CVI	IVI
1	*Acacia nilotica*	1	2.75	3.33	0.34	5.97	6.3	9.64
2	*Albizia zygia*	33	0.9	110	11.07	1.96	13.03	123.03
3	*Anogeissus leiocarpus*	1	2.01	3.33	0.34	4.37	4.7	8.04
4	*Azadirachta indica*	18	0.54	60	6.04	1.16	7.2	67.2
5	*Bridelia ferrunginea*	1	0.23	3.33	0.34	0.5	0.83	4.17
6	*Daniellia oliveri*	76	3.27	253.33	25.5	7.1	32.61	285.94

7	*Delonix regia*	43	4.55	143.33	14.43	9.9	24.33	167.66
8	*Detarium microcarpum*	1	3.21	3.33	0.34	6.96	7.3	10.63
9	*Eucalyptus camaldulensis*	3	3.65	10	1.01	7.93	8.93	18.93
10	*Eucalyptus spp*	2	1.09	6.67	0.67	2.38	3.05	9.71
11	*Ficus sycomorus*	1	2.96	3.33	0.34	6.42	6.76	10.09
12	*Ficus thonningii*	1	0.44	3.33	0.34	0.96	1.3	4.63
13	*Gmelina arborea*	11	1.97	36.67	3.69	4.29	7.98	44.65
14	*Hura crepitans*	7	1.65	23.33	2.35	3.59	5.94	29.27
15	*Khaya senegalensis*	46	1.07	153.33	15.44	2.32	17.75	171.09
16	*Leucaena seamis*	1	1.43	3.33	0.34	3.11	3.45	6.78
17	*Mangifera indica*	1	0.64	3.33	0.34	1.38	1.72	5.05
18	*Parkia biglobosa*	2	1.35	6.67	0.67	2.93	3.6	10.27
19	*Polyalthia longifolia*	5	0.31	16.67	1.68	0.66	2.34	19.01
20	*Prosopis Africana*	6	3.41	20	2.01	7.41	9.42	29.42
21	*Psidium guajava*	2	0.13	6.67	0.67	0.29	0.96	7.62
22	*Pterocarpus erinnaceus*	1	0.62	3.33	0.34	1.35	1.69	5.02
23	*Sarcocephalus latifolius*	1	0.5	3.33	0.34	1.09	1.43	4.76
24	*Semia seamis*	3	3.56	10	1.01	7.74	8.75	18.75
25	*Stereospermum kuathianum*	1	0.38	3.33	0.34	0.84	1.17	4.51
26	*Terminalia avicennioides*	1	0.44	3.33	0.34	0.96	1.3	4.63
27	*Terminalia mentalis*	6	0.29	20	2.01	0.64	2.65	22.65
28	*Unknown spp*	14	0.77	46.67	4.7	1.67	6.37	53.04
29	*Vitellaria paradoxa*	4	1.14	13.33	1.34	2.48	3.82	17.15
30	*Vitex doniana*	5	0.75	16.67	1.68	1.64	3.32	19.98

Table 4: Biomass, Total Sequestered Carbon and Sequestered CO_2 Equivalent of Trees Species in the various parks.

S/N	Species	AGB	DAGB (kg) (65% of AGB)	BGB (kg) (20% of AGB)	DBGB (kg) (65% of BGB)	Total Biomass (DAGB+DBGB)	TSC/Tree) (50% TB)	SCO2E (kg) Sequestered	SCO2E (kg) (Tonnes/Tree)
1	*Acacia nilotica*	9976.46	6484.7	1995.29	1296.94	7781.64	3890.82	14279.31	14.28
2	*Albizia zygia*	5714.49	3714.42	1142.9	742.88	4457.3	2228.65	8179.15	8.18
3	*Anogeissus leiocarpus*	9859.78	6408.85	1971.96	1281.77	7690.63	3845.31	14112.3	14.11
4	*Azadirachta indica*	4291.13	2789.23	858.23	557.85	3347.08	1673.54	6141.89	6.14
5	*Bridelia ferruginea*	515.79	335.26	103.16	67.05	402.32	201.16	738.25	0.74
6	*Daniellia oliveri*	29405.74	19113.73	5881.15	3822.75	22936.47	11468.24	42088.43	42.09
7	*Delonix regia*	36956.13	24021.48	7391.23	4804.3	28825.78	14412.89	52895.3	52.9
8	*Detarium microcarpum*	12805.27	8323.43	2561.05	1664.69	9988.11	4994.06	18328.18	18.33
9	*Eucalyptus camaldulensis*	10311.5	6702.47	2062.3	1340.49	8042.97	4021.48	14758.85	14.76
10	*Eucalyptus spp*	5580.99	3627.64	1116.2	725.53	4353.17	2176.59	7988.07	7.99
11	*Ficus sycomorus*	10737.34	6979.27	2147.47	1395.85	8375.13	4187.56	15368.36	15.37
12	*Ficus thonningii*	1123.35	730.18	224.67	146.04	876.21	438.11	1607.85	1.61
13	*Gmelina arborea*	11151.03	7248.17	2230.21	1449.63	8697.8	4348.9	15960.46	15.96
14	*Hura crepitans*	5990.33	3893.71	1198.07	778.74	4672.46	2336.23	8573.96	8.57
15	*Khaya senegalensis*	6775.74	4404.23	1355.15	880.85	5285.08	2642.54	9698.11	9.7
16	*Leucaena seamis*	8319.19	5407.47	1663.84	1081.49	6488.97	3244.48	11907.25	11.91
17	*Mangifera indica*	1617.62	1051.45	323.52	210.29	1261.74	630.87	2315.3	2.32
18	*Parkia biglobosa*	8078.3	5250.89	1615.66	1050.18	6301.07	3150.54	11562.47	11.56
19	*Polyalthia longifolia*	1914.33	1244.32	382.87	248.86	1493.18	746.59	2739.99	2.74
20	*Prosopis africana*	24173.65	15712.87	4834.73	3142.57	18855.45	9427.72	34599.75	34.6
21	*Psidium guajava*	366.88	238.47	73.38	47.69	286.17	143.08	525.11	0.53

22	*Pterocarpus erinnaceus*	2485.8	1615.77	497.16	323.15	1938.92	969.46	3557.92	3.56
23	*Sarcocephalus latifolius*	2191.06	1424.19	438.21	284.84	1709.03	854.51	3136.07	3.14
24	*Semia seamis*	22910.04	14891.53	4582.01	2978.31	17869.83	8934.92	32791.14	32.79
25	*Stereospermum kuathianum*	1118.35	726.93	223.67	145.39	872.32	436.16	1600.7	1.6
26	*Terminalia avicennioides*	1476.4	959.66	295.28	191.93	1151.59	575.8	2113.17	2.11
27	*Terminalia mentalis*	870.73	565.98	174.15	113.2	679.17	339.59	1246.28	1.25
28	*Unknown spp*	3729.28	2424.03	745.86	484.81	2908.84	1454.42	5337.72	5.34
29	*Vitellaria paradoxa*	8099.72	5264.82	1619.94	1052.96	6317.78	3158.89	11593.13	11.59
30	*Vitex doniana*	4468.21	2904.34	893.64	580.87	3485.21	1742.6	6395.35	6.4

AGB = Above Ground Biomass; BGB = Below Ground Biomass; DAGB = Dry Above Ground Biomass; DBGB = Dry Below Ground Biomass; TSC = Total Sequestered Carbon; 〖SCO〗_2E = Sequestered Carbon dioxide Equivalent.

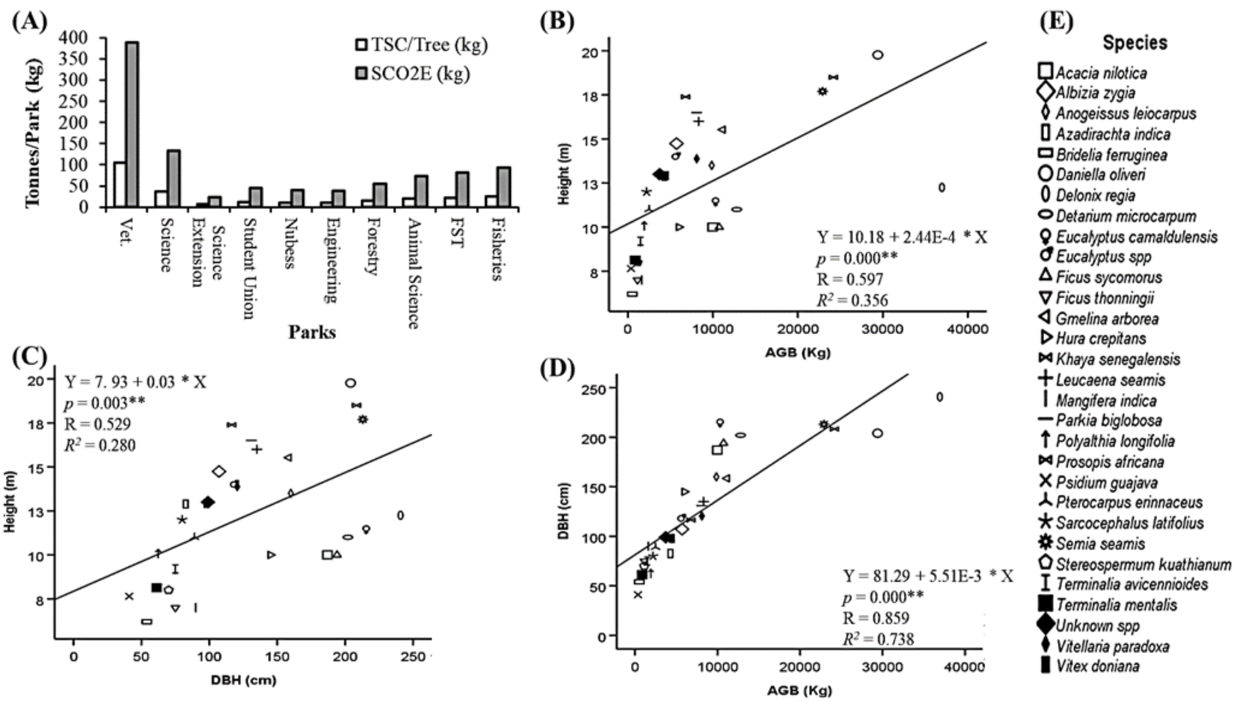

Figure 3: Sequestered Carbon (CO_2) and Correlation Result (A) Total sequestered carbon and carbon dioxide equivalent (SCO_2E) in the ten parks (B) Correlation between Height and Above Ground Biomass (AGB) (C) Correlation between Plant Height and DBH (D) Correlation between DBH and AGB (E) Trees Species. ** p<0.01 statistically significant at 99% confidence interval.

Discussion

The 30 species (298 trees) sampled in this study represents the diversity of species reported variously by previous researchers [10,11,3] in the study area. Although, many of the trees in the parks are planted to provide shades, they also serve as green infrastructure that provide multiple ecosystem services, including climate change mitigation and adaptation [34-36]. The dominant plants *(Daniellia oliveri* and *Delonix regia)* are species of moderate sizes between 11 m to 15 m (in height) and 51 cm to 100 cm (DBH) that spread close to the ground to provide shades for students on campus, hence the high IVI (285.94) and basal area (4.55), with the family Fabaceae having the highest FVI (684.39).

University land types are often considered a homogeneous land use type (institutional) but the types are designed and used for different purposes and have potential as living laboratories that make them suitable for further in-depth study [37]. The total sequestered carbon (TSC) and sequestered carbon dioxide equivalent (SCO_2E) estimated for all trees species in the study area were 264.35 and 970.16 (tonnes), respectively. The high amount of sequestered carbon and the carbon dioxide equivalent (105.65, 387.74 tonnes tonnes) recorded in veterinary park reflects the quantity of tree biomass recorded in the park, since carbon was determined as 50% of plant biomass, which was well within the range of other previously conducted estimates within the study area [16,17]. Similar studies have been carried out in other climes and results have elucidated the positive contributions of urban trees in carbon storage [37] [38,39]. The allometric model employed also incorporates plant height and diameter, therefore higher biomass implies larger plant size. These estimates are essential in view of their carbon dioxide equivalent (SCO2E), which is a measure of the plants' potential for mitigating atmospheric carbon dioxide (CO_2) concentrations [2,40].

The significant correlation between DBH and AGB implies that, AGB increases with increasing DBH, hence the suitability of the allometric model used in determining biomass, as earlier suggested by [16,17] in the study area. Imperative to effective carbon sequestration is the call for active participation of local communities in protecting and managing tree resources as well as in providing sustained financial and technical support. Although the research is limited to parks, the results demonstrate the need for more extensive estimates of carbon storage in the study area, as well as further comparative studies across urban environments. This will support better environmental planning and design, including policy and management measures related to climate change and urban resilience. More detailed information of various tree species, including allometric constants and region-specific growth estimates could support better accurate analyses and comprehensive future assessments.

Conclusion

The total of 298 trees (30 species and 16 families) sampled from 10 parks in this study revealed the utilization of trees for relaxation and ecosystem services. The results demonstrate that there are differences in carbon storage across the parks in JOSTUM campus and show the usability of allometric model to assess carbon storage in an urban environment. Total sequestered carbon (TSC) and the sequestered carbon dioxide equivalent (SCO_2E) were estimated for each tree in the study area resulting in an estimated 264.35 and 970.16 (tonnes) across all parks in Joseph Sarwuan Tarka University Makurdi, Nigeria. The approach could be used in other urban areas to obtain accurate estimations of urban carbon storage in support of urban landscape governance, planning, and management. Carbon storage by urban trees should be carefully integrated with the assessment of other ecosystem services, with a detailed information on the allometry and growth rates of urban trees, which would enhance efficiency of carbon stock assessments.

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