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CARBON CREDIT ASSESSMENT AND IMPORTANCE VALUE INDICES OF TREES IN URBAN PARKS: A CASE STUDY OF BENUE STATE SECRETARIAT, MAKURDI.

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ABSTRACT Assessment of carbon credit potentials of trees in the Benue State Secretariat Makurdi was done using a non-destructive allometric model, consisting of Above ground Biomass (ABG), Below Ground Biomass (BGB) and Diameter at Breast Height (DBH) using the equation: AGB = Exp [1.627 + 1.393 * Ln (DBH)]. DBH (cm) was measured at approximately 1.3 meter above the ground level on each tree. BGB was determined as 20% of AGB (kg/tree). Furthermore, dry AGB and BGB were determined as 65% of AGB and BGB, respectively, while Total biomass (TB) was determined by the summation of dry AGB and dry BGB (kg/tree). A total of 150 trees (from 15 species and 10 families) were sampled in the study area with *Khaya senegalensis* (66) being the most abundant. Diversity indices – Importance value index and family value index – were also evaluated to ascertain species and family distribution. *Khaya senegalensis* (Meliaceae) had the highest IVI (488.9). The DBH class range (cm), 101-150 had the highest frequency followed by 51-100 and 151-200, and the least DBH classes were 0-50 and 201-250, implying trees of moderate height. DBH (cm) and AGB (kg) correlated positively (R^2= 0.98, P= 0.000) in all the species sampled, hence AGB increased with increase in DBH. Furthermore, *Gmelina aborea* had the highest above ground biomass (10935.55), total biomass (8529.73), below ground biomass (2187.11), total sequestered carbon/tree (4264.86), sequestered carbon dioxide equivalent (kg) (15652.05), and sequestered carbon dioxide equivalent (tonnes/tree) (15.65), correspondingly. The study determined the total sequestered carbon (32.7 Tonnes) and sequestered carbon dioxide equivalent (120.23 tonnes/tree), thus, elucidating the potentials of these species and the urban park in carbon sequestration and climate change mitigation.
Keywords**:** Carbon Sequestration, Family Value Index, Importance Value Index, Sequestered CO_2 Equivalent, Urban Parks

INTRODUCTION

Urban areas have been predicted to increase due to increased human population, which results in loss of natural ecosystems to agriculture, accommodation and industrialization, thereby leaving a vegetation highly dynamic (higher mortality and faster growth rates) than natural forests (Hutyra *et al*., 2014; Pretzsch *et al*., 2017). Urban vegetation (including parks and gardens) is important in sequestrating anthropogenic carbon emissions, which are concentrated in urban cities. Anthropogenic activities have led to high vehicle emissions and industrial pollutions, as well as protection and enhancement of ecosystem services, such as water purification, noise reduction, habitat provision and recreational benefits (Gómez-Baggethun and Barton, 2013; ShahIDan, 2015; Davies *et al*., 2011; Ottelin *et al*., 2019).

Variability in carbon storage, as well as its relationship to urbanization and climate mitigation, is an emerging area of research (Sun *et al*., 2019). To this end, estimates on the distribution of urban vegetation is critical in understanding the extent of carbon storage needed to improve climate resilience and environmental quality by municipalities (Trlica *et al*., 2020). The methods designed for natural ecosystems may not be transferable to urban areas, hence the need to accurately assess and monitor carbon stored in urban vegetation (Hutyra *et al*., 2014; Tigges *et al*., 2017; McHale *et al*., 2018). Carbon sequestration by urban trees have been estimated and valued at £4.8 million ($6.3 million) per annum or £17.80 per tree in Greater London and $2 billion per annum in the USA, with large trees having more capacity to sequester carbon, since they accumulate biomass over relatively longer time (Stephenson, 2014; Churkina, 2016).

Currently, the contribution of urban parks and garden in the global carbon cycle is given little consideration, probably due to their relatively small coverage compared to global forest cover (Churkina, 2016; Wilkes *et al*., 2018). Although, the above ground carbon stocks trees in Joseph Sarwuan Tarka University Makurdi (Okoh *et al*., 2021) and Makurdi Zoological Garden (Paul *et al*., 2019) have been investigated in the study area, a lot more work is needed to update the national carbon credit system and report to the Paris Agreement (Climate), which

Nigeria is a party to. Nigeria's percentage of greenhouse gases for ratification, based on the Paris Agreement, is estimated at 0.57% of the total global output (UNFCCC, 2015). This represents a great potential for carbon credit trading if a comprehensive national database can be updated. The aim of this research therefore, was to contribute in updating the national database on above-ground carbon storage and to assess the distribution and importance value indices of trees species in the studied (Benue State Secretariat Makurdi, Nigeria) urban vegetation.

MATERIALS AND METHODS

Study Area

The Benue State Secretariat (7°42'48.1"N 8°31'21.6"E) is located at Abu Obe Road, off old Otukpo road, High level Makurdi, Benue State, Nigeria. It is the permanent administrative office for the State ministries, agencies and parastatals. The Secretariat is therefore planted with various trees that provide shade against the scourging sun to vehicles and humans, in addition to other ecological services (air purification and wind speed reduction). This Secretariat is covered with green vegetation, shrubs and trees from the entrance gate down to the entire surroundings.

Species Distribution/ Importance Value Indices

Species distribution in the secretariat was determined using line transect method. The entire park was divided into plots along a 300 m transect, and all tree species within each plot were sampled and identified.

Relative Frequency, relative density, and relative dominance were calculated using the formula described by De Oliveira-Filho *et al* (1989).

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of individual Species}}{\text{Total Frequency of all Species}} \times 100$$

$$\text{Relative Density (RDe)} = \frac{\text{Frequency of individual Species}}{\text{Total Frequency of all Species}} \times 100$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Basal Area of individual species}}{\text{Total Basal Area of all Species}} \times 100$$

Basal area, BA (m^2) was calculated from DBH using the following equation:

$$BA\ (m^2) = \frac{\pi \times (DBH/2)^2}{10{,}000}$$

Cover value index, importance value index and family value index were calculated using the formular by Philips (1959).

Cover Value Index (CVI) = RDe + RDo

Importance Value Index (IVI) = CVI + RF

Family Value Index (FVI) = Sum of IVI of all species in each family

Measurement of Tree Height and Diameter at Breast Height (DBH)

Tree height was measured using a Haga altimeter while, DBH (cm) was measured using a measuring tape at approximately 1.3 meter above ground on each tree. Only trees with DBH greater than 10 cm were sampled for the study.

Estimation of Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Total Biomass (TB)

Estimates of tree biomass were determined using a non-destructive allometric equation, which incorporates DBH and tree height. The allometric equation is as follows (Jibrin and Abdulkadir 2015):

$$AGB = Exp\ [1.627 + 1.393 * Ln\ (DBH)].$$

The Below Ground Biomass (BGB) was determined as 20% of AGB (Hangarge *et al*., 2012) using the following equation:

BGB (kg/tree) = 20% of AGB (kg/tree).

Dry above ground biomass and dry below ground biomass were estimated as 65% of AGB and BGB, respectively.

Total Biomass (TB) was estimated using the following equation:

Total biomass (TB; kg/tree) = Dry Above ground biomass + Dry Below ground biomass.

Estimation of Carbon

Generally, for any plant species, 50% of its biomass is considered as carbon (Pearson *et al*., 2005). The carbon dioxide equivalent (SCO_2E) was determined as the weight of carbon sequestered in the tree multiplied by 3.67 (weight of carbon in CO_2). Correlation analysis (Pearson's correlation) was used to determine relationship between AGB and DBH.

RESULTS

Species Distribution

A total of 150 trees (15 species and 10 families) were sampled in the study area (Table 1), which included:

Khaya senegalensis (66) being the most dominant, followed by *Azadirachta indica* (33), *Delonix regia* (10), *Terminalia catapa* (8) and *Plumeria alba* (8), *Tectona grandis* (6), *Daniellia oliveri* (5), *Gmelina arborea* (4), *Mangifera indica* (3), *Anacardium occidentale* (2). The least dominant species were *Albizia zygia*, *Combretum nigricans*, *Eucalyptus camaldulensis*, *Ficus trichopoda* and *Parkia biglobosa* each occurring once (Table 1). The percentage occurrence of each species is presented in Figure 1A, with *Khaya senegalensis* having 44% as the most dominant species in the park. Species importance value indices as well as family value indices are presented in Figures 1B and 1C, respectively, with *Khaya senegalensis* and Meliaceae having the highest IVI (488.9) and FVI (734.24), respectively.

Height and DBH classes Distribution

Height classes (m) 6 to 10, 11 to 15, and 16 to 20 had 4 species each, while class 21-25 had 3 species, respectively. The DBH class (cm) 101-150 had the highest frequency followed by class 51-100 and class 151-200, with classes 0-50 and 201-250 being the least, respectively (Table 2).

Correlation Analysis.

DBH (cm) and AGB (kg) correlates positively ($R^2 = 0.98$, $P = 0.000$) in all the species sampled in the study area, implying that AGB increases with DBH (Figure 1D).

Above Ground Biomass/ Total Biomass, Total Sequestered Carbon and Sequestered Carbon Dioxide Equivalent

Gmelina aborea had the highest above ground biomass (10935.55; Figure 2A), dry above ground biomass (7108.11; Figure 2B), below ground biomass (2187.11; Figure 2C) and dry below ground biomass (1421.62; Figure 2D), respectively. Furthermore, *Plumeria alba* had the least above ground biomass (1826.67; Figure 2A), dry above ground biomass (1187.34; Figure 2B), below ground biomass (365.33; Figure 2C) and dry below ground biomass (237.47; Figure 2D), respectively.

Also, *Gmelina aborea* had the highest total biomass (8529.73; Figure 3A), total sequestered carbon/tree (4264.86; Figure 3B), sequestered carbon dioxide equivalent (kg) (15652.05; Figure 3C) and sequestered carbon dioxide equivalent (tonnes/tree) (15.65; Figure 3D), respectively. Moreover, *Plumeria alba* had the least total biomass (1424.80; Figure 3A), total sequestered carbon/tree (712.40; Figure 3B), sequestered carbon dioxide equivalent (kg) (2614.51; Figure 3C) and sequestered carbon dioxide equivalent (tonnes/tree) (2.61; Figure 3D), correspondingly.

Table 1. Species distribution, frequency of occurrence, height and DBH of trees in Benue State Secretariat Makurdi (July, 2019).

S/N	Species	Family	Plot of Species Occurrence	Total Number of Trees	Height (m)	DBH (cm)	Basal Area (m2/hectare)
1	*Albizia zygia*	Mimosoideae	6	1	8.50	80.00	0.50
2	*Anacardium occidentale*	Anacardiaceae	7	2	11.25	160.00	2.01
3	*Azadirachta indica*	Meliaceae	1, 5 & 6	33	10.58	106.21	0.89
4	*Combretum nigricans*	Combretaceae	3	1	16.00	120.00	1.13
5	*Daniellia oliveri*	Fabaceae	3 & 7	5	22.80	148.00	1.72
6	*Delonix regia*	Fabaceae	2, 6 & 8	10	7.12	147.20	1.70
7	*Eucalyptus camaldulensis*	Myrtaceae	4	1	23.00	174.00	2.38
8	*Ficus trichopoda*	Moraceae	7	1	12.00	230.00	4.16
9	*Plumeria alba*	Apocynaceae	8	8	6.95	68.13	0.36
10	*Gmelina arborea*	Verbanaceae	7	4	19.25	242.25	4.61
11	*Khaya senegalensis*	Meliaceae	1, 2, 3, 4 & 5	66	21.14	129.77	1.32
12	*Mangifera indica*	Anacardiaceae	1, 3 & 7	3	14.67	150.00	1.77
13	*Parkia biglobosa*	Mimosoideae	6	1	16.00	150.00	1.77
14	*Tectona grandis*	Lamiaceae	7	6	18.33	155.00	1.89
15	*Terminalia catappa*	Combretaceae	2, 7 & 8	8	9.13	87.63	0.60

Table 2. Height class and DBH class distribution of trees in Benue State Secretariat Makurdi (July, 2019).

Height Class (m)	Frequency	DBH Class (cm)	Frequency
0 to 5	0	0 to 50	0
6 to 10	4	51 to 100	3
11 to 15	4	101 to 150	7
16 to 20	4	151 to 200	3
21 to 25	3	201 to 250	2

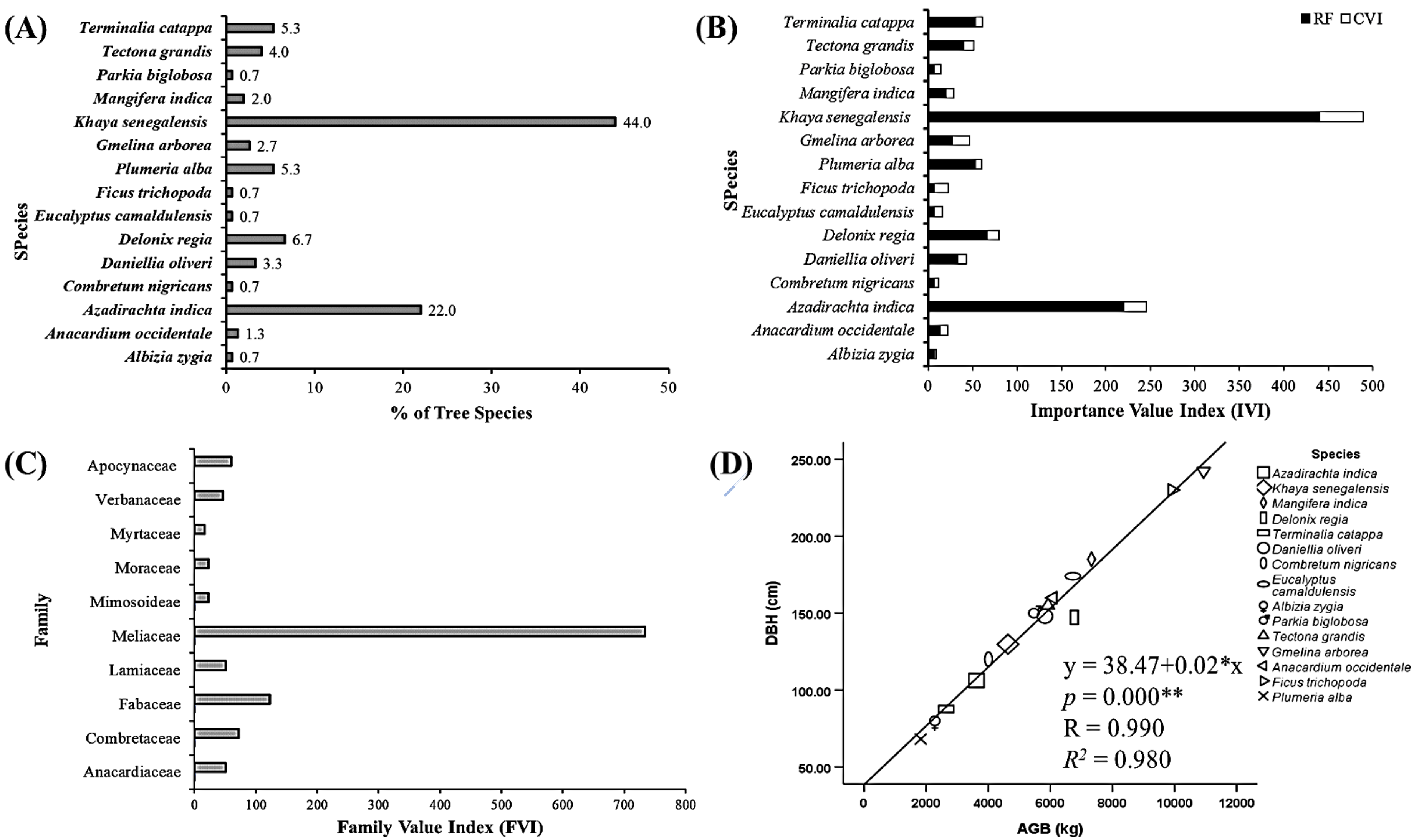

Figure 1. Species distribution, Important value indices and correlation between AGB and DBH of trees in Benue State Secretariat, Makurdi, Nigeria. (A) Percentage (%) Occurrence of trees species (B) Importance value Index of trees species (C) Family value Index of various plant families (D) Correlation between DBH (cm) and AGB (kg). ** p<0.01 statistically significant at 99% confidence interval.

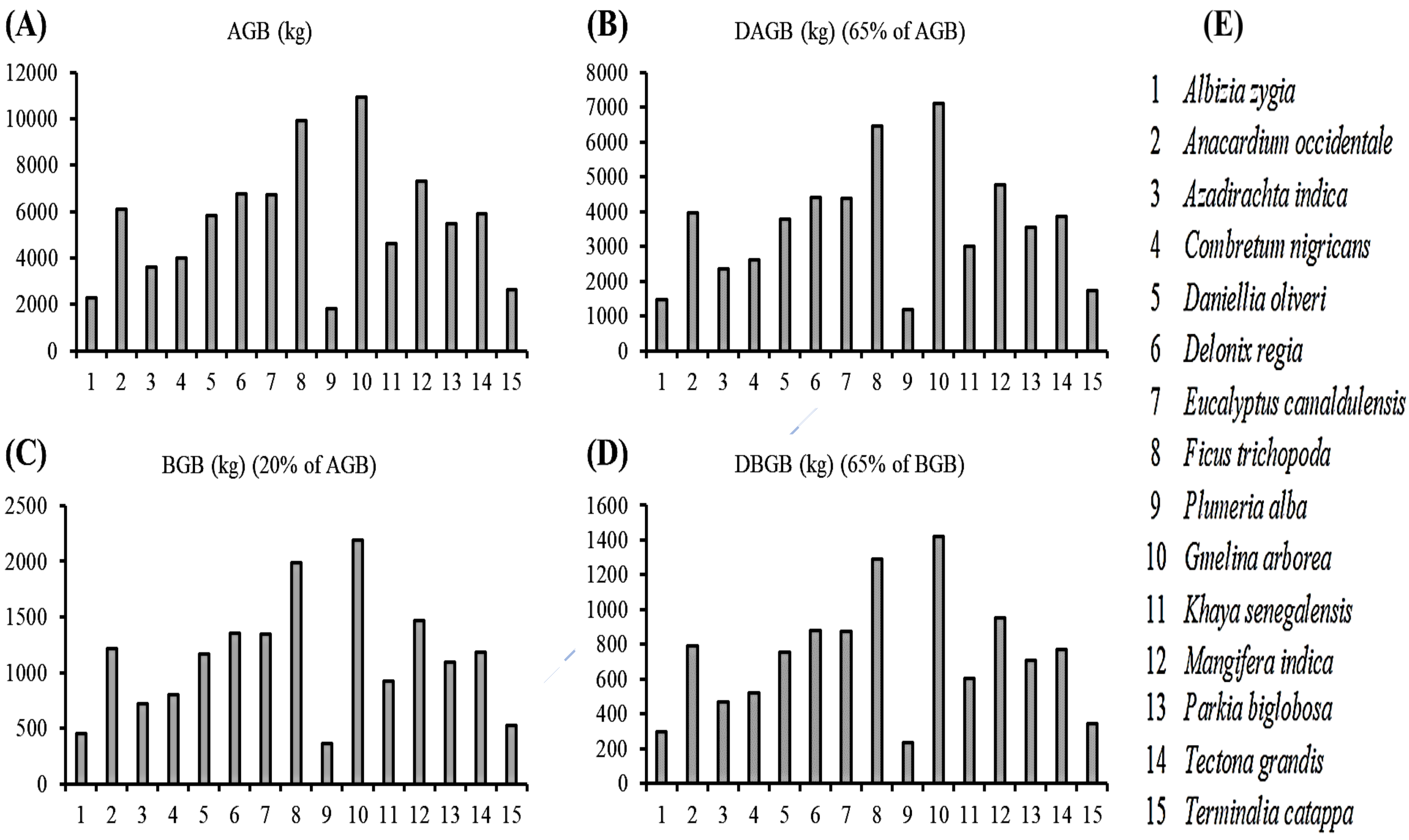

Figure 2. Above ground biomass, total sequestered carbon and sequestered carbon dioxide equivalent of trees in Benue State Secretariat Makurdi (July, 2019). (A) ABG (kg) (B) DAGB (kg) (C) BGB (kg) (D) DBGB (kg) (E) Species legend. AGB: Above Ground Biomass; BGB: Below Ground Biomass; DAGB: Dry Above Ground Biomass; DBGB: Dry Below Ground Biomass

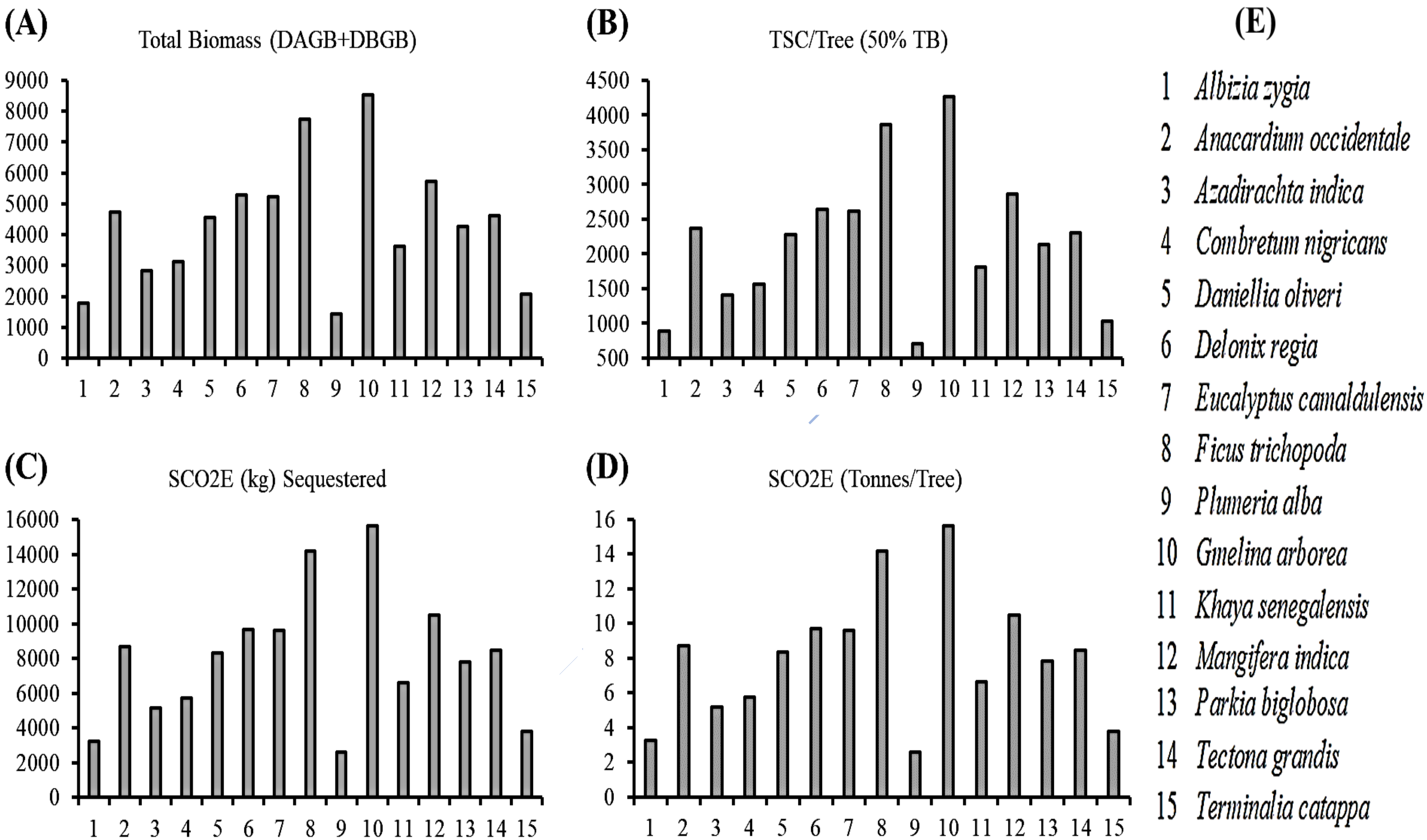

Figure 3. Total Biomass and carbon sequestration of trees in Benue State Secretariat Makurdi (July, 2019). (A) Total Biomass (B) TSC/Tree (C) SCO_2E (kg) (D) SCO_2E (Tonnes/Tree). TSC: Total Sequestered Carbon dioxide; SCO_2: Sequestered Carbon dioxide Equivalent.

DISCUSSION

The Benue State Secretariat Makurdi recorded a total of 150 trees (from 15 species and 10 families) in the study, which is relatively low. While the extent of the park is relatively small compared to the entire city, the trees no doubt contribute greatly to providing shade and air purification in the study area. More so, species such as *Khaya senegalensis* (66) are hard wood with high densities that confer higher biomass and carbon content. The study revealed a total of 32.7 Tonnes of carbon (120.23 Tonnes of CO_2) in the park, highlighting the huge carbon credits in the park. The positive correlation between AGB and DBH implies the reliability of the allometric equation employed in this research, since higher biomass results in higher carbon stocks. This is particularly important especially with the increase in population of urban centers and the likely rise in waste generations and higher vehicular emissions that would increase human carbon footprint.

Carbon storage and sequestration is one obvious benefit of green infrastructure. Many researches have quantified the amount of aboveground Carbon stored by greenspace in cities of the temperate climate zone (Davies *et al*., 2011; Hutyra *et al*., 2011; Wei *et al*., 2012; Strohbach and Haase, 2012; Schreyer *et al*., 2014; Ahmed *et al*., 2017) and in Nigeria (Eneji *et al*., 2014, Paul *et al*., 2019). The results indicate the role of tree density and size as two dominant factors determining the amount of aboveground carbon in urban greenspace (Davies *et al*., 2013; Kong *et al*., 2014). Although different methods of carbon stock estimates have been employed, the pattern of urbanization as well as species composition and age of urban forests determine Carbon stocks estimates (tonnes of carbon per hectare; C T/ ha^{-1}) between cities.

Although, the contribution of urban areas to global AGB may be relatively small owing to the limited spatial extent, some urban forests have AGB density comparable to tropical and temperate Forests (Wilkes *et al*., 2018). Consequently, it is imperative that these urban spaces are expanded and maintained as a sources of carbon sinks.

CONCLUSION

The study revealed a huge above ground carbon credits at the Benue State Secretariat Makurdi, as one of the benefits of urban green areas such as parks and gardens. The potentials of these species in climate change mitigation are hereby highlighted. Therefore, the importance of conserving these species and urban green areas as carbon sinks are necessary.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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