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IMPACT OF URBANIZATION ON URBAN ECOSYSTEM SERVICES DYNAMIC, STRUCTURAL ATTRIBUTES, CARBON STORAGE AND SEQUESTRATION IN TWO NIGERIA CITIES

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ABSTRACT

Urbanization can have positive or negative effect on diversity conservation and carbon sequestration. This study was conducted to evaluate the impact of urbanization on urban ecosystem services dynamic, structural attributes, carbon storage and sequestration Osogbo and Akure cities, using Simple Random Sampling. Biomass values, above-ground biomass (AGB) and below-ground biomass (BGB) was used to quantify carbon stock to estimate the amount of carbon sequestrated by the urban forests in the two cities. The results revealed a total of 455 individual trees distributed among 37 species and 19 families in Osogbo, while 985 individual trees distributed among 41 species and 21 families in Akure urban forest respectively. Shannon-Wiener diversity index (2.65 and 3.42) was higher in Akure and lower in Osogbo, with higher species recorded for Akure, this is an indication of a more pronounce greenness coverage for Akure metropolis than Osogbo metropolis. The total carbon stored by the urban forests of Osogbo and Akure were estimated at 405.73 and 1049.70 tons, respectively. Tree species diversity had greater influence in determining biomass accumulation, carbon sequestration and climate change mitigation. Selecting and planting the right species as avenue trees, building parks and gardens, urban landscaping could improve urban forest carbon sequestration and providing other essential urban forest ecosystem services.

Keywords: Above-ground biomass, below-ground biomass, biomass expansion factor, carbon storage, ecosystem functions, urban landscape, wood density.

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INTRODUCTION

Urban forest plays important role in urban ecosystems in delivering the numerous functions of ecosystem services to the populace such as offsetting carbon emission, removing air pollutants, regulating the micro environment and mitigating climate change (Agbelade *et al*. 2022; Agbelade and Onyekwelu 2020; Nowak *et al*. 2013). Quality urban trees are valuable components of the urban landscape and green infrastructure that tend to protect the urban environment from harsh climatic conditions and mitigate climate change, in providing conducive environment. Urban trees deliver ecosystem functions, benefits that improve the lives and livelihood of the urban populations (Agbelade and Onyekwelu 2020; McHale *et al.*, 2009). These ecosystem services contribute greatly to the improvement and sustainability of urban environment. Deforestation in urban forests, provision of infrastructures and indiscriminate exploitation of urban trees has impacted negatively on plants diversity conservation components of the urban environment (Miles *et al.*, 2006, Onkar *et al.*, 2016). Urban forest sequestrates carbon as much as other forests and it contribute greatly to plants diversity in offsetting carbon emission, removing air pollutants, regulating the micro, macro environment and mitigating climate change (Fuwape and Onyekwelu, 2011; Konijnendijk *et al*. 2006). Urban forests sequestrate carbon and remove carbon dioxide from the atmosphere resulting in the purification of the environment by releasing Oxygen into the environment during photosynthesis. Carbon dioxide emitted is being stored in the cell wall of urban trees in form of carbon to sequester carbon and mitigate global warming (Strohbach and Haase, 2012). Urban forest trees act as carbon sink and carbon dioxide stored in woody plants during the process of tree growth. Urban forests and landscape development in relation to tree planting would improve ecosystem function and enhance carbon sink in urban forests dynamics. This study is therefore aimed at restoring and improving the ecosystem services which are the benefits people obtain from their immediate environment such as nutritional values, regulating environmental temperature; relaxation centres to ease stress and properties value additions that enhances conditions of life of the populace in their immediate environment. There are several studies on urban forests but none has been reported on carbon stocks in the two cities in Nigeria, this study addressed this knowledge gap in Osogbo and Akure cities of Nigeria (Woldegerima *et al.* 2017; Fuwape and Onyekwelu 2011; Liu and Li 2012; Mchale *et al*. 2009). This study was carried out to determine urban forest structural attributes, carbon storage and sequestration of green landscapes in two Nigerian cities. Therefore, this research examined urban trees diversity and structural attributes of green landscape; and analyzed carbon storage and sequestration in Osogbo and Akure cities .

MATERIALS AND METHODS

Study area

The study was conducted in two selected cities (Akure and Osogbo), Southwest of Nigeria (Figure 1). The cities selected are the capital cities of these States with the highest population density and improved infrastructural development. Akure is the capital of Ondo State, located in 7º12'51.11"N to 7º16'56.70"N and 5º11'07.44"E to 5º12'19.49"E. The city is situated within the humid forest zone of Nigeria with rainfall for nine months (April to November), and dry season for three months (December to March). The annual rainfall ranged from 1500 mm to 2000 mm, with dry season average of 250 mm. Average relative humidity of Akure is 80 - 85% daily during raining season, while average annual temperature is 30°C, with lowest and highest temperature in August and February, respectively. Osogbo is the capital city of Osun State and the city is located in 7º45'19.96"N to 7º48'25.87"N and 4º34'45.10"E to 4º31'55.17"E. The city had 499,999 populations and an approximate land area of 2875 km^2. The average annual temperature is 28.0°C and the annual precipitation is1241 mm. The driest and wettest months are January and September with 9 mm and 202 mm values respectively, while the warmest and coldest month is August with an average 31.0°C and 24.0°C respectively. Infrastructural development had increase urbanization and population in flow with decrease in vegetation cover of the city.

Methods of data collection

Inventory data for this study were collected between October 2017 and June 2018. The major streets of the three selected cities. The inventory data for Osogbo were collected from the city metropolis: Sabo road, Old Ikirun road; Osogbo-Ilesa road, Ring road, Gbongan road, Isale Osun-shrine road, Asubiaro road, Isale Aro street, Bishop street, Olorunsogo lane, Oke Ayepe street, Ode Olowo Street, Awosuru street,Adejumobi street, Akindeko street and Osun state University campus. The inventory data for Akure were collected from the city core: Alagbaka, Oke Aro, Oba Adesida road, Oyemekun road, Ondo Road, Arakale street, NEPA street, Oke Eda, Araromi street, Oke Ijebu road, Akure-Oba Ile road, Tuyi street, Odo Ijoka street, Ijoka-Ijomimo road, Hospital lane and Federal University of Technology, Akure campus. All woody plants along the streets in the selected city section with diameter at breast height (dbh>10 cm) as suggested by Hall *et al*., (2003) were measured and identified. The following tree data were collected; diameter at breast height using girth tape, diameters over bark at the base, middle, merchantable height and total height using a Spiegel Relaskop. Forked trees were assessed as separate trees beneath the breast-height level. All species of tree have been classified with their botanical names and distributed to their respective families (Agbelade and Onyekwelu 2020).

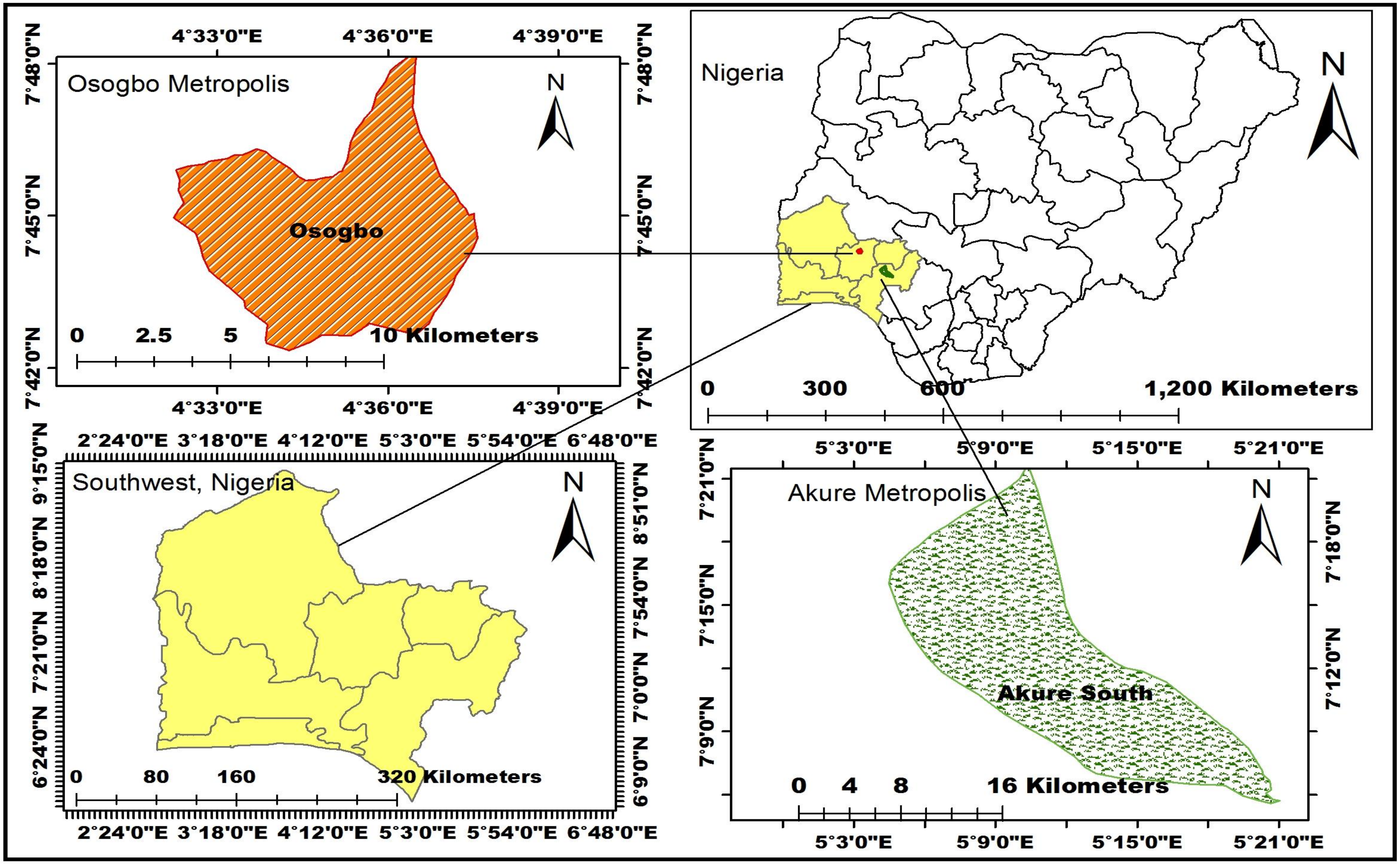

Figure 1: Study area map indicating Akure and Osogbo urban forest centres

Determination of urban trees structure, species diversity and biomass

Phyto-sociological properties of the cities were determined for ecosystem services and structural attributes of the cities. Tree species diversity, volume yield and biomass were estimated using the following equations: The basal area of each tree in the sampled cities was calculated using the formula in equation (1):

$$\mathrm{BA} = \frac{\pi D^2}{4} \;\ldots\ldots (1)$$

Where: BA = Basal area (m^2), D = Diameter at breast height (cm) and л= pie (3.142). The basal area of trees was obtained by adding basal areas of all trees within the selected areas of each selected city. The volume of each tree in the city was calculated using Newton's equation 2, the volume of trees was obtained by adding volumes of all trees in selected areas of each city.

$$\mathrm{V} = \frac{h}{6}(\mathrm{Db} + 4\mathrm{Dm} + \mathrm{Dt}) \;\ldots.. (2)$$

where: V = Tree volume (m^3), D_b, D_m and D_t = tree cross-sectional area (m^2) at the base, middle and total height respectively, and h = total height (in meters). Tree species diversity for each city was calculated using the Shannon-Wiener diversity index (H').

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) \;\ldots.. (3)$$

Where H' is the diversity index, S_i is the total number of species, p_i is the proportion of species S contributed by ith species and ln is natural logarithm. Species relative density (RD) was used by Brashears *et al*., (2004) equation

$$\mathrm{RD} = \left(\frac{\mathrm{ni}}{\mathrm{N}}\right) \mathrm{x}\; 100 \;\ldots. (4)$$

Where: RD (%) species relative density; n_i number of individuals of species i; N total number of all individual trees of all species in the entire city. Species relative dominance (RDo (%)), was assessed by Aidar *et al*., (2001) equation.

$$\mathrm{RDo} = \frac{(\Sigma \mathrm{Bai}\;\mathrm{x}\;100)}{\Sigma \mathrm{Ban}} \;\ldots\ldots (5)$$

Where: Ba_i basal area of all trees belonging to a particular species i; Ba_n basal area of all trees in a city. Importance value index (IVI) was estimated by Brashears *et al*., (2004) equation.

$$\mathrm{IVI} = \frac{(\mathrm{RD}\;\mathrm{x}\;\mathrm{RDo})}{2} \;\ldots\ldots. (6)$$

Species evenness in each city was determined using Shannon's equitability (E_H):

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \ln(P_i)}{\ln(S)} \;\ldots\ldots (7)$$

Shannon's maximum diversity index was calculated using (Guo *et al.* 2003).

H_{max}= In(S) …. (8)

Where: H_{max} Shannon's maximum diversity index; S total number of species in the community.

Biomass expansion factor (BEF) of 1.74 was used to estimate tree above ground biomass for tropical rainforest (Brown and Lugo 1992), multiple by volume over bark (m^3/ha) and wood density (kg/ m^3).

Above-Ground Biomass (AGB) = BEF * VOB * WD …. (9)

Where, VOB = Volume over bark (m^3); WD = Wood density (kg^{-2}). Wood density for tree species was acquired from Global Wood Density Database. Arithmetic mean of (0.60 gcm^3) for a tropical African forest was used for species that were not found in the database following (Chave *et al*. 2005). The carbon stock of the urban forests was determined by a fraction of 50% of biomass.

$$\mathrm{AGC} = \mathrm{AGB}\;\mathrm{x}\;0.5 \;\ldots.. (10)$$

Thus, above ground carbon (AGC) was calculated as a conversion factor of 0.5 multiplied by AGB.

$$\mathrm{BGC} = \mathrm{AGB}\;\mathrm{x}\;0.2 \;\ldots. (11)$$

Where below ground carbon was computed as 20% of AGB following Mac Dicken (1997) and IPCC (2006), using a synthesis of global data and a conservative ratio shoot-to-root biomass of 5:1 (Meragiaw *et al.* 2021).

$$\mathrm{TC} = \mathrm{AGC} + \mathrm{BGC} \;(12)$$

The estimation of carbon content in BGC is the same as that of AGC. Total carbon (TC mgha^{-1}) stock was done by adding up the carbon stock of AGC and BGC by Pearson *et al.* (2007).

Descriptive statistic and analysis of variance (ANOVA) was employed to test for the significance difference in the biodiversity indices, forest structure and biomass accumulation across the cities. Significant means were separated using Duncan Multiple Range Test. All statistical analyses were done using Statistical Package for Social Sciences (SPSS 20.0).

RESULTS

Biodiversity indices and Growth Variables of tree species in the Study areas

The biodiversity indices and mean growth variable of the tree species in Osogbo and Akure are shown in (Table 1). The numbers of each individual tree were 455 and 958 with families of 19 and 21 respectively. Numbers of tree species were also calculated to be 37 for Osogbo and 41 for Akure. Mean and maximum dbh (diameter at breast height) for the two study areas were 35.40 cm and 89.60 cm with 46.30 cm and 93.60 cm respectively. The calculated total basal area for Osogbo was 4.38 m² and for Akure was 8.26 m² also mean height for Osogbo and Akure were 15.8 m and 17.12 m. The volume for Osogbo and Akure were 41.51 m³ and 85.53 m³ while the Shannon-Wiener diversity index values for Osogbo and Akure (2.65 and 3.42), species evenness for Osogbo and Akure was (0.43 and 0.50), Shannon-Wiener maximum diversity index was 6.12 and 6.86 respectively. The total accumulation of biomass for trees in Osogbo was estimated at 486.88 tons while 1259.64 tons were calculated for Akure (Tables 1). The total carbon stored in Osogbo by trees was estimated at 243.44 tons and the carbon stored in Akure urban forest was estimated at 629.82 tons.

Partitioning of diameter to determine species diversity, structure and biomass

The pattern of species structure, diversity, biomass and carbon partitioning to tree dbh classes was at variance among the two cities (Table 2). In Osogbo urban forests, medium diameter at breast height trees (31.0 – 60.0 cm), had the highest values for volume, biomass and carbon stock (253.94 m³, 198.08 tons and 99.04 tons), followed by the small diameter at breast height trees (10.0 – 30.0 cm) for volume, biomass and carbon stock (191.29 m³, 180.05 tons and 90.03 tons) and the least value for volume, biomass and carbon stock was the largest diameter at breast height (182.18 m³, 108.74 tons and 54.37 tons). Akure urban forests with large diameter at breast height trees (> 60.0 cm) recorded the highest values for volume, biomass and carbon stock (1096.45 m³, 754.67 tons and 377.34 tons), followed by the medium diameter at breast height trees (31.0 – 60.0 cm), for volume, biomass and carbon stock (444.43 m³, 366.32 tons and 183.16 tons) and the small diameter at breast height trees (10.0 – 30.0 cm) had the least value for volume, biomass and carbon stock (168.04 m³, 138.65 tons and 69.32 tons).

Table 1: Biodiversity indices, growth variables and biomass of tree species in Osogbo and Akure cities

Locatio	Density	Family	Species	Dbh (cm)	BA (m^2)	Max Dbh (cm)	Mean Height (m)	Volume (m^3)	H'	EH	Hmax	Biomass (tons)	Carbon (tons)
Osogbo	455	19	37	35.40	4.38	89.60	15.80	41.51	2.65	0.43	6.12	486.88	243.44
Akure	958	21	41	46.30	8.26	93.60	17.12	85.53	3.42	0.50	6.86	1259.64	629.82

Table 2: Partitioning of the diameter at breast height to determine diversity, structure and biomass in Osogbo and Akure cities

Dbh (cm)	Basal Area (m^2)	Volume (m^3)	RD (%)	RDo (%)	IVI (%)	AGB (tons)	BGB (tons)	TCS (tons)
Osogbo Urban Forests								
10.0 - 30.0	0.990a	191.290a	60.000a	22.595a	41.297a	150.044a	30.009a	90.027a
31.0 - 60.0	1.755b	253.944b	28.571a	40.062a	34.317a	165.069b	33.014b	99.042b
>60cm	1.636b	182.151b	11.429b	37.353b	24.391b	90.616b	18.123b	54.369b
Akure Urban Forests								
10.0 - 30.0	0.605a	168.035b	37.891b	7.326b	22.609b	115.540b	23.108b	69.324b
31.0 - 60.0	2.774a	444.431a	35.699a	33.587a	34.643a	305.266a	61.053a	183.160a
>60cm	4.883a	1096.447a	26.409a	59.115a	42.762a	628.894a	125.779a	377.337a

Height and diameter at breast height distribution

The tree diameter distribution in these two cities indicated the presence of the highest number of individual trees in the small diameter class. In Osogbo and Akure, the highest number of trees was found in (20.0 - 29.9 cm) diameter class whereas the lowest number of trees was found in (80.0 - 89.9 cm) diameter class respectively. The diameter distribution of trees in each city followed inverted J distribution pattern (Figure 2) and also intercepting at diameter class range of (70.0 – 79.9 cm). Between Osogbo (54.1 %) and Akure (31.7 %) of the trees in the two cities fell within the low diameter range (dbh range: 10.0 cm – 39.9 cm), indicating that the urban forest is a growing forest and if well protected/conserved would produce active and healthy ecosystem. Large diameter trees (> 60 cm) accounted for (10.8 % and 26.8 %) in Osogbo and Akure for all the trees within the cities. Height distribution for the two cities Osogbo and Akure indicated that trees in the height class of 10.0-14.9 m had the highest height and in Osogbo the class 20.0-24.9 m had the lowest height. It is different for Akure, trees in the class 5.0-9.9 m and 25.0-29.9 m had the highest and lowest (Figure 3).

Ten species were selected with the highest relative abundance in both cities. In Osogbo the species with highest relative abundance was *Azadirachta indica* (72%), followed by *Gliricidia sepium* (72%), *Terminalia mantaly* (66%), *Poyalthia longifolia* (53%), *Gmelina arborea* (37%), *Magnifera indica* (28%), *Spondias mombin* (13%), *Terminalia catapa* (13%), *Tectona grandis* and *Cocos nucifera* (12%) respectively. Akure recorded *Gmelina arborea* (68%) followed by *Polyalthia longifolia* (62%), *Tectona grandis* (59%), *Terminalia catapa* (57%), *Delonix regia* (56%), *Terbebua rosea* (51%), *Terminalia mantaly* (50%), *Albizia lebbek* (44%), *Magnifera indica* (37%) and *Ficus benjamina* (34%) with the highest relative abundance (Figure 4).

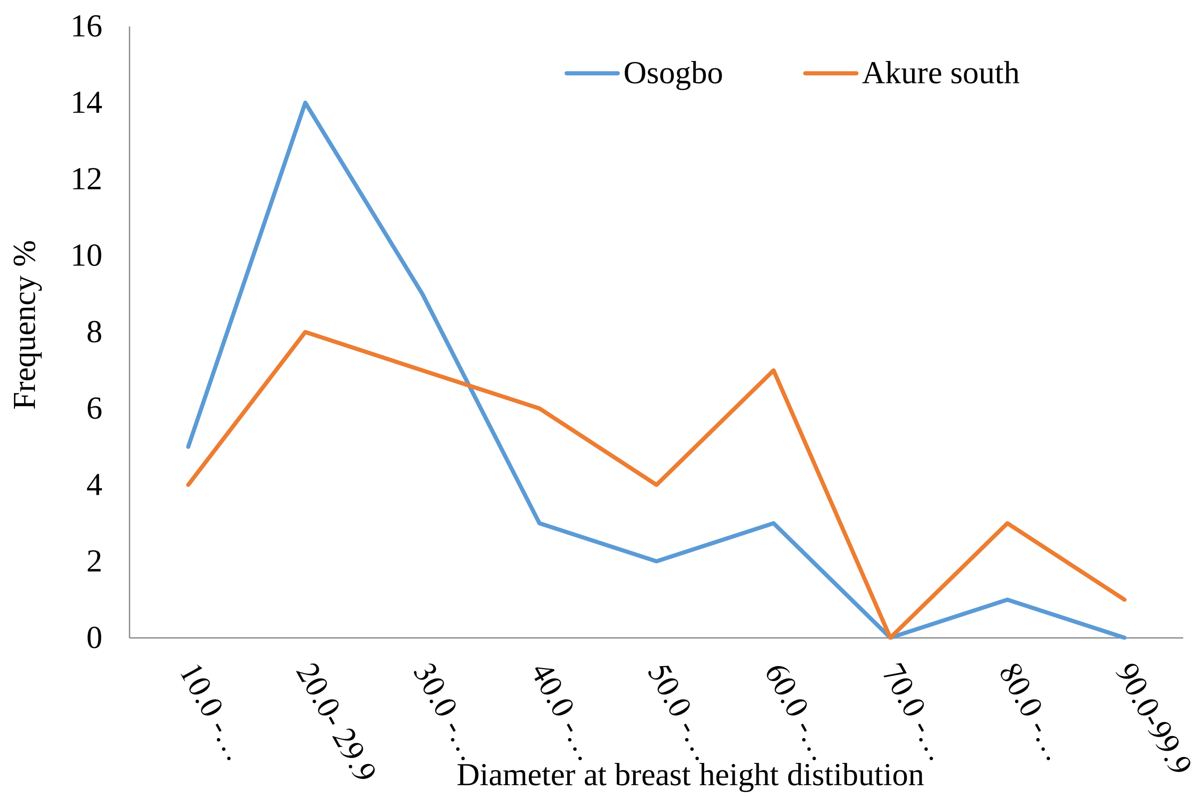

Figure 2: Diameter at breast height distribution of urban trees in Osogbo and Akure.

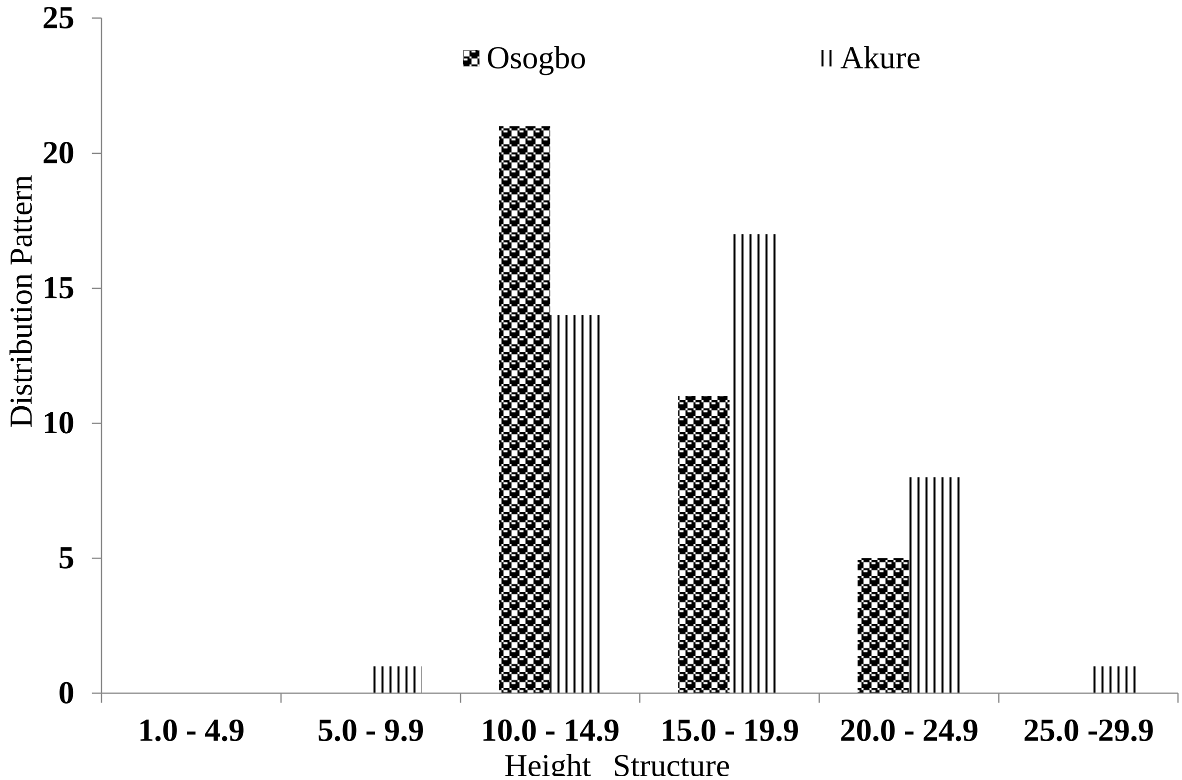

Figure 3: Height distribution of urban tree species in Osogbo and Akure

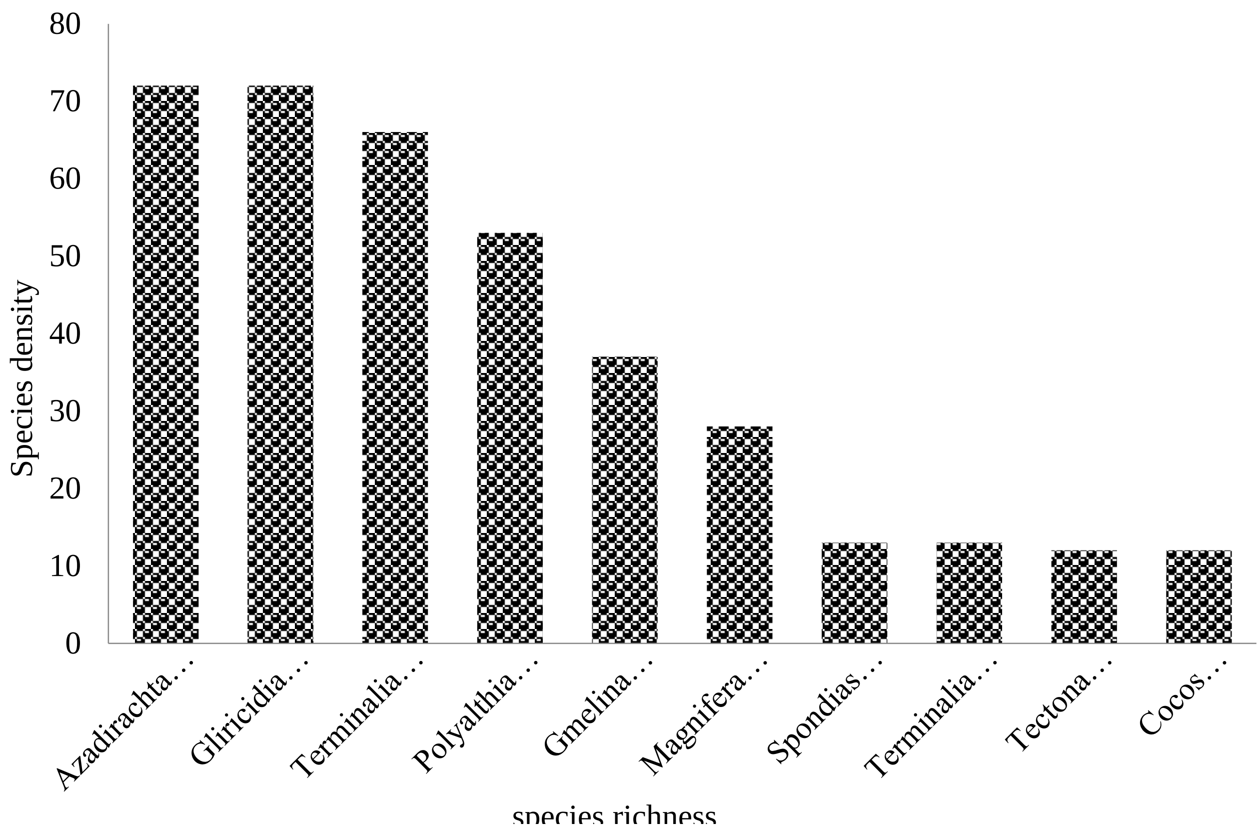

Figure 4: Ten tree species with the highest relative abundance in Osogbo.

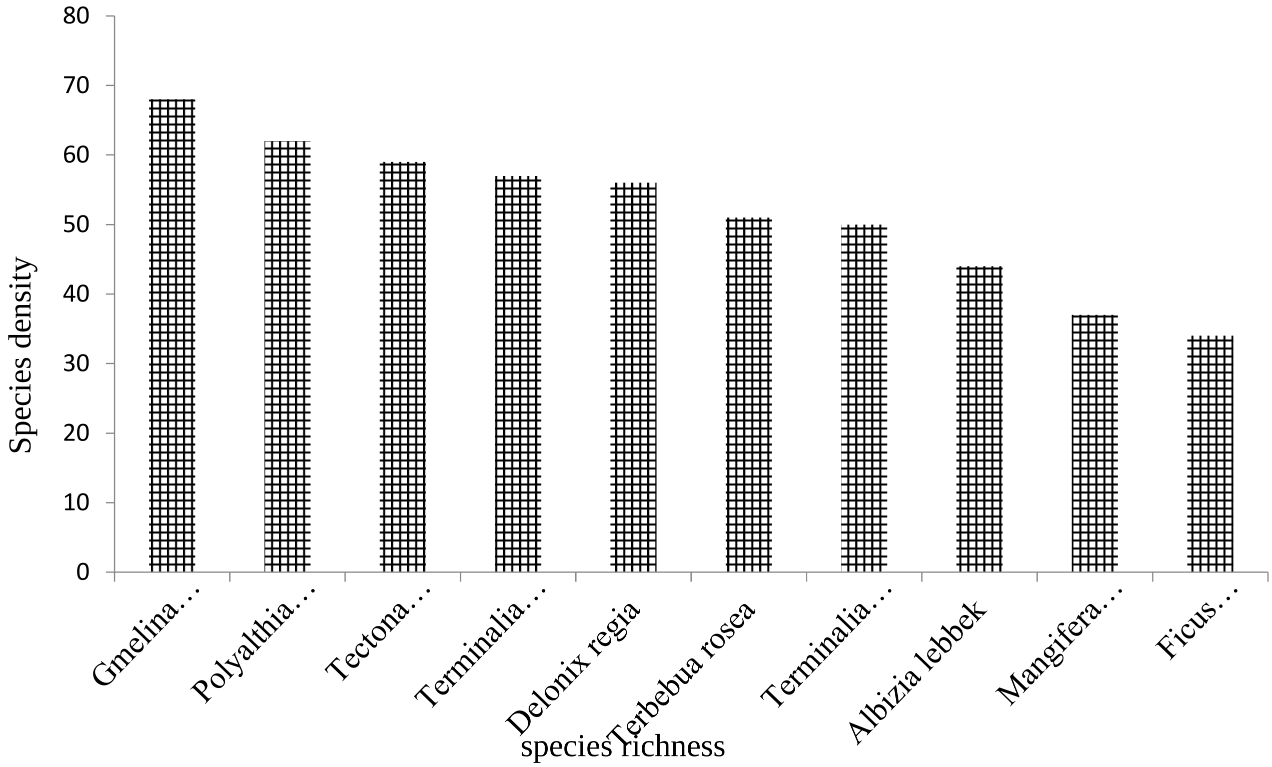

Figure 5: Ten tree species with the highest relative abundance in Akure

Relationship between urban tree structure, species diversity and biomass

The relationship between tree structure and biomass for the two cities (Osogbo and Akure) are presented (Figure 6). The relationship between measures of species diversity (Shannon-Wiener diversity index), forest structure (volume), and biomass indicated linear regression model for the cities (Figure 6). Positive linear patterns fitted best for the relationship between volume and biomass in the two cities in these urban forests. The estimated biomass in Osogbo had significantly higher mean for volume (35.67, SD = 7.61), compared to the Akure biomass estimates to volume (M = 19.38, SD = 6.98; t = 1.03; df = 32; p = 3.06). The relationship indicated strong positive correlation between volume and biomass (r = 0.978; 0.990, p = 0.05) between species diversity and biomass. The relationship between volume and biomass was not significant. The linear regression for Osogbo was ($y = 0.770x + 0.110$, $R^2 = 0.956$), and Akure was ($y = 0.685x + 2.184$, R2 = 0.932) for volume against biomass estimation in the two urban forests respectively (Figures 6).

Positive linear patterns fitted best for the relationship between Shannon-Wiener diversity index and biomass in the two cities within the urban forests. The estimated biomass in Osogbo had significantly higher mean for Shannon-Wiener diversity index (46.78, SD = 8.39), compared to the Akure biomass estimates against Shannon-Wiener diversity index (M = 22.24, SD = 8.93; t = 0.97; df = 32; p = 2.99). The relationship indicated strong negative correlation between diversity index and biomass (r = 0.678; 0.495, p = 0.002) between species diversity and biomass. The relationship between species diversity and biomass was not significant. The linear regression for Osogbo was ($y = 21.518x + 4.727$, $R^2 = 0.004$), and Akure was ($y = -5.497x – 27.286$, $R^2 = 0.0001$) for volume against biomass estimation in the two urban forests respectively (Figures 6).

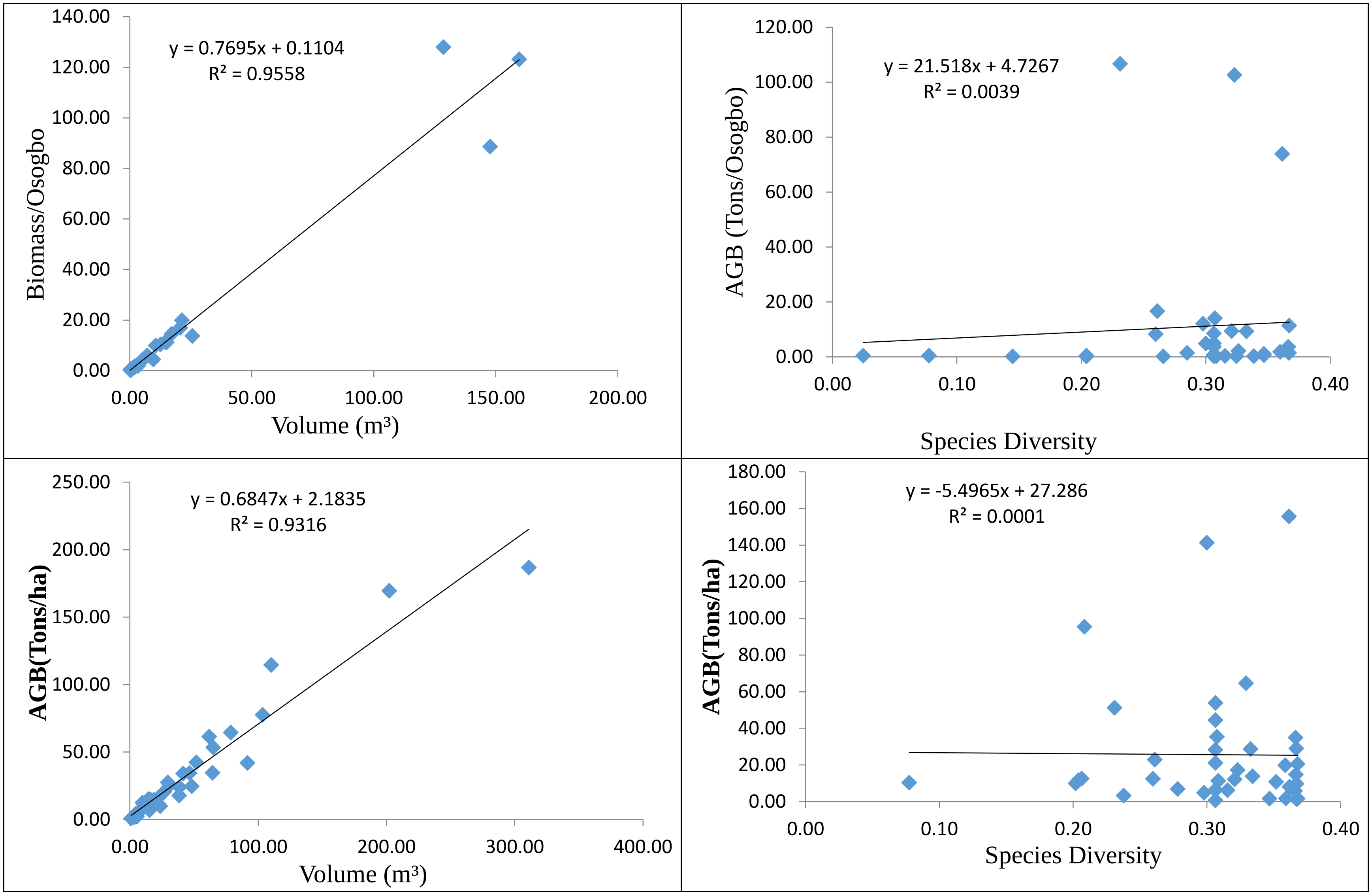

Figure 6: Relationship between biomass and urban tree structure in Akure and Osogbo.

DISCUSSIONS

The assessment of tree diversity, carbon storage, volume yield, biomass and forest structure result showed that the urban forests of both Osogbo and Akure have the potential to provide different ecosystem services to the environment and the population. Tree species that were found in the two cities belong to both indigenous and exotic tropical hard wood tree species as also reported by (Agbelade and Onyekwelu 2020). The species composition of these cities has the potential to sequestrate carbon, serve as reservoir for biodiversity; mitigate the effect of climate change; conserve ecosystem services and functions. This could reduce the challenges of urbanization, together with climate change, which has become the biggest environmental problem worldwide, resulting in increased carbon emissions and land surface temperature (Agbelade *et al.* 2022). Urbanization has greater effects on landscape green vegetation cover and conservation of diversity of forests, with significant influence on the structure and ecological functions of urban vegetation ecosystems (McHale *et al.* 2009; Agbelade *et al*. 2022). The results of this study have provided avenue to identify the challenges of urbanization and ways to mitigate the challenges through increase forests coverage of the urban environment.

Forest structure and Tree species diversity

The urban forests in these cities (Osogbo and Akure) were dominated by Fabaceae, Moraceae, Araceae and Meliaceae. Adekunle *et al*. (2014); Agbelade and Onyekwelu (2020) in their studies reported that tropical rainforest ecosystems of southwest Nigeria are dominated by some specific families such as the Sterculiaceae, Meliaceae, Moraceae and Ebenaceae. Tree stem volume at stand level has been reported to be the most important parameters in forest management, and the acquisition is very time-consuming and expensive (Adekunle *et al*. 2014). The volume obtained for the two urban areas; Osogbo (627.38 m^3) and Akure (1708.9 m^3) are higher when compared to Wittmann *et al*. (2008) who estimated volume of (259.45 m^3/ha) for Southern Pantanal, Brazil and similar when compared to that of Osogbo urban areas (627.38 m^3) because Italian Alps multilayer forest areas volume ranged from (174.40–777.38 m3/ha), (Tonolli *et al*. 2011). Analytical method of volume estimation could be considered the most accurate due to the formula which comprises of all the variables measured; diameter at the base (Db), diameter at the middle (Dm) and diameter at the top (Dt).

Urban forest trees composition and diversity

The estimated Shannon-Wiener diversity index was H′ = 2.65 for Osogbo and H′ = 3.42 for Akure. Adekunle *et al*., (2013) estimated 3.74 Shannon-diversity for Akure strict Nature Reserve, 2.12 for Eda protected forest, Agbelade *et al*., (2017) estimated 3.08 Shannon-diversity for Minna urban forest, and 3.56 Shannon-diversity for Abuja urban forest. Senbeta and Denich (2006) estimated Shannon diversity of 3.17 for Bonga forest which is higher compared to Osogbo = (2.65) and lesser compared to Akure = (3.42), 2.83 for Berhane-Kontir forest which is higher compared to Osogbo = (2.65) and lesser compared to Akure = (3.42), 2.60 for Harenna forest which is lesser compared to both Osogbo = (2.65) and Akure = (3.42) and 2.80 for Yayu forest which is higher compared to Osogbo = (2.65) and lesser compared to Akure = (3.42). There is a general relationship between biodiversity and ecosystem services.

Carbon storage capacity of the urban forest

The average carbon sequestration in the study areas were (60.58 tons/ha) and (150.36 tons/ha) in urban forests of Osogbo and Akure respectively. This value is less than the recorded urban forest in Addis Ababa, Port Harcourt and Ilorin (Woldegerima *et al.* 2017; Agbelade and Onyekwelu 2020). The average carbon density of 172 tons/ha of the urban forest of Addis Ababa is more than 33.22 tons/ha average carbon density recorded for urban forest of Shenyang, China (Liu and Li 2012). Carbon storage in urban forest areas of these cities are on the decline due to development of infrastructures as a result of urbanization and increase in rural-urban migration. The carbon sequestration in the study areas of Port Harcourt and Ilorin urban forests varied with the vegetation zones and climatic conditions of these locations 136.15 tons/ha and 7.82 tons/ha respectively (Agbelade *et al*. 2020). Tesfaye, (2007) reported carbon density of 403 tons/ha for a dry afromontane forest in central Ethiopia. This is assumed to correct because forest reserved areas tend to sequestrate carbon than the cities most especially in the developing countries.

CONCLUSION

The tree species diversity, biomass and carbon density estimates acquired in this study suggest that urban forests has the potential to sequester, store high volume of carbon and serve as biodiversity reservoir. The estimated volume of biomass and carbon is comparable to the mean carbon storage of some forest reserves in Nigeria. The results of this research have provided information on carbon accumulation and tree diversity conservation of these cities for healthy urban forest ecosystems functions. This study has revealed the potentials of urban forest to sequestrate carbon in Osogbo and Akure metropolis but high-level conservation is required most especially in Osogbo to improve the forested coverage of the city. However, the vulnerability of these cities to increased anthropogenic activities due to urban expansion and impacts of climate change threatens the existence of urban forests to perform the required ecosystem functions and services to the environment. It is believed that improved management of urban forest would increase the carbon storage potential and the provision of other ecosystem services. Moreover, further study is recommended on developing biomass and allometric equations for different urban forests which are highly important for carbon trading for green economy in Nigeria.

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