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Assessing Urban Forest Structure and Carbon Sequestration in Kano Metropolis, Kano State Nigeria

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ABSTRACT

Urban forests are critical carbon sinks and microclimate regulators, but their structure and sequestration potential remain underexplored in semi-arid African cities. This study quantified the structural characteristics, aboveground biomass (AGB), and carbon stock of urban forests in Kano Metropolis, Nigeria. Field inventory was conducted across institutional grounds, residential areas, parks, and roadside plantings. The following data were collected on all the sample trees such as the species identity, diameter at breast height (DBH), and total height. Biomass was estimated non-destructively using Pantropical allometric equation and converted to carbon using a 0.5 factor. Structural parameters such as DBH distribution, basal area, and density were also computed. Results revealed dominance of Azadirachta indica and Mangifera indica, which together comprised more than 60% of individuals. While most trees were small-sized (DBH < 30 cm), a few large trees (>60 cm DBH) accounted for more than half of total biomass. Total AGB was estimated at 7,858.17 tons, equivalent to 3,929.08 tons of carbon stock. Institutional grounds and parks stored the highest biomass per unit area. These findings demonstrated the ecological value of urban forests in carbon storage but also highlight structural vulnerabilities due to species dominance. Sustainable management should prioritize species diversification, protection of large-diameter individuals, and integration of AGB estimates into urban climate action plans.

Keywords: *Urban forest structure, aboveground biomass, carbon sequestration, semi-arid*

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INTRODUCTION

Urban forests provide essential ecosystem services, including microclimate regulation, stormwater control, and carbon sequestration (Escobedo *et al*., 2009; McPherson *et al*., 1997). Globally, studies show that large-canopy trees disproportionately contribute to aboveground biomass (AGB) and carbon storage (Nowak & Crane, 2002; Nero *et al*., 2018). In the context of climate change, quantifying AGB in urban areas has become central to climate adaptation and mitigation policies. Despite rapid urbanization across sub-Saharan Africa, few studies have empirically quantified the biomass and carbon storage potential of urban forests in semi-arid cities. Nigerian studies reveal species dominance by *Azadirachta indica* and *Mangifera indica* (Dangulla *et al*., 2019; Agbelade & Onyekwelu, 2020), reflecting ecological adaptation but raising concerns over resilience. This study focuses on Kano Metropolis, Nigeria's largest northern city, where urban forests are under increasing pressure from development. The objectives are to characterize the structural attributes of urban forests in Kano; estimate aboveground biomass and carbon stock, assess the distribution of biomass across the land-use types.

Tree height is a key structural attribute that significantly influences the estimation of aboveground biomass (AGB) and, by extension, carbon stock. Height reflects vertical growth, light competition strategies, and overall tree vigor, and is often correlated with stem volume and biomass accumulation (Goodman, Phillips, & Baker, 2014). In combination with diameter at breast height (DBH) and wood density, tree height enables more precise biomass estimations by capturing variation in tree form and taper that DBH alone cannot fully explain (Chave *et al*., 2014). From a geometric standpoint, tree volume is proportional to the product of basal area and height; thus, height serves as a multiplier that scales cross-sectional area into total stem and branch volume (Brown, 1997). Biomass is essentially the mass of woody tissue, height plays an essential role in converting two-dimensional diameter measurements into three-dimensional volume estimates. Trees with the same DBH but greater height typically have more woody volume and biomass, assuming similar crown architecture and wood density (Feldpausch *et al*., 2012).
However, most modern allometric models incorporate height to reduce bias and improve transferability across forest types. Chave *et al.* (2014) demonstrated that adding height to DBH–wood density models reduced biomass estimation errors by up to 20% in tropical forests, particularly in regions where height–diameter relationships differ from the datasets used to build DBH only models. This improvement is especially relevant for heterogeneous urban forests where open-grown trees may develop broader crowns and shorter heights compared to forest-grown counterparts, altering the DBH–height ratio (Nowak & Crane, 2002). Several studies in tropical and subtropical regions have confirmed a positive correlation between height and AGB. Similarly, in African savanna ecosystems, Feldpausch *et al.* (2011) found that accounting for height significantly improved the accuracy of biomass estimates, as height varies considerably among species and with site conditions. The implication is that, neglecting height may lead to systematic over- or underestimation of biomass depending on local growth forms.

Structural attributes, particularly DBH and tree height, were found to be critical predictors of biomass and carbon storage, with larger, mature trees contributing enormously to total carbon pools despite representing a smaller fraction of total stems. The diameter class distribution showed a reverse J-shaped pattern, with a higher frequency of trees in the smaller DBH classes and progressively fewer individuals in larger classes. This pattern is characteristic of regenerating or sustainable populations, where recruitment of young trees is ongoing. However, the relatively low number of individuals in the largest size classes suggests that few trees have reached full maturity, which could be a result of past removals, urban development pressures, or species longevity traits. In terms of height distribution, most trees fell within the medium height classes, with fewer individuals in the tallest category. This reflects the influence of species growth rates, site conditions, and urban management practices such as pruning for infrastructure clearance. Structural diversity, as evidenced by the variation in size and height classes, is ecologically beneficial as it supports a variety of ecosystem services including shade provision, habitat diversity, and resilience to pests and diseases.

Carbon stock is derived from AGB by applying a carbon fraction (usually 0.50 as per IPCC, 2006), meaning that any improvement in biomass estimation directly improves carbon stock estimates. As such, incorporating height into AGB models ensures that carbon accounting more accurately reflects actual standing stocks, especially in policy-relevant contexts such as urban carbon offsetting and climate mitigation reporting (Nowak *et al*., 2013). In urban environments, tree height varies widely due to species selection, site constraints, and management practices like pruning. Nowak *et al*. (2013) found that urban plots containing taller, mature trees had disproportionately higher biomass and carbon storage per hectare, despite sometimes having fewer stems overall. For example, in South-Western Nigeria, Agbelade & Onyekwelu (2020) assessed carbon stock of Ibadan and Ilorin metropolis, and reported that height was strongly correlated with biomass in institutional grounds and parks, where trees experience less pruning and better growth conditions compared to roadside plantings. In semi-arid West African cities like Kano, height–AGB relationships may differ from humid tropics because of water stress, soil limitations, and drought-tolerant species with inherently shorter stature (Dangulla *et al*., 2021). This ecological constraint means that height alone is a weaker predictor of biomass unless paired with DBH and wood density. Nonetheless, taller specimens of *Azadirachta indica*, *Khaya senegalensis*, and *Mangifera indica* tend to store significantly more biomass and carbon than smaller individuals, reinforcing the importance of height in urban biomass assessments. Accurate height measurement in urban inventories can be challenging due to obstruction by buildings, power lines, and irregular tree forms. Clinometers, can be used, but measurement error should be minimized, as small percentage errors in height propagate into biomass and carbon estimates (Goodman *et al.*, 2014). Understanding biomass distribution across these pools enables urban forest managers to make informed decisions about species selection for carbon sequestration and planning climate change mitigation strategies

MATERIALS AND METHODS

The Study Area

Kano Metropolis, covering Fagge, Tarauni, Nasarawa, Dala, and Kano Municipal LGAs. The metropolis lies in a semi-arid climate with an average annual rainfall of about 800 mm, concentrated between June and September, and a prolonged dry season with an average daily temperature usually of about 35°C. The city is undergoing rapid urban expansion leading to fragmentation of green spaces. The vegetation is categorized as the typical of Sudan Savannah ecosystem of northern Nigeria which is predominantly comprised of scattered xerophytic trees with a continuous layer of grasses (Ahmed et al., 2010). The dominant tree species include: *Acacia spp, Azadirachta indica, Parkia biglobosa, Tamarindus indica, Anogeissus leiocarpus, Mangifera indica, Adansonia digitata*, *Ziziphus spp,* among others.

Sampling Procedure

The study adopted a stratified random sampling based on structural heterogeneity of the urban forests, coupled with uneven distribution of trees among green space types (Nero *et al.*, 2018). Field inventory was conducted by dividing the urban forests according to the existing land use types such as parks, institutional grounds, residential areas, watersheds, farmlands, and roadside plantations form different strata. Stratified random sampling have been used by many scholars to study carbon stock of urban forests (Nowak & Crane, 2002; Josh *et al.*, 2021; Nero *et al.*, 2021, Dangulla *et al.*, 2021).

Data Collection

The inventory was conducted by earmarking of temporary sample plots of 30 m × 30 m using a distance measuring tape of 50 m length making 11 plots per hectare. A simple random sampling using balloting was used to select sample plots from each stratum. All trees within the selected plots with DBH ≥ 10 cm were identified, enumerated, and their DBH was measured with a girth tape in centimeters, and their height was measured with a Spiegel Relaskop in meters (Figure 1). Increment borer was used to collect wood samples at 1.30m above ground level for wood density estimation following the method used by Oke *et al.* (2020).

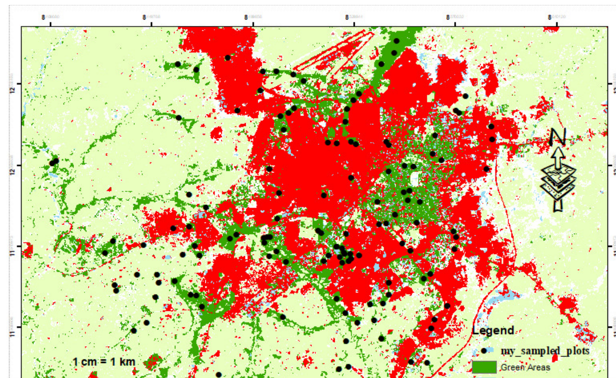

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Figure 1. Map of Study Area generated from Landsat Satellite Imagery (30m×30m) resolution.

Data Analysis

Tree Structure

Urban tree structural characteristics was analysed using the procedure used by Nero *et al.* (2021). The tree structural parameters include the tree total height, diameter at breast height (DBH), basal area and tree density were used to describe the urban forest structure (Magurran, 2004). The above-listed parameters were then used to describe the forest structure using the computed basal area, density, dominance, and importance value index (IVI).

Basal Area Computation

The basal area (BA) for each tree was calculated using the equation suggested by Husch et al. (2003), and it is mathematically presented as follows:

$$BA = \frac{\Pi D^2}{4} \quad (1)$$

where; BA = basal area in (m^2), pie (Π=3.142), D = DBH in (cm).

Tree Density Computation

Tree density is the number of individual trees per unit area and it is calculated as follows:

$$Species\ Density\ (ind/ha = \frac{number\ of\ individuals\ of\ a\ species}{total\ number\ of\ plots\ studied \times area\ of\ plot} \times 10000 \quad (2)$$

$$Relative\ density\ (\%) = \frac{density\ of\ a\ species}{density\ of\ all\ the\ species} \times 100 \quad (3)$$

$$Species\ frequency\ (\%) = \frac{no.of\ plots\ in\ which\ a\ species\ occured}{total\ number\ of\ plots\ sampled} \quad (4)$$

$$\text{Relative Frequency of a species} = \frac{\text{no. of quadrat a species appears}}{\text{total no. of quadrats sampled}} \times 100 \quad (5)$$

Species Importance Value Index (IVI)

Importance value index (IVI) is mainly for understanding the share of individual tree in an ecosystem class (Lahoti *et al.,* 2020a). The importance value for each species was calculated as the sum total of relative density, relative frequency, and relative basal area of the species constituted the IVI as used by Guo *et al.* (2023).

$$IVI = Relative\ density + Relative\ frequency + Relative\ dominance) \quad (6)$$

Volume Computation

Tree volumes were computed using Newton's volume formula as described by Avery &Burkhart (2002). The Newton's volume formula is mathematically presented as follows:

$$V = \frac{H}{6}[A_b + 4A_m + A_t] \quad (7)$$

Where V= tree volume (m^3), Ab = cross-sectional area at the base (m^2), Am = cross-sectional area at the middle (m^2), At = cross-sectional area at the top (m^2)
Cross-sectional area is expressed as follows:

$$A = \frac{\pi D^2}{4} \quad (8)$$

Where D is the diameter at breast height (cm). Therefore, substitute equation12 from equation13

$$V = \frac{\pi H}{24}[Db^2 + 4Dm^2 + Dt^2] \quad (9)$$

Where; V = Volume (m^3), h = height (m), Db = Diameter at the base (cm), Dm = Diameter at the middle (cm), Dt = Diameter at the top (cm), and pie = 3.142. The volume of every individual tree in the selected plots was summed up to obtain volume per plot. The mean volume per plot were then used to compute volume per hectare by multiplying it with the number of sample plots per hectare which is 11plots per hectare in this case.

Aboveground Biomass and Carbon Stock Estimation

Estimating aboveground biomass requires models that are based on forest parameters such as the Diameter at breast height (Dbh), tree height, and wood density (Brown, 1997; Chave *et al.*, 2014). In this study, improved allometric equation developed by Chave *et al.* (2014) for estimating biomass of tropical trees was used. While belowground biomass (BGB) was computed as a proportion of AGB (IPCC, 2006). Biomass values were converted to carbon using a 0.5 conversion factor (IPCC, 2007). The aboveground biomass and carbon stock distribution in the study area was computed and presented in (Figure 2). Aboveground biomass was determined using Pan-tropical allometric equation developed by Chave *et al.* (2014). The equation used breast height diameter, height and specific density of wood for calculating biomass. It is mathematically presented as follows:

$$AGB_{est} = 0.0673 \times (\rho D^2 \times H)^{(0.976)} \quad (10)$$

where AGB = above ground biomass (kg), ρ = wood density (g/cm3), D = tree DBH (cm), and H= tree height (m), 0.0673 and 0.976 are constants. In this research, Chave's biomass model was adopted based on its accuracy in estimating the aboveground biomass and carbon stock in tropical areas (Dangulla *et al.*, 2021; Nero *et al.*, 2018). The improved allometric equation was used to estimate aboveground biomass in tropical countries with semi-arid climate and recently, in the Savannah ecological zone of Nigeria, hence its selection (FAO Nigeria, 2020; Dangulla *et al.*, 2021).

Wood Density Estimation

The wood core density symbolizes as (ρ) was obtained by dividing mass by the wood volume as given in Equation.

$$D = \frac{mass}{volume} \quad (11)$$

Belowground Biomass Estimation

Belowground biomass can be estimated to be 20% of the aboveground biomass based on IPCC, (2006) recommendation, and it is mathematically presented below:

BGB=AGB×20%. (12)

Carbon Stock (CS)

Carbon stock was determined by multiplying AGB by a conversion factor of 0.5 (50% of AGB) as established by IPCC, (2006), and the formula is presented below:

AGB×0.5% (13)

Carbon Sequestration

The CO_2 equivalent was obtained by multiplying the total carbon stock with the ratio of the molecular weight of carbon to that of oxygen (i.e. 44/12) or 3.67 as recommended by IPCC, (2006), FAO Nigeria, (2020).

$$TCS \times 3.67 \quad (14)$$

RESULTS AND DISCUSSION

Tree Structure

A total of 623 trees were recorded within 154 established temporary sample plots distributed across the existing land use types. The following tree parameters such as mean diameter at breast height symbolizes as (M. Dbh), m.Ht (mean height), m.BA (mean basal area), and M. Vol (mean volume) provide insight into the structural characteristics of the species (Table 1). RF (relative frequency), RD (relative dominance), and RDO (relative density) highlight the distribution and abundance of species. The importance value index (IVI) combines these parameters to rank species by their ecological significance (Avery & Burkhart, 2002). In this study, *Azadirachta indica* had the highest IVI=26.18, followed by *Anacardium occidentale* and *Eucalyptus camaldulensis* with the IVI=15.41 and 15.24 respectively emerging as the key species. The mean values of Dbh and height exhibit a wide range, with Dbh spanning from the lowest 19.4 cm to the highest 80.7 cm, whereas the mean height ranges from 10.8 m to 25.7 m. Similarly, the mean basal area ranges from 0.5 to 5.1 m^2, and mean volume of 2.32 to 19.13 m^3. Structurally, *Adansonia digitata* had the highest mean diameter at breast height (Dbh) of 80.7 cm, followed by *Azadirachta indica* (60.8 cm) and *Faidherbia albida* (56.3 cm). The data highlights the heights of various tree species, with *Mangifera indica* reaching the highest mean height of 25.7 m, followed closely by *Azadirachta indica* (23.0 m), *Parkia biglobosa* (22.9 m), *Faidherbia albida* (22.5 m), *Ficus sycomorus* (20.4 m), and *Hyphaene thebaica* (20.1 m). The data also shows that *Mangifera indica* has the highest mean tree volume of 19.13 m^3, followed by *Adansonia digitata* with 17.67 m^3, and *Ficus platyphylla* with 13.84 m^3.

Aboveground Biomass and Carbon Stock

The results show that the total aboveground biomass (AGB) for the sampled urban trees in Kano Metropolis was estimated 7,858.17 tons, corresponding to a carbon stock (CS) of 3,929.08 tons and CO_2 equivalent of 14,537.61 tons. The mean AGB was 296.83 tons ha^{-1}, while the mean belowground biomass (BGB) was 59.37 tons ha^{-1}, reflecting the significant contribution of root biomass to total carbon storage. These values underscore the role of urban forests as important carbon sinks, even within the constraints of a highly urbanized landscape. The high variation in biomass values across sampling plots can be attributed to differences in species composition, tree size distribution, and site-specific conditions such as soil fertility and management practices. Species with larger DBH and higher wood density, such as *Azadirachta indica* and *Mangifera indica*, contributed disproportionately to total biomass and carbon stock. Among the urban land use types, the results revealed that the highest AGB & Carbon Stock were recorded in Green Areas (AGB ≈ 930.33 tons; C ≈ 558.20 tons) as shown in (Figure 2). This was closely followed by Roadside Trees with (AGB ≈ 444.10 tons; C ≈ 266.46 tons). On the other hand, the lowest (AGB ≈ 40.60 tons; C ≈ 24.36 tons) was recorded in Industrial Areas. The findings align with previous studies indicating that urban green areas and roadside plantations act as major carbon sinks due to tree density and species composition (Nowak & Crane, 2002; McPherson *et al*., 2013). In contrast, industrial zones and agricultural lands typically have lower tree biomass and, consequently, lower carbon storage (FAO, 2020). The variation among forest types highlights the influence of land use, vegetation management, and species diversity on carbon sequestration potential. However, compared to other tropical urban forests, the biomass and carbon stock in Kano Metropolis fall within the lower-to-moderate range. For example, urban forests in more humid climates often record higher biomass values due to faster growth rates and larger mature tree populations. Nonetheless, considering the city's semi-arid climatic conditions, the recorded values are significant and highlight the potential of urban greening in semi-arid zones for climate change mitigation. The estimated CO_2 equivalent of 14,537.61 tons demonstrates the capacity of Kano's urban trees to offset anthropogenic greenhouse gas emissions. Although urban forests cannot fully neutralize city-wide emissions, however, their contribution to carbon sequestration, combined with their microclimate regulation and air quality benefits, make them a vital component of sustainable urban development strategies.

Biomass and Carbon Storage Capacity by Different Urban Tree Species

The aboveground biomass and carbon storage capacity of every sampled tree species was computed in the field using equation (17), and the results are presented in (Table 2). It showed that *Azadirachta indica* had the highest AGB 259.2 tons (27.3% of total) and carbon stock (27.3%), BGB 51.84 tons, T.B 311.04 tons, and C.S 155.52 tons, among all the tree species in the study area. Similarly, *Eucalyptus camaldulensis* is another notable species in terms of carbon stock with the estimated AGB of 187.5 tons, BGB of 37.5 tons, T.B of 225 tons, and C.S of 112.5 tons respectively. Whereas, *Ziziphus spina-christi* and *Piliostigma reticulatum* had the least AGB 5.6 tons, BGB 1.12 tons, T.B 6.72 tons, C.S 3.36 tons, and AGB tons 4.1, BGB 0.82 tons, T.B 4.92, and C.S of 2.46

Table 1: Tree Species Composition and Structural Characteristics.

SN	Tree Species	Family	N	Dbh	H	BA	Vol.	RF	RD	RDO	IVI
1	*Acacia nilotica*	Fabaceae	4	51.8	14.7	2.1	6.72	3.04	8.64	4.86	8.54
2	*Acacia seyal*	Fabaceae	3	41.0	11.7	1.3	6.15	3.60	2.88	4.90	11.38
3	*Adansonia digitata*	Malvaceae	8	80.7	13.8	5.1	17.67	5.04	4.12	1.45	10.60
4	*Albizia lebbeck*	Fabaceae	15	41.0	13.0	1.3	8.42	3.60	2.06	3.19	8.85
5	*Anacardium occidentale*	Anacardiaceae	25	32.2	13.9	0.8	4.90	5.04	5.76	4.61	15.41
6	*Anogeissus leiocarpus*	Combretaceae	12	37.8	12.9	1.1	4.64	5.76	4.94	3.14	13.83
7	*Azadirachta indica*	Meliaceae	170	40.8	18.8	3.3	13.84	15.76	17.41	8.02	26.18
8	*Balanite aegyptiaca*	Zygophyllaceae	2	51.4	10.8	2.1	6.06	2.19	4.94	2.80	10.94
9	*Borassus aethiupum*	Arecaceae	7	43.5	18.2	1.5	6.42	3.60	5.35	2.55	11.50
10	*Boswellia odorata*	Burseraceae	2	41.1	13.7	1.3	7.67	0.72	0.41	7.21	8.34
11	*Cassia siamea*	Fabaceae	7	41.6	14.4	1.4	9.54	2.88	1.65	3.35	7.88
12	*Ceiba pentandra*	Malvaceae	6	40.6	14.0	1.3	8.90	2.16	1.65	3.29	7.09
13	*Combretum glutinosum*	Combretaceae	2	33.4	13.3	0.9	5.66	0.72	0.41	4.45	7.58
14	*Delonix regia*	Fabaceae	4	39.2	15.0	1.2	8.67	1.44	1.23	4.73	7.40
15	*Diospyrus mespiliformis*	Ebenaceae	3	54.8	17.3	2.4	9.00	2.88	2.06	2.43	7.36
16	*Eucalyptus camaldulensis*	Myrtaceae	54	43.4	15.2	1.5	9.28	4.32	6.17	4.76	15.24
17	*Faidherbia albida*	Fabaceae	6	60.8	22.5	2.9	7.21	3.60	4.12	3.12	10.83
18	*Ficus platyphylla*	Moraceae	5	56.3	23.0	2.5	6.17	3.60	2.47	3.03	8.09
19	*Ficus polita*	Moraceae	30	32.1	14.4	0.8	2.61	1.44	0.82	2.91	5.17
20	*Ficus sycomoros*	Moraceae	13	50.8	20.4	2.0	8.13	2.16	1.65	3.01	6.82
21	*Hyphaene thebaica*	Arecaceae	22	51.6	20.1	2.1	4.89	1.44	3.29	3.20	7.93
22	*Khaya senegalensis*	Meliaceae	63	51.4	13.5	2.1	5.61	2.16	1.65	2.34	9.15
23	*Mangifera indica*	Anacardiaceae	5	54.5	25.7	2.3	19.13	2.88	4.12	2.38	17.38
24	*Parkia biglobosa*	Fabaceae	13	50.3	22.9	2.0	9.56	3.60	3.29	2.75	9.64
25	*Phoenix dactylifera*	Arecaceae	36	41.2	16.4	1.3	4.24	4.32	4.12	3.36	10.79
26	*Piliostigma reticulatum*	Fabaceae	2	28.3	17.8	0.6	3.27	4.32	4.53	3.27	12.11
27	*Sygzigium guineense*	Myrtaceae	32	26.3	13.6	0.5	4.31	2.16	2.06	1.49	5.70
28	*Tamarindus indica*	Fabaceae	24	34.0	14.2	0.9	5.44	2.16	3.70	0.87	6.73
29	*Terminalia mantaly*	Combretaceae	41	19.4	11.7	1.2	5.17	2.88	2.06	0.93	8.86
30	*Vitex doniana*	Lamiaceae	4	44.8	12.4	1.6	3.68	0.72	0.41	3.37	4.50
31	*Ziziphus spina-christi*	Rhamnaceae	3	38.8	10.8	1.2	2.32	2.88	2.06	1.24	6.18
	TOTAL		623					100	100	100	300

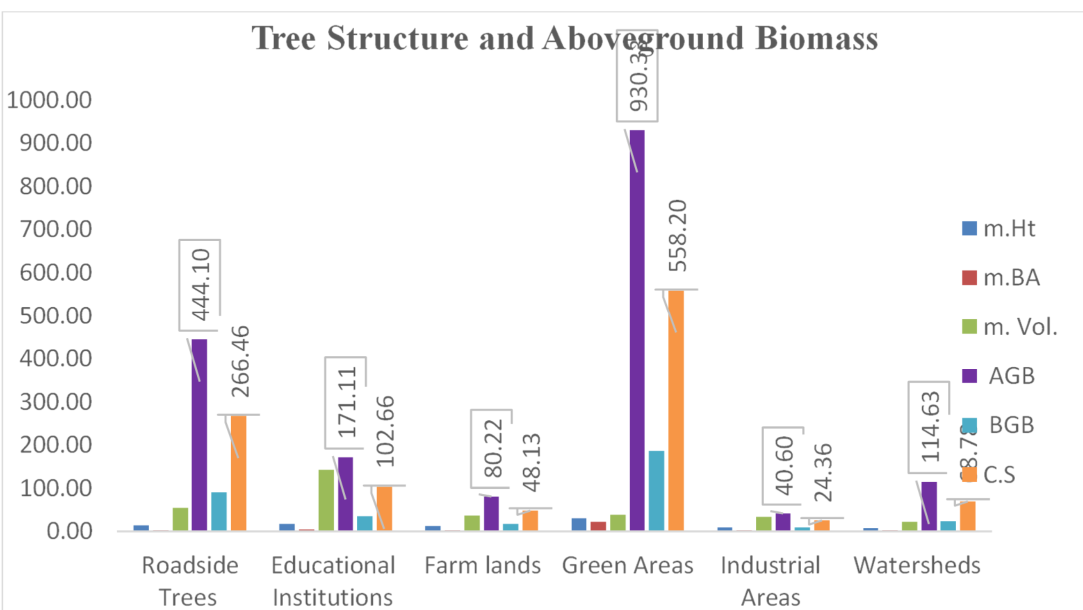

Figure 2: Summary of AGB and Carbon Stock across Urban Forest Types

Table 2. Shows Structure, Biomass and Carbon Storage Capacity of Urban Trees in tons.

Tree Species	Family	N	M.Dbh	M.ht	M.BA	M.Vol.	AGB	BGB	T. B	C.S
Acacia nilotica	Fabaceae	4	51.8	14.7	2.12	6.72	13.3	2.66	15.96	7.98
Acacia seyal	Fabaceae	3	41.2	11.7	1.31	6.15	6.99	1.398	8.388	4.194
Adansonia digitata	Malvaceae	8	80.7	13.8	3.10	17.67	115.6	23.12	138.72	69.36
Albizia lebbeck	Fabaceae	15	41.1	13.1	1.32	8.42	5.8	1.16	6.96	3.48
Anacardium occidentale	Anacardiaceae	25	32.2	13.9	0.81	4.9	12.9	2.58	15.48	7.74
Anogeissus leiocarpus	Combretaceae	35	57.8	32.9	5.10	4.64	187.5	37.5	225	12.5
Azadirachta indica	Meliaceae	157	50.8	28.8	4.30	13.84	259.2	51.84	311.04	155.52
Balanite aegyptiaca	Zygophyllaceae	2	21.4	10.8	2.16	6.06	13.3	2.66	15.96	7.98
Borassus aethiupum	AArecaceae	7	43.5	18.2	1.55	6.42	7.9	1.58	9.48	4.74
Boswellia odorata	Burseraceae	2	41.1	13.7	1.34	7.67	6.7	1.34	8.04	4.02
Senna siamea	Fabaceae	7	41.6	14.4	1.46	9.54	25.9	5.18	31.08	15.54
Ceiba pentandra	Malvaceae	12	40.6	14.0	1.38	8.90	31.6	6.32	37.92	18.96
Combretum glutinosum	Combretaceae	2	33.4	13.3	0.99	5.66	6.1	1.22	7.32	3.66
Delonix regia	Fabaceae	4	39.2	15.1	1.28	8.67	7.9	1.58	9.48	4.74
Diospyrus mespiliformis	Ebenaceae	3	54.8	17.3	2.46	9.00	18.2	3.64	21.84	10.92
Eucalyptus camaldulensis	Myrtaceae	74	43.4	25.2	1.55	9.28	139.7	27.94	167.64	83.82
Faidherbia albida	Fabaceae	6	60.8	22.5	2.95	7.21	28.9	5.78	34.68	17.34
Ficus platyphylla	Moraceae	5	56.3	23.2	2.50	6.17	52.1	10.42	62.52	31.26
Ficus polita	Moraceae	20	32.1	14.4	0.80	2.61	14.4	2.88	17.28	8.64
Ficus sycomoros	Moraceae	13	50.8	20.4	2.20	8.13	13.6	2.72	16.32	8.16
Hyphaene thebaica	Arecaceae	11	51.6	20.1	2.12	4.89	10.5	2.1	12.6	6.3
Khaya senegalensis	Meliaceae	53	51.4	13.5	2.11	5.61	113.5	22.7	136.2	68.1
Mangifera indica	Anacardiaceae	15	54.5	25.7	2.31	19.13	175	35.0	210.0	105.0
Parkia biglobosa	Fabaceae	13	50.3	22.9	2.31	9.56	110.2	22.04	132.24	66.12
Phoenix dactylifera	Arecaceae	16	41.2	16.4	1.33	4.24	106.7	21.34	128.04	64.02
Piliostigma reticulatum	Fabaceae	2	28.3	17.8	0.61	3.27	4.1	0.82	4.92	2.46
Sygzigium spp	Myrtaceae	32	26.3	13.6	0.51	4.31	115	23	138	69.0
Tamarindus indica	Fabaceae	24	34.1	14.2	0.90	5.44	105.1	21.02	126.12	63.06
Terminalia mantaly	Combretaceae	46	19.4	11.7	1.23	5.17	71.5	14.3	85.8	42.9
Vitex doniana	Lamiaceae	4	44.8	12.4	1.62	3.68	9.5	1.9	11.4	5.70
Ziziphus spina-christi	Rhamnaceae	3	38.8	10.8	1.22	2.32	5.6	1.12	6.72	3.36
Total		623	43.7	17.11	1.83	7.26	1780.9	356.20	2137.2	1068.60

Where n= number of trees, M.dbh=mean diameter at breast height (cm), m.Ht=mean height (m), m.vol=m^3 AGB= aboveground biomass, BGB=belowground biomass, TB=total biomass, CS= carbon stock, CO_2_equiv. =carbon dioxide equivalent (tons/ha).

respectively. Several species, such as *Anacardium occidentale* and *Polyalthia longifolia*, contributed less than 1%, reflecting their low abundance and/or smaller size classes.

Tree Structure

Structurally, the DBH (diameter at breast height) distribution is skewed toward the lower classes (≤20 cm), indicating that much of the urban forest is relatively young. This is attributed to the ongoing planting programs and urban greening initiatives by Kano State Ministry of Environment. Although small-diameter trees currently contribute modestly to biomass and carbon stock, they represent significant future carbon sequestration potential if adequately maintained. Larger diameter classes (>50 cm), though less represented, are disproportionately important to ecosystem service provision particularly carbon storage, microclimate regulation, and habitat creation as confirmed by Chave *et al*. (2014) and Nowak *et al*. (2013). Protecting these mature individuals should be a key management priority. Height distribution patterns mirror the DBH findings, with a strong representation of medium-height trees (5–10 m) and fewer specimens exceeding 15 m. This suggests that while vertical structure exists, the urban forest has yet to develop a fully stratified canopy typical of mature and biodiverse systems. Canopy spread data further highlight the predominance of medium coverage classes (4–8 m), which contribute to shading, evapotranspiration cooling, and urban biodiversity. The limited number of broad-canopy trees (>10 m spread) represents an opportunity for strategic planting of species capable of achieving greater lateral coverage to enhance thermal comfort and storm water interception.

Tree Structure and Aboveground Biomass

Table 2 presents the statistical relationships between diameter at breast height (DBH), tree height (H), and aboveground biomass (AGB) for the urban trees of Kano Metropolis. The results indicated that strong positive correlations between DBH and AGB, and between height and AGB, with DBH exhibiting the strongest association ($P<0.05$). This pattern is consistent with numerous biomass studies in tropical environments, which consistently identify DBH as the single most important predictor of tree biomass due to its direct relationship with basal area and stem volume (Brown, 1997; Chave *et al*., 2014). The high Dbh–AGB correlation reflects the fact that trunk diameter integrates cumulative growth over time and serves as a reliable predictor for woody volume. Larger Dbh values generally indicate greater biomass accumulation, assuming similar wood density across trees (Henry *et al.*, 2011). Tree height also showed a positive correlation with AGB, which aligns with findings that taller trees tend to have greater total volume and thus higher biomass (Goodman *et al.*, 2014; Chave *et al.*, 2014). However, in many cases, the DBH–AGB relationship is stronger than the height–AGB relationship because height is more variable and can be influenced by environmental factors such as site conditions, light competition, and pruning practices common in urban landscapes (Nowak *et al.*, 2013). The combined influence of Dbh and height on AGB estimation underscores the advantage of multivariate allometric models. While Dbh alone can explain a large portion of biomass variation, adding height often improves model accuracy by accounting for tree form differences between species and size classes (Chave *et al.*, 2014). This is particularly relevant in heterogeneous urban forests, where species diversity and management regimes produce a wide range of canopy shapes and stem tapering patterns. From the management perspective, these relationships confirm the practical value of including Dbh measurements as the core variable in urban biomass inventories, with height as a useful supplementary parameter where measurement is feasible. In the context of carbon accounting, these findings validate the use of Dbh-based allometric equations as a robust approach to estimating urban forest carbon stocks, while highlighting that incorporating height can further refine estimates in diverse tree populations. The observed mean DBH suggests a predominance of mature individuals, which aligns with similar findings in Nigerian urban forestry studies (Fuwape & Onyekwelu, 2011; Agbelade & Onyekwelu, 2020). Similarly, species-level patterns in Kano Metropolis conformed to the findings of many studies in other Nigerian cities, where *Azadirachta indica* often dominates biomass and carbon storage due to its abundance, fast growth, and tolerance to urban stresses (Agbelade & Onyekwelu, 2020). The variation among forest types highlights the influence of land use, vegetation management, and species diversity on carbon sequestration potential.

Conclusion

Kano Metropolis exhibits a biomass and carbon stock structure dominated by the stem pool and by a few species, particularly *Azadirachta indica*. Although this configuration maximizes short-term carbon gains, it poses long-term resilience risks. Urban forestry policies should integrate biomass pool analysis with diversity metrics to guide planting programs. Increasing the representation of underutilized native species can improve both biodiversity and carbon stability in the urban forest. This involved measuring of cross-sectional area at breast height of all trees with Dbh ≥ 10 cm using a girth tape in centimeters as recommended by Husch *et al.* (2003), Avery & Burkhart, (2002). All trees with were identified, DBH measured with diameter tape, and height recorded using a clinometer. The biomass distribution aligns with Nero *et al.* (2018) and Nowak & Crane (2002), who emphasize the disproportionate role of large trees. Structural vulnerability is evident: loss of a few large individuals could substantially reduce carbon stock. Urban forestry policy in Kano should therefore prioritize protecting existing large trees, integrating native drought-tolerant species, and ensuring structural diversity. The findings align with previous studies indicating that urban green areas and roadside plantations act as major carbon sinks due to tree density and species composition (Nowak & Crane, 2002; McPherson *et al.*, 2013). In contrast, industrial zones and agricultural lands typically have lower tree biomass and, consequently, lower carbon storage (FAO, 2020). The variation among forest types highlights the influence of land use, vegetation management, and species diversity on carbon sequestration potential. Overall, the biomass and carbon storage potential in urban forests is strongly influenced by forest type, with structured and managed green areas playing a disproportionately large role. Finally, management strategies should prioritise the protection of large-diameter trees, and integrate AGB and carbon estimates into climate action plans to enhance urban resilience in semi-arid regions.

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