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Research Article

Assessment of growth, biomass, and carbon sequestration potential of three urban tree species in Calabar

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Abstract

Urban forests play a vital role in climate change mitigation by sequestering carbon and providing essential ecosystem services. This study assessed the growth, biomass accumulation, and carbon sequestration potential of three commonly planted urban tree species in Calabar, Nigeria: *Azadirachta indica*, *Delonix regia*, and *Terminalia mantaly*. A total of 100 trees per species were sampled across Calabar Municipality and Calabar South. Growth parameters, including diameter at breast height (DBH) and height, were recorded, and allometric equations were used to estimate aboveground biomass (AGB), aboveground carbon density (ACD), belowground carbon density (BCD), basal area (BA), and volume. Results indicated significant differences in DBH and height among species, with *Terminalia mantaly* exhibiting the highest values (DBH: 56.93 ± 3.42 cm; Height: 12.84 ± 0.26 m). However, AGB, ACD, BCD, BA, and volume did not differ significantly among species, despite *Terminalia mantaly* having the highest mean values. Strong positive correlations were observed between DBH and AGB (r = 0.87), ACD (r = 0.87), BCD (r = 0.87), BA (r = 0.89), and volume (r = 0.87), suggesting DBH as a key predictor of carbon sequestration potential. Conversely, tree height exhibited weak correlations with biomass parameters. The study highlights the comparable carbon sequestration potential of these species despite differences in growth traits, emphasizing the need for species-specific assessments to enhance urban forest planning. These findings contribute to sustainable urban management strategies aimed at maximizing the ecological benefits of urban trees.

Keywords: Biomass accumulation, urban forestry, allometric equations, carbon storage, ecological benefits

Introduction

Urban forests are critical in mitigating climate change, enhancing biodiversity, and improving air quality in cities worldwide. Trees in urban environments provide essential ecosystem services, including temperature regulation, stormwater management, and carbon sequestration (Kacprzak et al., 2024). As global urbanization accelerates, assessing the capacity of urban tree species to sequester carbon has become increasingly important for sustainable urban planning and climate resilience strategies (Kang et al., 2025).

Carbon sequestration by trees is largely influenced by their growth characteristics, biomass accumulation, and environmental adaptability (Akter et al., 2025). Urban trees experience unique challenges such as soil compaction, pollution, limited rooting space, and altered microclimates, which can significantly impact their growth and physiological functions (Czaja et al., 2020; Egerer et al., 2024). Numerous studies have examined urban tree biomass and carbon sequestration potential in various regions (Ariluoma et al., 2020; Steenberg et al., 2023; Nero et al., 2024), but knowledge gaps persist regarding the performance of specific tree species under different urban conditions, particularly in tropical and subtropical regions. Additionally, variations in tree allometry, wood density, and physiological adaptation necessitate region-specific analyses of tree species to provide better estimates of urban carbon sequestration.

This study assesses the growth, biomass accumulation, and carbon sequestration potential of *Azadrachta indica* A. Juss., *Delonix regia* (Bojer ex Hook.) Raf., and *Terminalia mantaly* H. Perrier, three commonly planted urban tree species in the southeast region of Nigeria. Growth parameters were measured, and allometric equations were used to estimate the biomass accumulation and carbon sequestration potential of the urban trees. The findings contribute to the growing body of literature on urban forest carbon dynamics, informing policy, urban planning, and environmental management professionals on maximizing the climate benefits of urban trees.

Material and methods

Study area

This study was conducted in Calabar Municipality and Calabar South, Nigeria, from December 2024 to February 2025. Calabar is situated at 4°58'N and 8°21'E within the coastal zone of Nigeria and experiences a tropical climate. The region receives an average annual rainfall exceeding 3000 mm during the wet season (Adefolalu, 1984; Uchenna et al., 2023).

Tree sampling

A total of 100 trees each of *Azadirachta indica* A. Juss, *Delonix regia* (Bojer ex Hook.) Raf, and *Terminalia mantaly* H. Perrier with diameters greater than 5 cm were sampled across both locations. Sampling was conducted along 100-meter transects, which were systematically positioned parallel to roadsides and green areas. The starting points for each transect were preselected using the OpenStreetMap layer in QGIS Version 3.2.23 Lima. For each tree, diameter at breast height (DBH) was measured at 1.3 m above the ground using a fiberglass diameter tape (Germany), while tree height was recorded using a Nikon Forestry Pro Laser Rangefinder (Japan).

Biomass and Carbon Density Assessment

Aboveground biomass (AGB), aboveground carbon density (ACD), belowground carbon density (BCD), basal area (BA) – the cross-sectional area of a tree trunk at the diameter at breast height, and volume were estimated using modified allometric equations developed by Chave et al. (2005), as cited in Fatimah et al. (2024).

$AGB = D^2Hpk$ - - - - - - - (1)

where: AGB = Aboveground biomass (t ha^{-1})

D = DBH (cm)

H = Tree height (m)

p = Wood density of the species (g cm^{-3})

k = Scaling constant for forest biomass estimation (*0.0673*)

$ACD = AGB \times u$ - - - - - - - (2)

where ACD = aboveground carbon density (t C ha^{-1})

u = Carbon fraction in biomass (0.47).

$BCD = ACD \times y$ - - - - - - - (3)

where BCD = belowground carbon density (t C ha^{-1})

y = Belowground-to-aboveground carbon ratio (0.24).

$BA = \pi(DBH^2/4)$ - - - - - - - (4)

where BA = the basal area in square meters (m^2) and is the cross-sectional area of a tree trunk at the diameter at breast height.

$\pi = 3.142$

$V = \pi(DBH^2/4) \times h$ - - - - - - - (5)

where V = volume

h = height

$\pi = 3.142$

Data analysis

Allometric equation-derived data were analyzed using R software. Analysis of variance (ANOVA) was used to determine significant differences among species, while Pearson's correlation analysis was used to assess relationships between DBH, height, AGB, ACD, BCD, BA, and volume. Results were presented in graphs and tables.

Table 1. Number of tree samples evaluated at Calabar Municipality and Calabar South

S/N	Species name	Calabar Municipality	Calabar South	Total
1.	*Azadirachta indica* A. Juss	71	29	100
2	*Delonix regia* (Bojer ex Hook.) Raf	44	56	100
3.	*Terminalia mantaly* H. Perrier	76	24	100

Results

Biomass and carbon density

The mean diameter at breast height (DBH) varied significantly among the three tree species ($p < 0.05$ (Fig. 1). *Terminalia mantaly* had the highest DBH (56.93 ± 3.42 cm) and was significantly larger than *Azadirachta indica* 48.43 ± 1.29 cm ($p < 0.05$). *Delonix regia* (54.55 ± 1.65 cm) showed moderate values, not differing significantly from either species. Tree height also showed significant variation across species. *Terminalia mantaly* was significantly taller 12.84 ± 0.26 m ($p < 0.05$) than *Azadirachta indica* 9.80 ± 0.21 m and *Delonix regia* 9.29 ± 0.90 m, which did not differ from each other (Fig. 2).

In contrast, aboveground biomass (AGB), aboveground carbon density (ACD), belowground carbon density (BCD), basal area (BA), and volume did not show significant differences among the species. Although *Terminalia mantaly* exhibited the highest mean AGB 2069.33 ± 628.48 t ha^{-1} and ACD 972.59 ± 295.39 t C ha^{-1}, these values were not statistically different from those of *Azadirachta indica* AGB 1107.65 ± 73.01 t ha^{-1}; ACD 520.60 ± 34.31 t C ha^{-1} or *Delonix regia* AGB 1094.00 ± 105.46 t ha^{-1}; ACD: 514.18 ± 49.57 t C ha^{-1} (Fig. 3 and Fig. 4). Similarly, BCD ranged from 124.94

± 8.24 to 233.42 ± 70.89 (Fig. 5), BA ranged from 19.71 ± 1.06 m^2 ha^{-1} to 34.53 ± 10.31 m^2 ha^{-1} (Fig. 6), and volume ranged from 20.20 ± 1.33 m^3 ha^{-1} to 45.57 ± 13.84 m^3 ha^{-1} (Fig. 7).

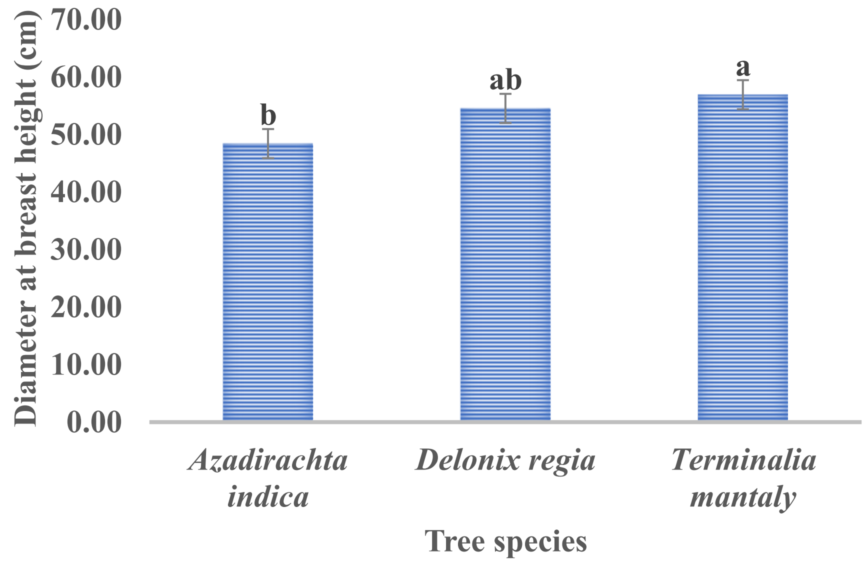

Figure 1. Mean diameter at breast height of *A. indica, D. regia, and T. mantaly*

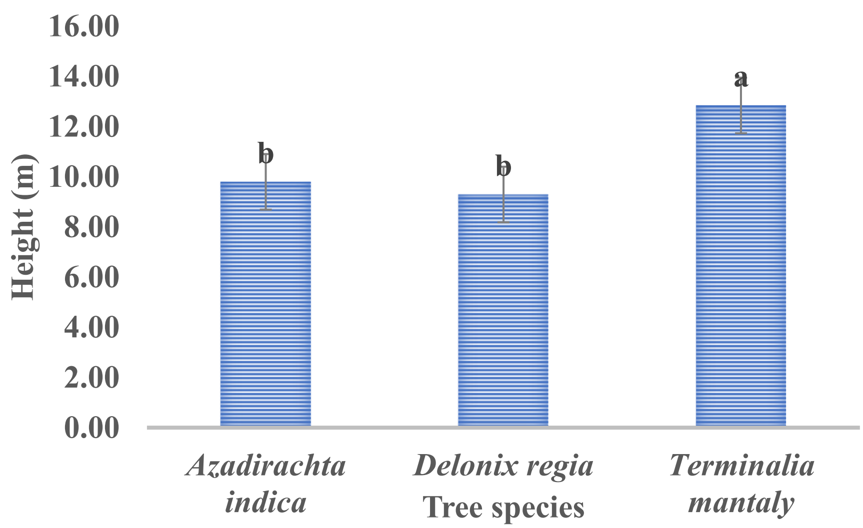

Figure 2. Mean height of *A. indica, D. regia, and T. mantaly*

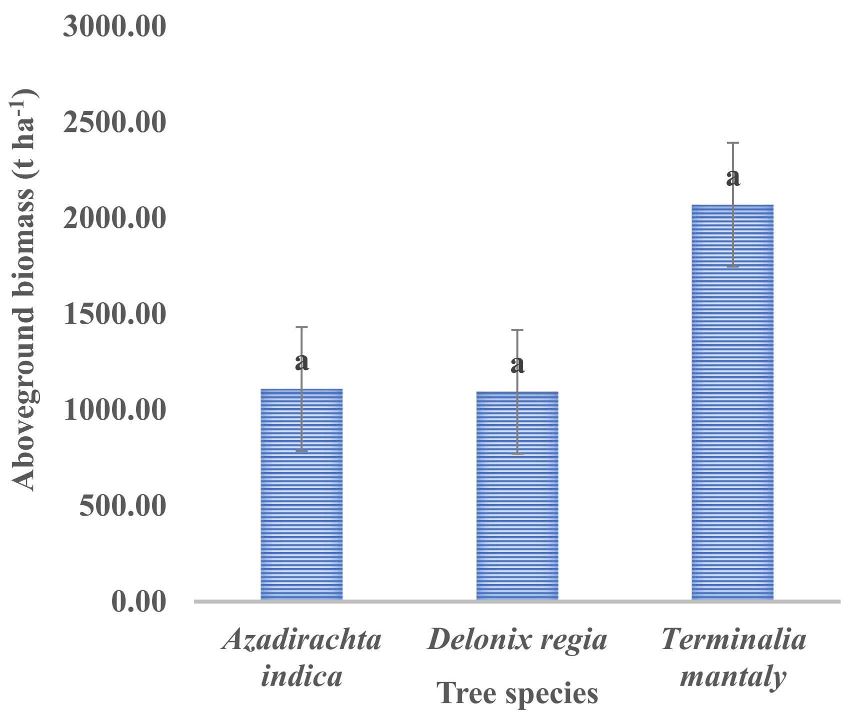

Figure 3. Mean aboveground biomass of *A. indica, D. regia, and T. mantaly*

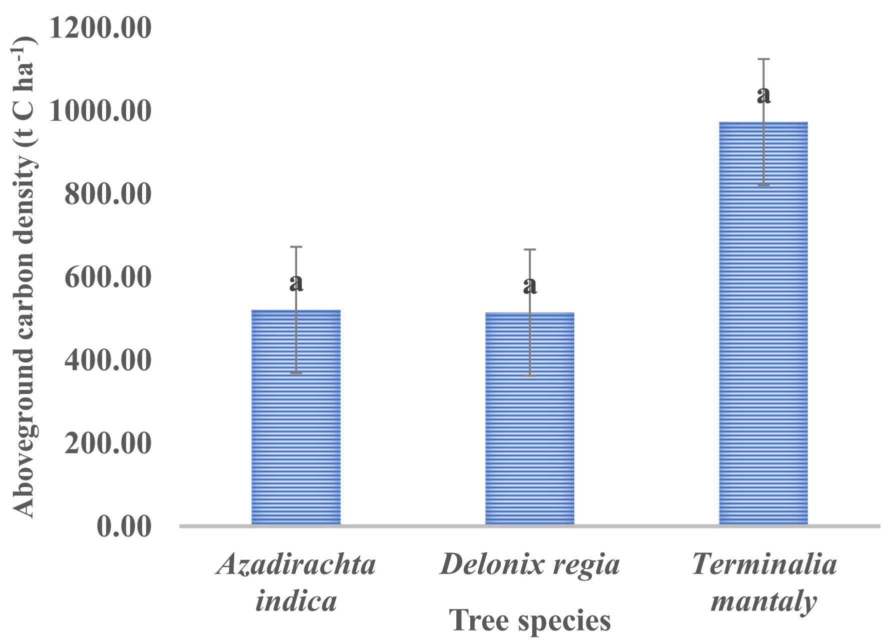

Figure 4. Mean aboveground carbon density of *A. indica, D. regia, and T. mantaly*

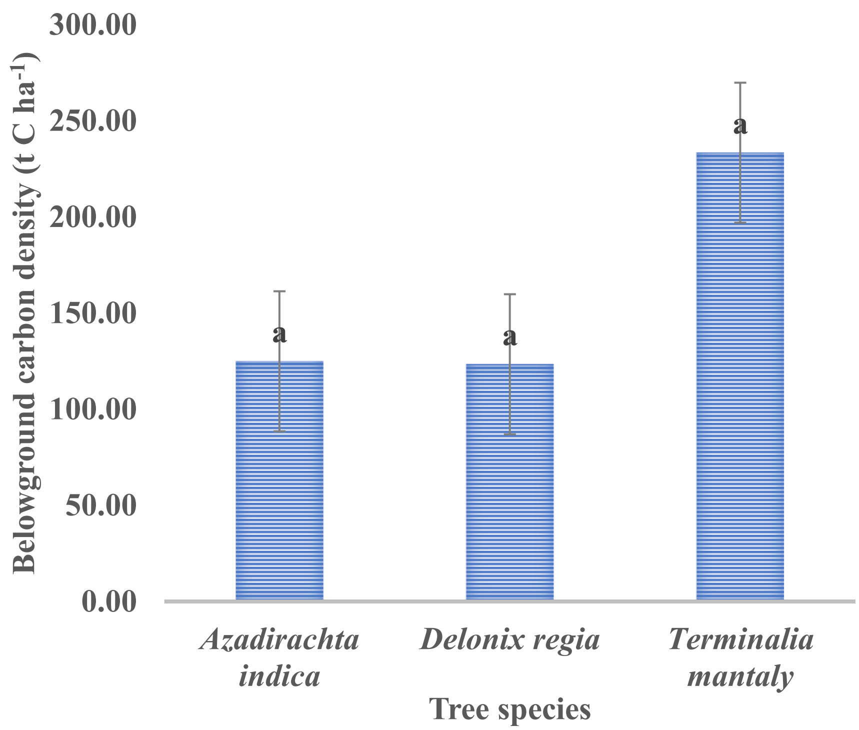

Figure 5. Mean belowground carbon density of *A. indica, D. regia, and T. mantaly*

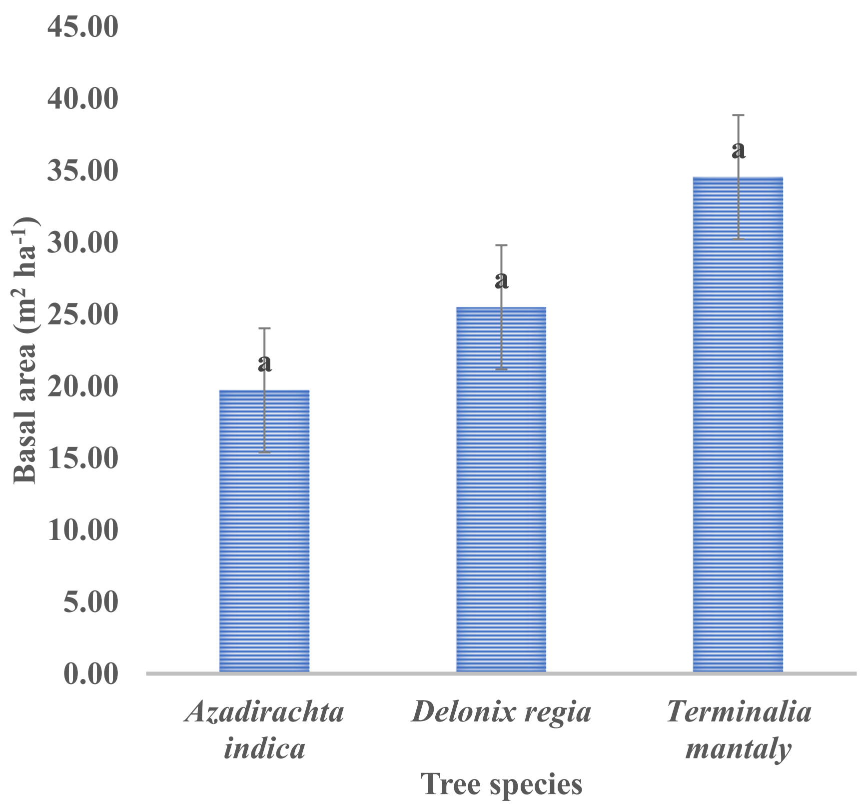

Figure 6. Mean basal area of *A. indica, D. regia, and T. mantaly*

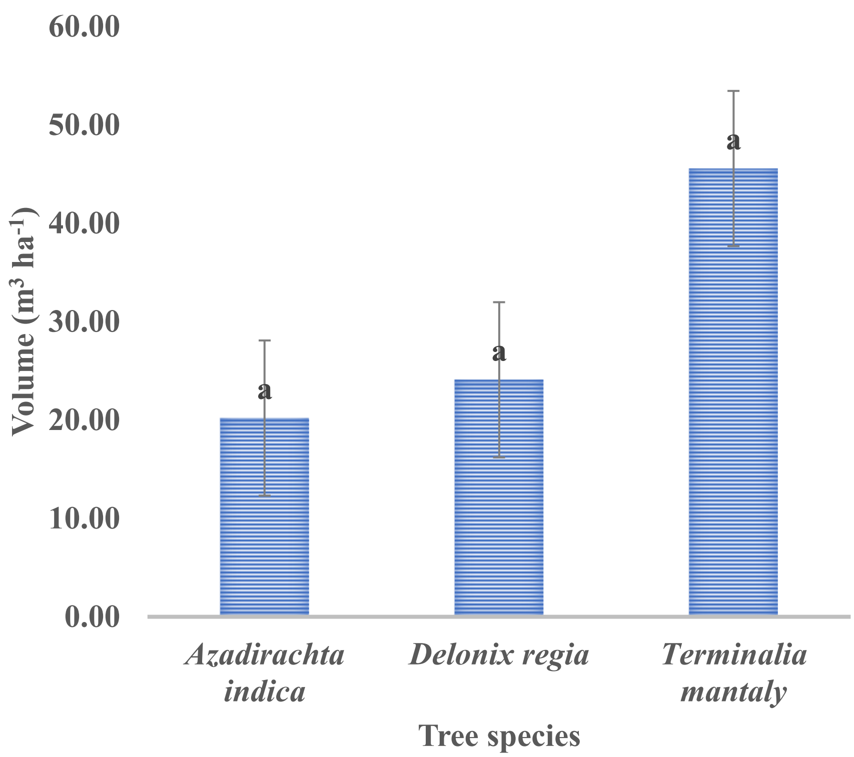

Figure 7. Mean volume of *A. indica, D. regia, and T. mantaly*

Correlation of tree structural and biomass parameters

The correlation matrix (Table 2) showed a strong positive correlation between diameter at breast height (DBH) and aboveground biomass (AGB) (r = 0.87), aboveground carbon density (ACD) (r = 0.87), belowground carbon density (BCD) (r = 0.87), basal area (BA) (r = 0.89), and volume (r = 0.87). DBH had a weak correlation with height (r = 0.10). Tree height showed weak correlations with all other parameters, with the highest correlation observed with AGB (r = 0.19) and the lowest with BA (r = 0.048). AGB, ACD, and BCD were perfectly correlated (r = 1.00), and they also exhibited strong correlations with BA (r = 0.99) and volume (r = 0.999). BA was highly correlated with DBH (r = 0.89) and strongly associated with biomass-related parameters (r = 0.99). Volume was strongly correlated with all biomass-related variables, particularly AGB (r = 0.99).

Table 2. Correlation matrix of seven parameters across *A. indica, D. regia, and T. mantaly*

	DBH	Height	AGB	ACD	BCD	BA	Volume
DBH	1.00 ***	0.10 ***	0.87 ***	0.87 ***	0.87 ***	0.89 ***	0.87 ***
Height	0.10 ***	1.00 ***	0.19 ***	0.19 ***	0.19 ***	0.048	0.19 ***
AGB	0.87 ***	0.19 ***	1.00 ***	1.00 ***	1.00 ***	0.99 ***	1.00 ***
ACD	0.87 ***	0.19 ***	1.00 ***	1.00 ***	1.00 ***	0.99 ***	1.00 ***
BCD	0.87 ***	0.19 ***	1.00 ***	1.00 ***	1.00 ***	0.99 ***	1.00 ***
BA	0.89 ***	0.048	0.99 ***	0.99 ***	0.99 ***	1.00 ***	0.99 ***
Volume	0.87 ***	0.19 ***	1.00 ***	1.00 ***	1.00 ***	0.99 ***	1.00 ***

DBH - Diameter at breast height (cm), Height (m), AGB - Aboveground biomass (t ha^{-1}), ACD - Aboveground carbon density (t ha^{-1}), BCD - Belowground carbon density (t ha^{-1}),
BA - Basal area (m^2 ha^{-1}), Volume (m^3 ha^{-1})
*** - significant at $p < 0.0001$

Discussion

The significant variation in diameter at breast height (DBH) among the three tree species suggests differences in growth strategies and resource allocation (Petrova & Petkova, 2023). *Terminalia mantaly* exhibited the largest DBH, indicating a higher radial growth capacity, potentially due to its species-specific physiology or favorable growing conditions (Chen et al., 2022). Similarly, the significant variation in tree height highlights species-specific differences in vertical growth potential. The height of *Terminalia mantaly* compared to *Azadirachta indica* and *Delonix regia* suggests a superior competitive ability for light acquisition, which could be advantageous in mixed or closed-canopy environments (Forrester et al., 2016; Combaud et al., 2024). The lack of significant height differences between *Azadirachta indica* and *Delonix regia* may indicate that these species adopt similar height-growth strategies, potentially influenced by environmental constraints or genetic factors (Miao et al., 2024).

In contrast, the lack of significant differences in aboveground biomass (AGB), aboveground carbon density (ACD), belowground carbon density (BCD), basal area (BA), and volume among species suggests that these attributes may not be solely driven by DBH and height variations. Other factors may include species composition, forest age, climate, soil characteristics, disturbance regimes, and management practices (Pragasan, 2020; Song et al., 2024). Despite *Terminalia mantaly* having the highest mean biomass and carbon density values, the absence of statistical differences implies that the total biomass accumulation and carbon sequestration potential are relatively comparable among the three species. This could be due to compensatory factors such as differences in wood density, branching patterns, or stand age (Hoover & Smith, 2023; Guo et al., 2024; Peng et al., 2025). The comparable basal area (BA) across species further reinforces that tree size distribution is relatively uniform in the study area. Since BA is a function of DBH, the observed similarities indicate that even though individual trees may exhibit differences in DBH, the cumulative basal area per hectare remains relatively stable (Seiwa et al., 2023). Additionally, the lack of significant differences in volume suggests that all three species contribute similarly to stand structure and total biomass storage despite variations in their diameter and height (Agbelade & Onyekwelu, 2020). The strong positive correlation between DBH and AGB (r = 0.87), ACD (r = 0.87), BCD (r = 0.87), BA (r = 0.89), and volume (r = 0.87) highlights the critical role of DBH as a predictor of tree biomass and carbon storage (Abich et al., 2021). This suggests that DBH can serve as a reliable proxy for estimating tree carbon stocks in similar ecosystems without direct biomass measurements (Mukuralinda et al., 2020). The weak correlation between diameter at breast height (DBH) and tree height (r = 0.10) suggests that larger stem diameters do not always result in taller trees. This might stem from species-specific growth habits, where some trees favor radial growth rather than vertical height (Yrttimaa et al., 2023). Research has revealed varying correlations between DBH and height, for instance, Upadhyay and Khadka (2024) reported a strong correlation (r = 0.86) in *Pinus roxburghii* which contrasts with the findings of this study. However, DBH and tree height have been reported to vary independently in some species (Looney et al., 2020). The similarly weak correlation between tree height and AGB (r = 0.19) suggests that tree height alone is not a strong determinant of biomass accumulation. This aligns with the reports of Patel and Majumdar (2011), suggesting that height may not be a strong predictor of AGB. In contrast, Jiang and Wang (2017) reported a strong positive correlation between tree height and AGB.

The perfect correlation between AGB, ACD, and BCD (r = 1.00) underscores their direct mathematical relationship, given that carbon density is derived from biomass (Zhou et al., 2023). Their strong correlations with BA (r = 0.99) and volume (r = 0.99) further indicate that trees with larger biomass contributions also have greater structural attributes in terms of cross-sectional area and total volume. This reinforces the importance of BA as an integrative structural parameter in biomass estimation models (Padmakumar et al., 2018; Fatimah et al., 2024). The strong relationship between volume and AGB (r = 0.99) suggests that volumetric measurements can be effectively used for biomass estimation (Afroonde et al., 2018). This is particularly useful in forestry applications where volume-based equations assess timber stock and carbon sequestration potential.

Conclusion

This study provided valuable insights into the carbon sequestration potential of three widely planted urban tree species in southeastern Nigeria. Despite variations in DBH and height, the overall biomass accumulation and carbon storage capacity of *Azadirachta indica*, *Delonix regia*, and *Terminalia mantaly* were not significantly different, indicating their comparable contributions to urban carbon sinks. The strong correlation between DBH and biomass parameters underscores the importance of DBH as a reliable predictor of carbon storage. These findings support the need for strategic tree selection and planting to optimize urban forest benefits. This study utilized allometric equations to estimate biomass and carbon density rather than direct measurements, which may have introduced some estimation errors. Additionally, the research focused on only three tree species within a specific urban area, potentially limiting the generalizability of the findings to other regions or species. However, the use of well-established allometric equations provides a scientifically validated, non-destructive approach to estimating biomass and carbon sequestration. The large sample size (100 trees per species) enhances the reliability of the results. Future research may incorporate destructive sampling for more precise biomass estimates, expand the study to include a wider range of species, and assess long-term carbon sequestration dynamics through repeated measurements or remote sensing techniques.

References

Abich, A., Alemu, A., Gebremariam, Y., Mucheye, T., Gurebiyaw, K., & Kassie, M. (2021). Allometric models for predicting aboveground biomass of Combretum-Terminalia woodlands in Amhara, Northwest Ethiopia. *Trees Forests and People*, *5*, 100122. https://doi.org/10.1016/j.tfp.2021.100122

Adefolalu, D. O. (1984). Weather hazards in Calabar ? Nigeria. *GeoJournal*, *9*(4), 359–368. https://doi.org/10.1007/bf00697964

Afroonde, A., Kiani, B., & Attarod, P. (2018). Allometric equations for determining volume and biomass of Acer monspessulanum L. subsp. cinerascens multi-stemmed trees. *Caspian Journal of Environmental Sciences*, *16*(2), 111–119. https://doi.org/10.22124/cjes.2018.2954

Agbelade, A. D., & Onyekwelu, J. C. (2020). Tree species diversity, volume yield, biomass and carbon sequestration in urban forests in two Nigerian cities. *Urban Ecosystems*, *23*(5), 957–970. https://doi.org/10.1007/s11252-020-00994-4

Akter, R., Hasan, M. K., Roshni, N. A., Hemel, S. a. K., & Islam, M. T. (2025). Biomass accumulation and carbon stocks of soil and tree components of different agroforestry systems in tropical moist regions of Bangladesh. *Trees Forests and People*, 100793. https://doi.org/10.1016/j.tfp.2025.100793

Ariluoma, M., Ottelin, J., Hautamäki, R., Tuhkanen, E., & Mänttäri, M. (2020). Carbon sequestration and storage potential of urban green in residential yards: A case study from Helsinki. *Urban Forestry & Urban Greening*, *57*, 126939. https://doi.org/10.1016/j.ufug.2020.126939

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J., Nelson, B. W., Ogawa, H., Puig, H., Riéra, B., & Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, *145*(1), 87–99. https://doi.org/10.1007/s00442-005-0100-x

Chen, Y., Rademacher, T., Fonti, P., Eckes-Shephard, A. H., LeMoine, J. M., Fonti, M. V., Richardson, A. D., & Friend, A. D. (2022). Inter-annual and inter-species tree growth explained by phenology of xylogenesis. *New Phytologist*, *235*(3), 939–952. https://doi.org/10.1111/nph.18195

Combaud, M., Cordonnier, T., Pérot, T., Morin, X., & Vallet, P. (2024). How dominant height responds to mixing species: Effect of traits and height difference between species. *Forest Ecology and Management*, *572*, 122298. https://doi.org/10.1016/j.foreco.2024.122298

Czaja, M., Kołton, A., & Muras, P. (2020). The complex issue of Urban Trees—Stress factor accumulation and ecological service possibilities. *Forests*, *11*(9), 932. https://doi.org/10.3390/f11090932

Egerer, M., Schmack, J. M., Vega, K., Barona, C. O., & Raum, S. (2024). The challenges of urban street trees and how to overcome them. *Frontiers in Sustainable Cities*, *6*. https://doi.org/10.3389/frsc.2024.1394056

Fatimah, H., Farooq, S., Anwar, T., Qureshi, H., Hashmi, F., Ahmad, T., Ullah, N., Munazir, M., Naseem, M. T., & Soufan, W. (2024). Assessment of growth, biomass, and carbon sequestration potential of urban tree species in greenbelts. *BMC Plant Biology*, *24*(1). https://doi.org/10.1186/s12870-024-05935-3

Forrester, D. I., Benneter, A., Bouriaud, O., & Bauhus, J. (2016). Diversity and competition influence tree allometric relationships – developing functions for mixed-species forests. *Journal of Ecology*, *105*(3), 761–774. https://doi.org/10.1111/1365-2745.12704

Guo, P., Zhao, X., Wang, X., Feng, Q., Li, X., & Tan, Y. (2024). Wood density and carbon concentration jointly drive wood carbon density of five Rosaceae tree species. *Forests*, *15*(7), 1102. https://doi.org/10.3390/f15071102

Hoover, C. M., & Smith, J. E. (2023). Aboveground live tree carbon stock and change in forests of conterminous United States: influence of stand age. *Carbon Balance and Management*, *18*(1). https://doi.org/10.1186/s13021-023-00227-z

Jiang, Y., & Wang, L. (2017). Pattern and control of biomass allocation across global forest ecosystems. *Ecology and Evolution*, *7*(14), 5493–5501. https://doi.org/10.1002/ece3.3089

Kacprzak, M. J., Ellis, A., Fijałkowski, K., Kupich, I., Gryszpanowicz, P., Greenfield, E., & Nowak, D. (2024). Urban forest species selection for improvement of ecological benefits in Polish cities - The actual and forecast potential. *Journal of Environmental Management*, *366*, 121732. https://doi.org/10.1016/j.jenvman.2024.121732

Kang, J., Zhang, B., Zhang, Q., Li, C., Ma, J., Yin, J., Yu, K., Hu, Y., & Bou-Zeid, E. (2025). Global urbanization indirectly 'enhances' the carbon sequestration capacity of urban vegetation. *Geography and Sustainability*, 100268. https://doi.org/10.1016/j.geosus.2025.100268

Looney, C. E., Previant, W. J., & Nagel, L. M. (2020). Variations in tree growth provide limited evidence of species mixture effects in Interior West USA mixed-conifer forests. *Journal of Ecology*, *109*(2), 952–965. https://doi.org/10.1111/1365-2745.13523

Miao, L., Wang, X., Yu, C., Ye, C., Yan, Y., & Wang, H. (2024). What factors control plant height? *Journal of Integrative Agriculture*, *23*(6), 1803–1824. https://doi.org/10.1016/j.jia.2024.03.058

Mukuralinda, A., Kuyah, S., Ruzibiza, M., Ndoli, A., Nabahungu, N. L., & Muthuri, C. (2020). Allometric equations, wood density and partitioning of aboveground biomass in the arboretum of Ruhande, Rwanda. *Trees Forests and People*, *3*, 100050. https://doi.org/10.1016/j.tfp.2020.100050

Nero, B., Kuusaana, E., Ahmed, A., & Campion, B. (2024). Carbon storage and tree species diversity of urban parks in Kumasi, Ghana. *City and Environment Interactions*, *24*, 100156. https://doi.org/10.1016/j.cacint.2024.100156

Padmakumar, B., Sreekanth, N., Shanthiprabha, V., Paul, J., Sreedharan, K., Augustine, T., Jayasooryan, K., Rameshan, M., Mohan, M., Ramasamy, E., & Thomas, A. (2018). Tree biomass and carbon density estimation in the tropical dry forest of Southern Western Ghats, India. *iForest - Biogeosciences and Forestry*, *11*(4), 534–541. https://doi.org/10.3832/ifor2190-011

Patel, N., & Majumdar, A. (2011). Comparative assessment of the relationship of satellite data with the above ground biomass of Sal trees (Shorea robusta) determined from phenologically different time periods. *Geo-spatial Information Science*, *14*(3), 177–183. https://doi.org/10.1007/s11806-011-0492-1

Peng, J., Jiang, Y., Shi, L., Xie, S., Zhang, X., Wu, P., Ma, X., & Li, M. (2025). Effects of Planting Density on Branch Development and Spatial Distribution in Two Elite Chinese Fir (Cunninghamia lanceolata (Lamb.) Hook.) Clones. *Forests*, *16*(1), 63. https://doi.org/10.3390/f16010063

Petrova, S., & Petkova, M. (2023). Plant Traits of Tilia tomentosa Moench, Fraxinus excelsior L., and Pinus nigra J.F.Arnold as a Proxy of Urbanization. *Forests*, *14*(4), 800. https://doi.org/10.3390/f14040800

Pragasan, L. A. (2020). Tree carbon stock and its relationship to key factors from a tropical hill forest of Tamil Nadu, India. *Geology Ecology and Landscapes*, *6*(1), 32–39. https://doi.org/10.1080/24749508.2020.1742510

Seiwa, K., Sasaki, T., & Masaka, K. (2023). Important role of a few large-diameter tree species in basal area and its increase in an old-growth deciduous broadleaf forest in Japan. *Trees Forests and People*, *13*, 100421. https://doi.org/10.1016/j.tfp.2023.100421

Song, Z., Shi, P., Li, P., Li, Z., Niu, H., Zu, P., Cao, M., & Jia, Y. (2024). Effects of forest type on carbon storage in the hilly region of Loess Plateau, China. *Frontiers in Forests and Global Change*, *7*. https://doi.org/10.3389/ffgc.2024.1349047

Steenberg, J. W. N., Ristow, M., Duinker, P. N., Lapointe-Elmrabti, L., MacDonald, J. D., Nowak, D. J., Pasher, J., Flemming, C., & Samson, C. (2023). A national assessment of urban forest carbon storage and sequestration in Canada. *Carbon Balance and Management*, *18*(1). https://doi.org/10.1186/s13021-023-00230-4

Uchenna, U. P., Lancia, M., Viaroli, S., Ugbaja, A. N., Galluzzi, M., & Zheng, C. (2023). Groundwater sustainability in African Metropolises: Case study from Calabar, Nigeria. *Journal of Hydrology Regional Studies*, *45*, 101314. https://doi.org/10.1016/j.ejrh.2023.101314

Upadhyay, J., & Khadka, S. (2024). Modelling Height-Diameter Relationship of <i>Pinus Roxburghii </i>in Nepal. *American Journal of Biological and Environmental Statistics*, *10*(3), 49–59. https://doi.org/10.11648/j.ajbes.20241003.12

Yrttimaa, T., Junttila, S., Luoma, V., Pyörälä, J., Puttonen, E., Campos, M., Hölttä, T., & Vastaranta, M. (2023). Tree height and stem growth dynamics in a Scots pine dominated boreal forest. *Trees Forests and People*, *15*, 100468. https://doi.org/10.1016/j.tfp.2023.100468

Zhou, X., Hu, C., & Wang, Z. (2023). Distribution of biomass and carbon content in estimation of carbon density for typical forests. *Global Ecology and Conservation*, *48*, e02707. https://doi.org/10.1016/j.gecco.2023.e02707