



(KEJAANS)

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES

September, 2025, Vol. 1, issue 2



KEJAANS

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ISSN: 1595-5776



KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES
(KEJAANS)

September, 2025; Volume 1, Issue 2

OFFICIAL JOURNAL OF THE
FACULTY OF AGRICULTURE
ABDULLAHI FODIO UNIVERSITY OF SCIENCE AND TECHNOLOGY,
ALIERO

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The Kebbi Journal of Agriculture and Natural Sciences has the sole aim of providing an intellectual platform and ideas for scholars, by promoting interdisciplinary studies related to agriculture and natural science through publishing the latest scientific research findings that are of direct policy implications and beneficial to the research community. Consequently, the journal covers all aspects of Crop Science, Animal Science, Agricultural Economics, Agricultural Extension and Rural Development, Food Science, Fisheries and Aquaculture, Biotechnology, Soil Science and Agricultural Engineering, Forestry and Environment, Wildlife, Agricultural Education, Agro-allied Industries as well as all Natural Science researches related to Agriculture.

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ESTIMATION OF ABOVEGROUND BIOMASS AND CARBON STOCK ASSESSMENT IN THE BUILT-UP AREA OF ABDULLAHI FODIYO UNIVERSITY OF SCIENCE AND TECHNOLOGY ALIERO, KEBBI STATE

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ABSTRACT

This study assessed the aboveground biomass (AGB), belowground biomass (BGB), and carbon sequestration capability of tree species in the developed area of Abdullahi Fodio University of Science and Technology, Aliero (KSUSTA). A total of 106 stems from seven species were catalogued over 15 plots utilizing conventional dendrometric metrics, including diameter at breast height (DBH) and tree height. Biomass was calculated using standard allometric formulae, and carbon stock was determined as 50% of total biomass. The results indicated substantial differences in tree dimensions and carbon sequestration among the plots. Plots with greater average DBH, namely Plot 10 and Plot 2, had the greatest carbon stores of 5.01 Mg C and 4.25 Mg C, respectively, while plots with smaller stems held negligible carbon, frequently below 0.20 Mg C. At the species level, *Azadirachta indica* was the predominant contributor, with 9.84 Mg C (36.07 Mg CO_{2e}), followed by *Eucalyptus camaldulensis* with 5.60 Mg C (20.55 Mg CO_{2e}). Other species, such as *Khaya senegalensis*, *Terminalia mantally*, and *Albizia spp.*, contributed somewhat, although *Gmelina arborea* and *Olea europaea* played minimal roles due to their low abundance. The findings reveal that carbon storage is unevenly distributed among a limited number of dominant species and larger individuals, consistent with worldwide data on tree size-carbon relationships. The study concludes that institutional plantations possess considerable potential for carbon sequestration when managed with an emphasis on high-performing species. It recommends the conservation of mature trees, diversification of species, and the incorporation of carbon management strategies into campus landscaping as components of climate change mitigation efforts.

Keywords: Aboveground Biomass; DBH; Carbon equivalent; Sequestration and Dendrometric

Introduction

Climate change persists as a primary environmental problem of the 21st century, primarily propelled by increasing atmospheric levels of carbon dioxide. Although woods and tree plantations are well acknowledged for their carbon sequestration capabilities, the contribution of institutional and urban trees has not been well studied, especially in Nigeria's

semi-arid areas. The majority of existing research on carbon stock assessment in Nigeria has focused on natural forests, savanna woodlands, or agroforestry systems, resulting in a notable deficiency in understanding the carbon storage capacity of campus plantations and other developed landscapes (Adesina *et al.*, 2021; Aliyu *et al.*, 2020).

In developing nations, where deforestation and land degradation jeopardise the stability of carbon reservoirs, both planted and naturally regenerated trees in agricultural lands, educational institutions, and urban areas are increasingly recognised as essential elements of climate change mitigation strategies (Návar, 2019; Aliyu *et al.*, 2020). Trees in these environments can function as accessible carbon repositories while enhancing environmental quality and human well-being. Campus plants are primarily managed for shade, aesthetic enhancement, and research, although their contribution to carbon sequestration is hardly measured, particularly in Nigeria's semi-arid area, where the effects of climate change are both severe and enduring.

The estimation of biomass and carbon stock depends on tree characteristics, including diameter at breast height (DBH), height, and wood density, which are utilised in recognised allometric models (Chave *et al.*, 2014). Aboveground biomass typically constitutes the predominant element of tree biomass, whereas belowground biomass is frequently approximated as a proportion of aboveground values (Henry *et al.*, 2021). Transforming biomass into carbon and subsequently into carbon dioxide equivalents quantifies the mitigation capacity of tree stands in counterbalancing emissions from fossil fuel consumption and land use alterations (IPCC, 2006).

In Nigeria, prior research indicates that species like *Azadirachta indica* and *Eucalyptus camaldulensis* predominate in urban and institutional plantations, significantly enhancing carbon sequestration due to their rapid growth, adaptability, and drought resilience (Aliyu *et al.*, 2020; Tesfaye *et al.*, 2022). Nevertheless, the majority of existing research has been on natural forests and

agroforestry systems, whereas campus and urban plantings have been little examined. In semi-arid regions like Kebbi State, characterised by limited tree cover and delicate ecosystems, it is crucial to measure the contribution of campus plants to biomass and carbon sequestration to comprehend their significance in climate change mitigation and sustainable landscape management.

At Abdullahi Fodio University of Science and Technology, Aliero (AFUSTA), trees are primarily cultivated for shade, aesthetic enhancement, and climatic management. Nonetheless, their contribution to carbon sequestration has not been extensively measured. This exclusion is problematic for several reasons. Firstly, disregarding the carbon sequestration role of campus vegetation diminishes their impact on climate change mitigation in semi-arid habitats. Secondly, given the absence of empirical evidence, campus management strategies cannot comprehensively include carbon sequestration into sustainable environmental planning. The disproportionate influence of certain species, such as *Azadirachta indica* and *Eucalyptus camaldulensis*, on the carbon balance of these plantations is inadequately studied.

Consequently, it is essential to examine and estimate the biomass and carbon reserves of tree species within the AFUSTA developed region. This will yield baseline data for climate change mitigation initiatives, guide sustainable campus landscaping practices, and enhance the overall comprehension of carbon sequestration dynamics in institutional plantations throughout Nigeria's semi-arid region.

Methodology

Study Area

The research was carried out within the built-up area of Abdullahi Fodiyo University of Science and Technology, Aliero (AEUSTA), situated in Kebbi State, northwestern Nigeria. The institution is situated in a semi-arid ecological zone marked by pronounced wet and dry seasons, with an average annual precipitation of 600–800 mm and typical temperatures frequently above 30°C in the dry season (NIMET, 2020). The institution's developed area includes both planted and naturally occurring tree stands that offer shade, aesthetic appeal, and ecological benefits, including carbon sequestration.

Sampling Design and Plot Establishment

A systematic sampling method was utilised to pick 15 plots, each measuring 20 m x 20 m (0.04 hectare). This strategy guaranteed sufficient geographical coverage of the research region while reducing sampling bias (Philip, 2002). In each plot, all live trees with a diameter at breast height (DBH) of 5 cm or greater were counted and identified to the species level using field guides and expert consultation.

Tree Measurements

DBH for each tree in the plots was measured at 1.3 m above ground level with a diameter tape, while total height was assessed using a graduated pole and a clinometer for higher specimens. These parameters were used since diameter at breast height (DBH) and height are the most often utilised dendrometric variables for biomass estimate (Henry *et al.*, 2011).

Estimation of Aboveground Biomass (AGB)

The allometric equation derived by Chave *et al.* (2014) for tropical trees was utilised to estimate the aboveground biomass (AGB) of

each documented individual. This model integrates diameter at breast height (DBH), tree height, and wood density, yielding accurate biomass estimations in tropical and subtropical habitats.

$$AGB = 0.0673 \times (\rho \times D^2 \times H)^{0.976}$$

Where:

- AGB = aboveground biomass (kg),
- ρ = wood density of the species ($g\ cm^{-3}$),
- D = diameter at breast height (cm),
- H = total height of tree (m).

Wood density values were obtained from the Global Wood Density Database (Zanne *et al.*, 2009) and relevant literature for West African tree species.

Estimation of Belowground Biomass (BGB)

Belowground biomass (BGB) was estimated indirectly as a fixed proportion of the aboveground biomass, using the equation proposed by Cairns *et al.* (1997):

$$BGB = 0.25 \times AGB$$

This assumes that belowground biomass constitutes approximately 25% of aboveground biomass for tropical trees.

Estimation of Carbon Stock and Carbon Dioxide Equivalent

Carbon stock was derived from the total biomass (AGB + BGB) by applying the standard conversion factor that **50% of dry biomass is carbon** (IPCC, 2006):

$$C = 0.5 \times (AGB + BGB)$$

The corresponding **carbon dioxide equivalent (CO₂e)** was obtained by multiplying the carbon stock by a conversion factor of **3.67**, representing the molecular weight ratio of CO₂ to C (IPCC, 2006):

$$CO_2e = C \times 3.67$$

Data Analysis

Field-collected data were synthesised in Microsoft Excel for analysis. Biomass, carbon stock, and carbon equivalent were calculated at both the plot and species levels. Descriptive statistics, encompassing means and totals, were produced to compare carbon storage potentials among plots and species. Results were shown in tables and analysed in conjunction with prior research.

Results and Discussion

Biomass and Carbon Stock at Plot Level

Table 1 indicates significant disparities in tree structure and carbon sequestration potential across the 15 systematically created plots within KSUSTA. A total of 106 stems were counted across all plots, with mean DBH values varying from 20.7 cm (Plot 13) to 110.1

cm (Plot 10), and mean tree heights ranging from 4.0 m (Plot 14) to 13.5 m (Plot 2). The structural characteristics directly affected the biomass and carbon stock levels observed in each plot.

Plots with bigger trees demonstrated increased aboveground biomass (AGB) and total carbon levels. For instance, Plot 10, with the highest mean DBH (110.1 cm), included the most biomass and carbon reserves, with AGB of 8.82 Mg, BGB of 2.13 Mg, and total carbon of 5.01 Mg C, equating to 18.36 Mg CO_{2e}. Likewise, Plot 2, with a mean DBH of 76.6 cm and a mean height of 13.5 m, made a substantial contribution of 7.24 Mg AGB, 1.81 Mg BGB, and 4.25 Mg C. Conversely, smaller plots like Plot 13 (DBH = 20.7 cm; Height = 4.2 m) and Plot 15 (DBH = 29.8 cm; Height = 4.2 m) exhibited minimal carbon storage, with 0.05 Mg C and 0.17 Mg C, respectively.

Table 1: Biomass and Carbon Stock at Plot Level

Plot	No. of stems	Mdbh (cm)	Mh (m)	AGB (Mg)	BGB (Mg)	TC (Mg C)	CO _{2e} (Mg)
1	7	44.3	9.9	1.48	0.37	0.87	3.19
2	8	76.6	13.5	7.24	1.81	4.25	15.59
3	9	41.6	11.6	1.68	0.42	0.99	3.62
4	10	39.9	7.0	1.01	0.25	0.59	2.18
5	8	46.1	7.3	1.32	0.33	0.78	2.85
6	5	55.0	6.9	1.46	0.32	0.74	2.71
7	7	38.6	9.8	0.94	0.23	0.55	2.02
8	5	36.1	12.8	0.78	0.19	0.46	1.68
9	6	63.9	11.2	3.17	0.79	1.86	6.83
10	3	110.1	12.1	8.82	2.13	5.01	18.36
11	5	49.7	6.3	0.92	0.23	0.54	1.98
12	12	31.7	6.2	1.18	0.29	0.69	2.54
13	6	20.7	4.2	0.19	0.02	0.05	0.19
14	7	40.0	4.0	0.41	0.10	0.24	0.88
15	8	29.8	4.2	0.29	0.07	0.17	0.62
Total	106						

key: Mdbh (cm): mean diameter at breast Height; **Mh:** Mean height in metres; **AGB:** aboveground biomass, **BGB:** Belowground Biomass; **TC:** Total Carbon per species and family and **CO_{2e}** is carbon equivalent

The results affirm the robust positive association between tree size and carbon storage, a relationship constantly emphasised in biomass studies (Chave *et al.*, 2014; Bastin *et al.*, 2019). Henry *et al.* (2021) assert that diameter at breast height (DBH) is the most dependable predictor of tree biomass, whilst height functions as an ancillary variable to enhance precision. The present study further illustrates that plots with a greater number of stems (e.g., Plot 12 with 12 stems) do not inherently sequester more carbon if the tree sizes are comparatively diminutive. This discovery supports previous findings by Návár (2019), who indicated that forest stands including fewer but larger trees sequestered more carbon than denser stands with smaller trees.

The prevailing tendency highlights the ecological importance of safeguarding large-diameter trees in institutional environments. Research in tropical Africa and other regions has demonstrated that giant trees, despite their lower abundance, represent a significant amount of forest carbon reserves (Pan *et al.*, 2020; Lutz *et al.*, 2018). The presence of mature, large-stemmed trees in KSUSTA's developed area is crucial for improving the plantation's carbon sequestration capacity.

Biomass and Carbon Stock by Species and Families

Table 2 highlighted that, seven tree species from six families were documented across the 15 plots at the species level. *Azadirachta indica* (Meliaceae) was the predominant species, including 54 stems with an average diameter at breast height (DBH) of 45.5 cm

and an average height of 7.7 m. It represented the largest biomass and carbon reservoir, sequestering 16.76 Mg of above-ground biomass (AGB), 4.19 Mg of below-ground biomass (BGB), and 9.84 Mg of carbon, which is equivalent to 36.07 Mg of CO_{2e}. This predominance underscores the ecological resilience and adaptation of neem in semi-arid habitats. Comparable results have been shown in northern Nigeria, where neem trees are recognised as significant contributors to carbon sequestration owing to their rapid growth and drought resistance (Aliyu *et al.*, 2020). *Eucalyptus camaldulensis* (Myrtaceae), including 26 stems, contributed significantly by sequestering 9.54 Mg of aboveground biomass (AGB), 2.39 Mg of belowground biomass (BGB), and 5.60 Mg of carbon (C), equivalent to 20.55 Mg of CO_{2e}. Although it had fewer stems than *A. indica*, its superior mean DBH (47.9 cm) and greater height (8.8 m) augmented its carbon output. This corresponds with data from East Africa, indicating that eucalyptus plantations exhibit significant biomass buildup and carbon sequestration potential, especially in semi-arid regions (Tesfaye *et al.*, 2022). Other species made modest contributions: *Khaya senegalensis* (Meliaceae) sequestered 1.08 Mg C, *Terminalia mantally* (Combretaceae) sequestered 0.73 Mg C, and *Albizia spp.* (Fabaceae) contributed 0.75 Mg C. In contrast, *Gmelina arborea* (Lamiaceae) and *Olea europaea* (Oleaceae) contributed minimally, with only 0.23 Mg C and 0.02 Mg C, respectively, primarily due to their limited representation (one or two stems).

Table 2: Biomass and Carbon Stock by Species and Families

S/No	Species	Family	No. of stems	M dbh (cm)	Mh (m)	AGB (Mg)	BGB (Mg)	TC (Mg C)	CO _{2e} (Mg CO _{2e})
1	<i>A indica</i>	Meliaceae	54	45.5	7.7	16.76	4.19	9.84	36.07
2	<i>E. camadulensis</i>	Myrtaceae	26	47.9	8.8	9.54	2.39	5.60	20.55
3	<i>K.senegelensis</i>	Meliaceae	8	43.8	9.2	1.84	0.46	1.08	3.96
4	<i>T. mantally</i>	Combretaceae	14	35.9	6.5	1.25	0.31	0.73	2.69
5	<i>G. arborea</i>	Lamiaceae	1	52.3	6.3	0.39	0.10	0.23	0.84
6	<i>Albizia spp.</i>	Fabaceae	2	64.3	12.7	1.28	0.32	0.75	2.76
7	<i>Olea europaea</i>	Oleaceae	1	10.0	14.0	0.04	0.01	0.02	0.09
	Grand Total		106	44.9	8.1	1.10	7.78	18.26	66.95

key: S/No: Sequential Number; **Species:** All species within the family; **Family:** Botanical Family Name; **No. of stems:**Total trees belonging to the family; **M dbh:**Average DBH of all trees in the family; **Mh (m):** Average Height of all trees in the family; **AGB (Mg):**Total Aboveground Biomass for the family; **BGB (Mg):**Total Belowground Biomass for the family; **TC (Mg C):** Total Carbon Stock for the family; **CO_{2e}:** Carbon Equivalent (Mg CO_{2e}) which is Total CO₂ equivalent for the family

The species-level findings highlight that a few handful of predominant trees provide the majority of carbon sequestered in plantations. Bastin *et al.* (2019) and Lutz *et al.* (2018) documented analogous worldwide trends, wherein huge specimens of certain species predominate ecological carbon budgets. The Meliaceae family emerged as the predominant contributor in KSUSTA, owing to the synergistic contributions of *Azadirachta indica* and *Khaya senegalensis*, hence underscoring its ecological and economic significance in West African ecosystems (Adesina *et al.*, 2021).

The comparative underachievement of less prevalent species indicates a necessity for variety in campus plantings. Augmenting the representation of indigenous plants like *Khaya senegalensis* and *Terminalia mantally* may bolster ecosystem resilience, biodiversity, and sustained carbon sequestration. This aligns with the suggestions of Pan *et al.* (2020), who emphasised that species variety enhances ecological stability throughout climate change.

Collectively, both plot-level and species-level studies indicate that the carbon sequestration capacity in KSUSTA's developed area is predominantly influenced by tree size and species dominance. Large-stemmed trees, particularly neem and eucalyptus, provide for the majority of sequestered carbon, whereas smaller-stemmed plots and less prevalent species contribute insignificantly. These results reflect worldwide patterns indicating that a limited number of species and individuals are responsible for carbon buildup in forests and plantations (Lutz *et al.*, 2018; Bastin *et al.*, 2019).

The study emphasises the necessity of preserving mature trees and including high-performing species into planting initiatives,

while also varying species composition to enhance resilience. Institutional plantations, although being frequently underestimated, may function as essential carbon sinks in semi-arid regions if maintained well.

Conclusion

The research evaluated the carbon sequestration capacity of trees on the KSUSTA campus, documenting 106 stems from seven species over 15 plots. The findings indicated that tree dimensions, namely diameter at breast height (DBH) and height, had a more significant impact on carbon stock than stem density. Plots with large-stemmed trees, particularly those dominated by *Azadirachta indica* and *Eucalyptus camaldulensis*, sequestered much greater quantities of carbon than plots with smaller-stemmed species. Despite limited species diversity, *A. indica* accounted for approximately fifty percent of the entire carbon pool, with *E. camaldulensis* following, so underscoring their significance in semi-arid carbon sequestration systems. Other species, like *Khaya senegalensis* and *Terminalia mantally*, assumed secondary roles, while less prevalent species contributed less to the total carbon supply. This underscores the predominance of select species in influencing the carbon equilibrium of institutional plantations.

This study's findings indicate that carbon sequestration in the KSUSTA plantation is predominantly influenced by tree size and species dominance. Although elevated stem density enhances stand structure, the presence of large-diameter individuals is the paramount determinant in biomass accumulation and carbon sequestration. *Azadirachta indica* and *Eucalyptus camaldulensis* emerged as the primary donors to the carbon pool, highlighting their ecological significance and ability to flourish in semi-arid conditions. The

inadequate representation of various species indicates an imbalance that may jeopardise ecological resilience and long-term sustainability. The study finds that preserving big trees and carefully diversifying species are crucial for improving carbon sequestration capacity and ecological value in institutional plantations.

Recommendation

It is advised that KSUSTA prioritise the preservation of mature and large-stemmed specimens, namely neem and eucalyptus, as they constitute the predominant portion of the carbon reservoir. Simultaneously, species diversification should be promoted via the enrichment planting of under-represented native trees, such as *Khaya senegalensis* and *Terminalia mantaly*, to enhance ecosystem resilience. The institution ought to incorporate carbon stock monitoring and management into its campus landscaping and environmental policy, thereby guaranteeing that tree planting actively aids in climate change mitigation. Furthermore, systematic enrichment planting in understocked areas should be implemented to enhance biomass density and total carbon sequestration. Establish long-term monitoring of carbon stock dynamics by integrating field-based inventories with remote sensing techniques to detect changes over larger geographical scales. Ultimately, these findings should serve as a paradigm for other institutions and metropolitan centres in northern Nigeria to illustrate the essential function of institutional plantings in climate mitigation and environmental sustainability.

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