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ABOVE GROUND BIOMASS AND CARBON STOCK SEQUESTRATION POTENTIALS AND ECONOMIC VALUE OF FOREST PLANTATION ESTABLISHED IN NASARAWA

[1]Nasiru S., [2]Balogun P. B., [2]Danlami F. A., [2]Egbewole Z. T. and *[3]Sa'aondo S. M.

[1]Department of Forestry and Wildlife, Prince Abubakar Audu University, P.M.B. 1008, Anyigba, Kogi State Nigeria.
[2]Department of Forestry Wildlife and Ecotourism, Nasarawa State University Keffi, Shabu-Lafia, Nasarawa State, Nigeria.
[3]Department of Forestry and Environmental Technology, College of Agriculture, Science and Technology, P.M.B. 33 Lafia, Nasarawa State, Nigeria.

*Corresponding authors' email: saaondomaxwell@coastlafia.edu.ng Phone: +2348062211641

ABSTRACT

Forest plantations serve as vital carbon sinks for climate change mitigation and provide economic opportunities via carbon credit trading. This study evaluated the aboveground biomass (AGB), carbon sequestration potential, and economic value of a 10-year-old plantation integrated with native tree species at Nasarawa State University, Shabu-Lafia Campus, Nigeria. In the 1.90-hectare site, seven plots were randomly selected, measuring tree DBH and height for all the species. AGB was calculated using allometric model incorporating wood density. Total aboveground carbon stock was 15.49 tonnes, equating to 56.80 tonnes of CO_2, primarily from large native trees like Parkia biglobosa (1314.9kg) on average and abundant species such as Khaya senegalensis (73.23kg), Gmelina arborea (51.795kg), and Tectona grandis (60.96kg). This shows that the rate of AGB accumulation is higher in K. senegalensis with lower numbers of trees, 66 compare to G. arborea with higher number of trees,117 lower in AGB, all planted within the same period. Economic valuation estimated US $930 (NGN 1.42 million) in potential revenue. The plantation represents a significant carbon sink with economic benefits, highlighting the value of conserving native species alongside exotic management for optimal sequestration. It is therefore recommended that pursuing carbon credit certification, silvicultural planning with thinning and enrichment, and long-term monitoring for climate finance and research.

Keywords: Aboveground Biomass, Carbon Sequestration, Carbon Credits, Economic Valuation, Forest Plantation, Nasarawa State

INTRODUCTION

Forest plantations act as carbon sinks, absorbing and storing carbon dioxide (CO_2) from the atmosphere. The plantation at Nasarawa State University contributes to mitigating climate change by reducing atmospheric CO_2 levels, thus providing the university with the potential to generate carbon credits (Carter *et al.,* 2019). These carbon credits can be traded in national and international carbon markets, creating an economic incentive for environmental conservation. The global demand for carbon credits is growing, driven by international climate agreements such as the Paris Agreement (UNFCCC, 2015). Forests, as carbon offset mechanisms, are increasingly recognized for their role in achieving emission reduction targets (Chazdon, 2008). The plantation in Nasarawa State University can monetize its carbon sequestration capacity, contributing to the university's revenue through the sale of carbon credits on regulated carbon markets or voluntary markets. The forest plantation offers environmental benefits beyond carbon sequestration, such as supporting local biodiversity and contributing to ecosystem services like soil stabilization and water retention (FAO, 2016). These benefits can further enhance the plantation's economic value through the promotion of sustainable practices and potential funding from conservation-focused initiatives. The plantation creates local employment opportunities in plantation management, maintenance, and research.

These plantations not only contribute to mitigating climate change by absorbing atmospheric carbon dioxide but also present potential revenue streams through carbon stock trading. Assessing the above ground carbon sequestration capacity and economic value of these plantations is essential for informed decision-making and sustainable land management. Beyond environmental benefits, forest plantations offer economic opportunities through carbon stock trading. This market-based approach allows entities to earn revenue by selling carbon credits, representing the amount of CO_2 sequestered by their forests. The economic viability of such initiatives depends on factors like forest growth rates, carbon credit market prices, and verification costs. While specific data on the economic value of the Shabu-Lafia Campus plantations are limited, existing studies provide a framework for estimation.

Climate change has extensively been linked to increased greenhouse gas concentration in the atmosphere, resulting in increases in the average global temperature, causing physical and economic damage to society. Some regions may benefit from climate change through increasing crop yields (Cosentino *et al.,* 2017), and energy-saving for heating (Gonseth *et al.*, 2019) particularly in the upper northern hemisphere. Environmental policy internalizing carbon externalities into the decision-making process became a priority for most countries around the world through international agreements such as the recent Paris Agreement in 2016 carbon sequestration. One of the important elements of achieving REDD+ activities is the measurement and reporting activities on carbon stocks (Masripatin, *et al.*, 2010). Measurement activities are carried out to find out how much absorption and carbon stock is contained in an individual stand and in a forest area. Information on the absorption capacity and carbon stock in a stand and area is expected to support related parties in making policies to reduce the release of GHG. Information on carbon absorption in individual stands and forest area is also expected to provide an overview for related parties of the potential added value that can be obtained if it maintains and develops a certain plant species to support the reduction of greenhouse gas emissions.

Biomass is the amount of organic matter stored in a plant. During process of photosynthesis, plants absorb CO_2 from the atmosphere and allocate carbon to different plant components. Measuring biomass therefore provides an estimate of the amount of carbon sequestered. Biomass estimation is fundamental to carbon stock assessments and can be achieved through ground measurements, allometric equations, and remote sensing approaches (Chave *et al.,* 2016). Allometric models that use tree diameter (DBH) and/or height provide practical methods for estimating tree and stand biomass. Studies such as Brown *et al.* (2019) have applied allometric equations to estimate biomass across tropical regions, providing valuable databases for carbon stock evaluations.

Nasarawa State University, Keffi Shabu-Lafia Campus, through its forest plantation initiatives, has the opportunity to serve as a model for the economic valuation of forest-based carbon stocks. However, a gap exists in understanding the exact carbon storage capacity of the plantation, the economic benefits derived from carbon trading, and how these factors can influence both environmental sustainability and local economic development, hence the need for this study.

METHODOLOGY

Study Area

The research was conducted in the forest plantation established by the Department of Forestry, Wildlife and Ecotourism, Nasarawa State University, Keffi (NSUK), Faculty of Agriculture, Shabu-Lafia Campus, Nasarawa State, Nigeria. Lafia is situated between longitude 08°35′N and latitude 08°33′E, within the Guinea Savannah zone of North Central Geopolitical zone, Nigeria, at an altitude of approximately 177 m above sea level. The mean monthly maximum temperature ranged from 35.06 °C to 36.40 °C, while the mean minimum temperature ranged from 20.16 °C to 20.50 °C. The relative humidity varied between 40–89%, with average daylight duration of 9–12 hours (Jayeoba, 2013). The established forest plantation which is approximately ten years old(10years) is located within the Faculty of Agriculture, Shabu-Lafia Campus, and covered two nearby sites measuring approximately 15,775 m² (1.58 ha) and 3,597.06 m² (0.36 ha) respectively, giving a total plantation size of about 18,988.4 m² (1.90 ha). Shabu lies within Lafia North Local Government Area of Nasarawa State, which had a total population of about 103,253 people and a land area of 599 km². The climate is typically warm and humid, characterized by two distinct seasons: the rainy season, which spanned from April to November, and the dry season, which lasted from November to March typical of a Guinea Savannah. The natural vegetation is dominated by a mixture of tree species, shrubs, and grasses, typical of the Guinea Savannah ecosystem.

Research Design

This study employed a quantitative and descriptive research design to assess the biomass, carbon stock, and economic valuation of the Forest Plantation. Quantitative design was selected because it allows for precise measurement of tree growth parameters such as diameter at breast height (DBH), height, which are essential for biomass and carbon estimation. The research design followed a cross-sectional approach, meaning that data were collected at a single point in time. This choice was made because tree biomass and soil carbon pools can be reliably estimated from one-time measurements, unlike variables such as seasonal leaf fall that may require repeated observations. Several studies (Chave *et al.,* 2014; Henry *et al.,* 2009) have adopted a similar design in tropical forestry research, making this approach scientifically reliable and contextually relevant.

Population and Sampling Procedure

The population of interest in this study comprised all tree species within the plantation. The plantation consists of exotic and indigenous species, arranged in blocks with an estimated age of over ten years, making them suitable for biomass and carbon assessment. To capture variability across the stand, a plot-based sampling method was used. A total of sixteen (16) plots of size 20 m × 20 m were demarcated, but seven (7) plots were purposively selected for intensive data collection. The purposive sampling was guided by the need to represent species diversity, stand density, and accessibility. While random or systematic sampling is common in forest inventories, purposive sampling was adopted because the objective was not generalization across a very large heterogeneous forest, but detailed assessment within a defined plantation block. Similar approaches have been reported in Nigerian forestry studies (Akindele and LeMay, 2006; Ogundele *et al.,* 2020).

Methods of Estimating Plant Biomass

Aboveground biomass (AGB) was estimated using the allometric model developed by Chave *et al.* (2014), which is widely used for tropical forests:

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

Where ρ is the wood density (g/cm³), DBH is diameter at breast height (cm), and H is total height (m). Wood density values were obtained from published databases.

Estimation of total carbon stock

Carbon stock was computed by applying the (Thomas and Matin, 2012) guideline that assumes about 47% of dry biomass is carbon:

$$C = 0.47 \times Biomass \quad 4$$

To convert carbon stock into CO_2 equivalent, the molecular weight ratio of CO_2 to C (44/12) was applied:

$$CO_2eq = C \times (44/12) \quad 5$$

This provides the total amount of carbon dioxide potentially mitigated by the plantation.

Estimation of the Economic Value of Carbon

The economic value of the carbon stock was estimated by applying a premium carbon price of US$40-80 per tonne of CO_2 equivalent, consistent with recommendations by Mario *et al.* (2022). This price reflects the true climate mitigation potential of forestry projects compared to the lower rates found in voluntary offset markets (US$5–15/t$CO_2$e). The valuation formula used was:

$$CEV(US\$) = CS(tCO2e) \times CP(USD/tCO2e) \quad 6$$

Where CEV= carbon economic value, CS= Carbon stock in *tCO2e*, and CP = carbon price in USD.

This formula is in line with (Mario, *et al.,* 2022).

In order to capture not only the baseline market value but also the premium associated with high-quality, nature-based carbon offsets, this research adopted a premium carbon price approach. Several authorities and institutions have demonstrated the use of premium carbon prices in evaluating carbon economic value: The Integrity Council for the Voluntary Carbon Market (ICVCM) and Calyx Global have shown that "Tier 1" high-integrity credits trade at a 65% premium compared to lower-quality credits (ICVCM, 2025). BeZero Carbon reported that each step-up in credit rating commands an average 20% higher price, with some improved forest management projects trading at premiums of up to 400% (BeZero, 2024). Mere Plantations in Ghana applies a minimum premium price of US $40 per tonne, far above the $8–15/tCO₂e average voluntary market rate, for its high-integrity forestry credits (Reuters, 2024). Swiss Re implements an internal carbon levy of US $100–200/tCO₂e to fund ecosystem restoration and removals (Sustain. Life, 2024). Microsoft and Shell also apply internal premium prices (US $40–80/tCO₂e) for carbon in investment decisions, showing institutional recognition of the added economic and social value of premium pricing (Global Data, 2023).

Based on these authorities, the present study adopted a premium carbon price benchmark rather than the average voluntary market price, ensuring that the calculated carbon economic value reflects both the environmental integrity and the co-benefits associated with high-quality, sensitivity analysis was performed by comparing results under alternative carbon prices (US$15 and US$40), in line with Nordhaus (2017) and EPA estimates.

Data Analysis

Data collected were analyzed using descriptive statistics (mean, standard deviation, and coefficient of variation) to summarize stand attributes. Regression analysis was performed to develop predictive models of biomass using tree parameters such as DBH and height. Analysis of variance (ANOVA) was used to test differences between dominant and recessive trees in terms of biomass contribution.

Ethics and Privileges

The study adheres strictly to the ethics of environmental research, minimizing disturbances given to the plantation ecosystem through all the work field activities. Informed consent was sought from the relevant authorities of the institution before conducting this research. The securely guarded data was collected for research purpose only, ensuring the interest of the environment, privacy protection, and moral uprightness of the participants involved.

RESULTS AND DISCUSSION

The result in table 1 shows the structural composition characteristics of the 10-year-old forest plantation at Nasarawa State University, Shabu-Lafia Campus. The plantation is numerically dominated by a few key species, with *Gmelina arborea* (117 trees), *Tectona grandis* (73 trees), and *Khaya senegalensis* (66 trees) forming the backbone of the planted stand. These fast-growing exotic and native species are commonly used in tropical plantations for timber and ecosystem services, a practice well-documented in similar Nigerian ecological zones (Egbewale *et al.,* 2023). However, the stand's is highlighted by the presence of 11 volunteer species with very low stem counts (2-4 individuals each). However, *Parkia biglobosa* (Locust bean) has the highest average DBH of 55.54 cm and a high basal area of 0.27 m². This, along with substantial trees like *Terminalia elliptica* (32.78 cm DBH) and *Daniela oliverii* (22.92 cm DBH) are the remnant native trees that are retained when the plantation was established, rather than planted individuals.

This size distribution creates a multi-layered canopy structure. The large *Parkia* and *Terminalia* trees form an emergent or upper canopy layer. The dominant populations of *Gmelina, Tectona*, and *Khaya*, with their moderate DBHs (10.9 - 13.0 cm) and heights (8.5 - 11.8 m)—which are typical for a 10-year-old stand in the Guinea Savannah as earlier reported by (Jayeoba, 2013)—constitute a dense middle canopy. In contrast, the very small trees like *Mangifera indica* (2.39 cm DBH, 3.25 m height) and *Vitex doniana* (2.86 cm DBH, 5.8 m height) exist in the suppressed understory. This structural heterogeneity is ecologically beneficial, as it enhances habitat complexity and supports greater biodiversity compared to monoculture plantations in line with the findings of (Chazdon, 2008; Egbewale *et al.*, 2023).

Since Aboveground Biomass (AGB) is largely a function of tree diameter (DBH) and wood density as earlier reported by (Chave *et al.,* 2014), the few large-diameter individuals are predicted to contribute disproportionately to the total carbon stock. A single *Parkia biglobosa* tree, with its high DBH and consequent large basal area and volume, likely stores more carbon than dozens of smaller *Gmelina* trees combined. This underscores a critical principle in forest carbon management: a small number of large, mature trees can dominate the total carbon storage of an ecosystem in line with (Lutz *et al.*, 2018). Therefore, the conservation of these large remnant trees within the plantation matrix is not just a biodiversity strategy but a core carbon management strategy. The results of the growth parameters indicate that the site conditions are generally favourable for the main plantation species. The achieved heights and diameters align with expectations for the age and climate of the region, suggesting successful establishment and growth.

Table 1: Summary Statistics of the Growth Parameters

Species	Tree count	DBH (cm) ± Std.Dev	Height (m) ± Std.Dev	Basal Area (m^2)	Tree Vol (cm^3)
Azadirachta indica	4	11.22±7.99	9.28±6.44	0.01±0.02	0.24±0.3
Anacardium occidentale	2	7.64±0.0	8.40±0.0	0.0046±0.0	0.04±0.0
Daniela oliverii	4	22.92±23.5	8.48±6.70	0.07±0.09	3.23±4.1
Gmelina arborea	117	12.96±5.90	8.56±2.34	0.02±0.02	0.3±0.78
Iivingia gabonenensi	2	5.73±0.0	7.80±0.0	0.003±0.0	0.01±0.0
Khaya Senegalensis	66	11.53±4.74	9.49±3.07	0.02±0.02	0.23±0.23
Mangifera indica	2	2.39±0.67	3.25±1.34	0.0±0.0	0±0.0
Parkia biglobosa	2	55.54±25.4	11.90±0.14	0.27±0.22	17.69±19.13
Syzygium cumini	2	11.46±0.0	6.20±0.0	0.01±0.0	0.12±0.0
Sterculia setigera	2	5.41±0.0	5.90±0.0	0.002±0.0	0.01±0.0
Sterculia siamae	3	15.91±6.62	16.00±3.82	0.02±0.02	0.41±0.23
Terminalia elliptica	2	32.78±0.0	9.60±0.0	0.08±0.0	2.77±0.0
Tectona grandis	73	10.90±3.41	11.79±2.77	0.01±0.01	0.13±0.1
Vitex doniana	2	2.86±0.0	5.80±0.0	0.001±0.0	0±0.0
Mean	**283**	**13.26±7.76**	**10.01±3.43**	**0.02±0.03**	**0.47±2.02**

The results in table 2 confirms table 1; how a few large trees dominate the ecosystem's carbon pool. *Parkia biglobosa*, with only two individuals, has by far the highest average AGB per tree (1314.9 kg) and carbon stock (763.24 kg). This is over 25 times the biomass of an average *Gmelina arborea* tree, despite *Gmelina* being the most numerous species. This pattern is repeated with *Daniela oliverii* (436.18 kg AGB) and *Terminalia elliptica* (392.68 kg AGB), which, though few in number, are major carbon reservoirs. This finding aligns with global research emphasizing the outsized role of large-diameter trees in forest carbon dynamics (Lutz *et al*., 2018). It underscores that for carbon sequestration, quality (tree size) can be more significant than quantity (tree count) in a established stand with native species allowed to coexist with the exotic species. The role of wood density (ρ) as a key factor in carbon estimation is clearly demonstrated. The allometric model used (Chave *et al.*, 2014) explicitly incorporates wood density, and its effect is visible; *Sterculia siamae* has a very high wood density (0.95 g/cm³). Despite having a moderate DBH (15.91 cm from Table 1), it achieves the fourth-highest AGB (258.9 kg), outperforming species with larger diameters but lower wood density like *Azadirachta indica* (ρ=0.63 g/cm³). Conversely, *Sterculia setigera* has a very low wood density (0.35 g/cm³), which explains its low biomass (3.69 kg) even with a DBH similar to other small trees. This highlights the importance of using species-specific wood density values rather than generic defaults for accurate carbon accounting, a practice emphasized in recent methodological guides (Egbewale *et al.*, 2024). The results also indicate that tree species such as *Khaya senegalensis* (66 trees, 42.50 kg C/tree), *Tectona grandis* (73 trees, 35.39 kg C/tree), and *Gmelina arborea* (117 trees, 30.07 kg C/tree) contributed the largest overall impact on the total plantation carbon sequestration due to their population. While their per-tree storage is modest compared to the giants, their collective contribution is substantial. This mixture of a few heavy-hitting carbon stocks (large native trees) with a matrix of consistent, fast-growing species is a highly effective model for maximizing sequestration in agroforestry and plantation systems (Egbewale *et al.*, 2023). The very low biomass values for species like *Mangifera indica* and *Vitex doniana* (both <1 kg AGB) confirm their status as suppressed or juvenile trees, contributing minimally to the current carbon stock but potentially representing future recruitment. The result validates the plantations significant carbon sink potentials. The strategic preservation of high-wood-density species and large remnant trees, combined with the management of the dominant plantation blocks, creates a synergistic effect that maximizes the carbon sequestration service of the landscape.

Table 2 Summary Statistics of the Tree Biomass Parameters

Species	Tree count	Wood Density (g/cm3) ± Std.Dev	AGB (kg) ± Std.Dev	Carbon stock (kg) ± Std.Dev	CO2 EQUIV
Azadirachta indica	4	0.63±0.09	81.12±94.24	47.08±54.7	172.79±200.7
Anacardium occidentale	2	0.49±0.0	14.17±0.0	8.22±0.0	30.19±0
Daniela oliverii	4	0.61±0.0	436.18±531.8	253.18±308.7	929.17±1132.83
Gmelina arborea	117	0.45±0.0	51.80±86.07	30.07±49.96	110.34±183.3
Iivingia .gabonenensi	2	0.72±0.0	10.94±0.0	6.35±0.0	23.31±0.0
Khaya Senegalensis	66	0.71±0.07	73.23±62.39	42.50±36.22	155.99±132.91
Mangifera indica	2	0.59±0.0	0.80±0.67	0.47±0.39	1.7±1.44
Parkia biglobosa	2	0.62±0.0	1314.9±1059.8	763.24±615.16	2801.06±2257.64
Syzygium cumini	2	0.77±0.0	36.14±0.0	20.98±0.0	76.98±0.0
Sterculia setigera	2	0.35±0.0	3.69±0.0	2.14±0.0	7.85±0.0
Sterculia siamae	3	0.95±0.0	258.9±186.7	150.28±108.37	551.53±397.72
Terminalia elliptica	2	0.70±0.0	392.68±0.0	227.93±0.0	836.51±0.0
Tectona grandis	73	0.65±0.01	60.96±39.53	35.39±22.95	129.86±84.21
Vitex doniana	2	0.40±0.0	1.19±0.0	0.69±0.0	2.54±0.0
Mean		**0.59±0.14**	**95.45±176.53**	**55.41±102.46**	**203.34±376.04**

There was a concentration of stems in the <10 cm (98) and 10-15 cm (152) DBH class: These encompass the dominant plantation species like *Gmelina arborea, Tectona grandis*, and *Khaya senegalensis*, reflecting the even-aged, 10-year-old population that forms the plantation's backbone. The Isolated trees in 40-49.9 and >70 in larger diameter classes represent the large native trees such as *Daniela oliverii,* and *Parkia biglobosa* respectively. The height class distribution correlate with the diameter classes, echoing the moderate relationship among these two growth parameters (r = 0.508) as found in Table 4. A large number of trees in the 5-9.9 m and 10-14.9 height classes correlate with the main plantation tree population. A smaller number of very tall trees (such as the 16 m *Sterculia siamae* and the ~12 m *Parkia biglobosa*) forms a separate peak. The data provides visual proof that the plantation was established around existing natural trees. The gap between the size classes suggests limited recruitment of new saplings into the larger size classes as a result of intensive management of the plantation. The current carbon stock is heavily influenced by the few large trees. For the carbon sink to be sustained, the dense cohort of middle-sized trees must successfully grow into the larger diameter classes. Figure 1 allows managers to project future carbon storage by modeling the growth of this large cohort into higher volume classes as reported by (Egbewale *et al*., 2023) and Magaji *et al.,* (2025) on carbon storage and sequestration dynamics among tree species.

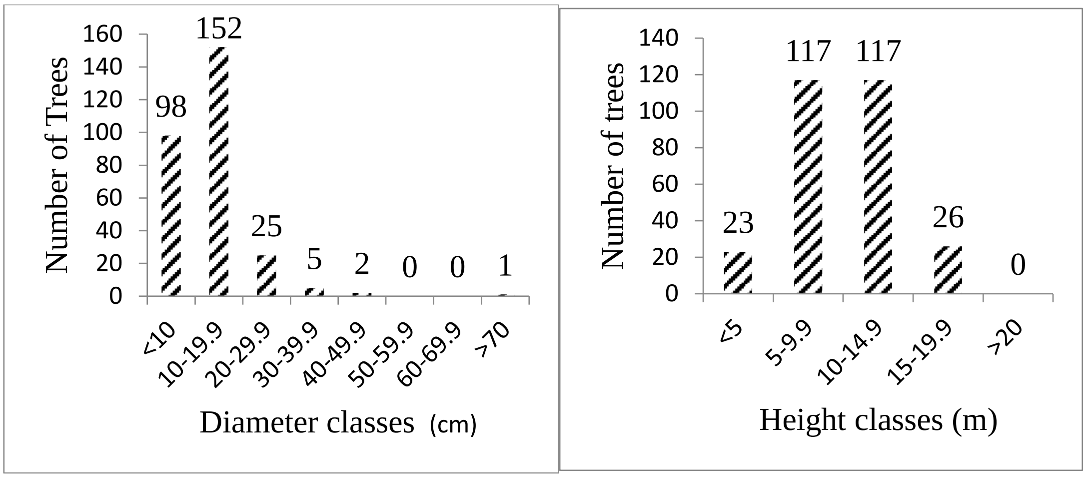

Figure 1: Diameter (cm) and Height (m) Classes

The result in table 4 shows that *Parkia biglobosa* has the largest mean AGB of 1314.9 kg/tree, significantly higher than any other species as a result of age variation. This finding powerfully reinforces the narrative from Tables 1 and 2: the preservation of large, mature native trees like *Parkia biglobosa* is the single most effective strategy for maximizing carbon storage in this ecosystem. As noted by Egbewale *et al.*, (2024), these "native mother trees" provide an immediate and massive carbon stock that would take decades for planted species to achieve. The second tier consists of *Daniela oliverii* (436.18 kg/tree) and *Terminalia elliptica* (392.68 kg/tree), both categorize in the same group. *Sterculia siamae* (258.91 kg/tree, was found to be a high-value native trees that contribute substantially to the carbon pool. The numerically dominant species such as *Gmelina arborea, Tectona grandis*, and *Khaya senegalensis* indicates that, on a per-tree basis, there is no significant difference in their AGB. These results underscore the importance of diverse species composition in carbon sequestration management. A successful carbon sequestration strategy must involve the protection of existing high-biomass trees and the intentional incorporation of high-performance native species in future afforestation efforts.

Table 3: Above Ground Biomass of the Plantation Per Species (kg)

S/N	Species	Tree count	Mean
1	*Parkia biglobosa*	2	1314.9[a]
2	*Daniela oliverii*	4	436.18[b]
3	*Terminalia elliptica*	2	392.68[b]
4	*Sterculia siamae*	3	258.91[c]
5	*Azadirachta indica*	4	81.12[e]
6	*Khaya Senegalensis*	66	73.23[e]
7	*Tectona grandis*	73	60.9610[e]
8	*Gmelina arborea*	117	51.7952[e]
9	*Syzygium cumini*	2	36.1400[e]
10	*Anacardium occidentale*	2	14.1700[e]
11	*Irvingia .gabonenensi*	2	10.9400[e]
12	*Sterculia setigera*	2	3.6900[e]
13	*Vitex doniana*	2	1.1900[e]
14	*Mangifera indica*	2	0.795[e]

Mean values with same superscript are not significantly different from each other

Table 4 shows the relationship between the various assessed indices. The most dominant pattern in the table is the exceptionally strong positive correlation (>.88) between the core carbon stock variables: AGB (kg), Carbon stock (kg), and CO_2 Equivalent. This is an expected and necessary result, as carbon stock is directly derived from AGB (by multiplying by 0.47), and CO_2 equivalent is directly derived from carbon stock (by multiplying by 3.67). These near-perfect correlations (0.997 and 0.999) indicate a high degree of internal consistency in the calculations and confirm that AGB is the foundational variable from which the other two are scaled. The most critical finding for field methodology is the very strong positive correlation between DBH and AGB (r = 0.887). This relationship forms the bases of allometric modeling and underscores why DBH is the most commonly measured variable in forest inventories. It demonstrates that in this plantation, over 78% ($r^2 \approx 0.787$) of the variation in a tree's biomass can be explained by its diameter alone. This justifies the heavy reliance on DBH in rapid carbon stock assessments, as it is a much easier parameter to measure accurately than tree height. The relationship between Height and AGB is positive but notably weaker (r = 0.440). This is common in mixed-species stands, as height growth can be influenced by competition, light availability, and species-specific traits. A tree with a large DBH might not be the tallest if it is in a crowded stand, yet it will still have high biomass. This weaker correlation highlights a key advantage of the allometric model by Chave *et al.* (2014) used in this study, which incorporates both DBH and height, thereby capturing a more nuanced picture of tree volume and biomass than DBH alone would. The correlation of Wood Density (ρ) with AGB is positive but weak (r = 0.239). While counterintuitive, this can be explained by the fact that some species with high wood density (e.g., *Sterculia setigera*) were very small, while the largest trees (e.g., *Parkia biglobosa*) had moderate wood density. This indicates that in this particular stand, tree size (DBH) is a much stronger driver of total biomass than wood density. However, as discussed for Table 2, wood density remains crucial for accurate per-species estimation, as it prevents the overestimation of biomass in low-density, fast-growing species and vice-versa. Furthermore, the strong correlation of Tree Volume and Basal Area with AGB (0.884 and 0.803 respectively) is logical, as both are geometric expressions of tree size. The very strong correlation between Tree Volume and Basal Area themselves (0.984) is expected, as basal area is a key component in volume calculations.

Table 4 Correlation Between the Assessed Parameters

Parameters	DBH (cm)	Height (m)	Wood Density (g/cm3)	AGB (kg)	Carbon stock (kg)	CO2 EQUIV	Tree Vol (cm^3)	Basal Area(m^2)
DBH (cm)	1							
Height (m)	0.508**	1						
ρ(g/cm^3)	0.114	0.386**	1					
AGB (kg)	0.887**	0.440**	0.239**	1				
Carbon stock Kg)	0.887**	0.440**	0.239**	0.997**	1			
CO2 EQUIV	0.887**	0.440**	0.239**	0.989**	0.999**	1		
Tree Vol (cm^3)	0.718**	0.161**	0.041	0.884**	0.884**	0.884**	1	
Basal area (m^2)	0.607**	0.094	0.022	0.803**	0.803**	0.803**	0.984**	1

** = Correlation is significant at the 0.01 level (2-tailed). * = Correlation is significant at the 0.05 level (2-tailed)

Table 5 indicate the carbon stock results by each species in tonnes, and then applies a premium carbon price of US $60 per tonne of CO_2 equivalen (the midpoint of the cited $40-$80 range) to calculate an economic value. The total carbon stock of the 1.90-hectare plantation is 15.49 tonnes, which translates to a total Carbon Economic Value (CEV) of $929.53 (or ₦1,415,527.13). While *Gmelina arborea* and *Khaya senegalensis* contribute the largest share of the total value due to their high stem counts (contributing $211.06 and $352.03 respectively), the outsized value of large individual trees is again evident. For instance, the two *Parkia biglobosa* trees alone account for a carbon value of $91.59, and the four **Daniela oliverii* trees contribute $60.76. This means that just six trees represent over 16% of the total estimated carbon value of the entire plantation, illustrating the economic argument for conserving high-carbon-stock native trees. The use of a premium carbon price is a significant and defensible methodological choice. By opting for a price of $40-$80/tCO_2e instead of the lower voluntary market average ($5-$15), the study aligns with recommendations from institutions like Microsoft and Shell and reflects the growing market premium for "high-integrity, nature-based" carbon credits (Mario *et al.*, 2022; ICVCM, 2025). This approach more accurately captures the true social cost of carbon and the added value of projects that provide biodiversity and community co-benefits, as this university plantation does through research and local employment. However, this valuation represents a potential or theoretical revenue. Realizing this value requires navigating complex processes like third-party verification, registration with a carbon standard, and finding a buyer on the voluntary carbon market (VCM). The costs of these processes must be deducted from the gross value presented. Furthermore, this is a stock value at a single point in time. For continuous revenue, the plantation would need to be certified to sell credits based on the additional carbon sequestered annually (the flow), not just the existing stock. This provides the University administration with a meaningful, evidence-based figure to justify continued investment in the plantation. It demonstrates that environmental stewardship can be economically rational, transforming the plantation from a cost center into a potential asset that contributes to both climate goals and institutional finance (Egbewale *et al.*, 2017).

Table 5 Estimated Value of the Carbon Stock in the Plantation

Species	Tree count	Carbon stock (kg)	Carbon stock (tons)	Economic value ($)	Economic value (₦)
Azadirachta indica	4	188.3258	0.18833	11.2996	17207.52
Anacardium occidentale	2	16.44992	0.01645	0.987	1503.045
Daniela oliverii	4	1012.718	1.01272	60.7631	92533.03
Gmelina arborea	117	3517.58	3.51758	211.055	321404.8
Iivingia .gabonenensi	2	12.70563	0.01271	0.76234	1160.926
Khaya Senegalensis	66	5867.192	5.86719	352.032	536091.2
Mangifera indica	2	0.924882	0.00093	0.05549	84.50741
Parkia biglobosa	2	1526.464	1.52646	91.5879	139474.6
Syzygium cumini	2	41.95224	0.04195	2.51713	3833.218
Sterculia setigera	2	4.280177	0.00428	0.25681	391.084
Sterculia siamae	3	263.1357	0.26314	15.7881	24042.97
Terminalia elliptica	2	455.8627	0.45586	27.3518	41652.63
Tectona grandis	73	2583.107	2.58311	154.986	236021
Vitex doniana	2	1.385674	0.00139	0.08314	126.6104
Mean	**283**	**15,492.08**	**15.4921**	**929.525**	**1,415,527.13**

Carbon credits taken at $40-$80 per metric tons according to Premium price 2024-2025

CONCLUSION

This study successfully quantified the aboveground biomass, carbon stock, and economic value of the 10-year-old forest plantation at Nasarawa State University, Shabu-Lafia Campus in cooperated with existing native tree species. The findings revealed a complex, multi-layered ecosystem that serves as a significant carbon sink, with a total aboveground carbon stock of 15.49 tonnes stored within the 1.90-hectare area. This translates to a substantial carbon economic value of approximately $930 (₦1.42 million), when valued at a premium price reflective of high-integrity, nature-based sequestration projects. This research underscores a critical insight: carbon storage is not uniform. The plantation's carbon pool is dominated by a combination of a few large, remnant native trees, such as *Parkia biglobosa* and *Daniela oliverii*, and the dense matrix of established plantation species like *Gmelina arborea*, *Tectona grandis*, and *Khaya senegalensis*. This structure highlights the synergistic value of integrating conservation of high-biomass indigenous trees with strategic afforestation. The strong correlation between Diameter at Breast Height (DBH) and biomass reaffirms the reliability of allometric models for carbon accounting in similar Guinea Savannah ecosystems. In essence, the Nasarawa State University plantation is not merely a collection of trees but a viable, revenue-generating asset that contributes to climate change mitigation, biodiversity conservation, and the university's sustainability goals. It stands as a potent model for other academic institutions and landholders in Nigeria, demonstrating that environmental stewardship can be aligned with economic incentive through carbon markets. It is therefore recommended that the University should proactively initiate the process of registering the plantation under a recognized voluntary carbon standard (e.g., Verra's VCS or the Gold Standard) to enable carbon credit monetization

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