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QUANTIFICATION OF ABOVEGROUND BIOMASS AND CARBON SEQUENSTRATION POTENTIALS OF *Eucalyptus cameldulensis* SPECIE AT DAYI PLANTATION, KATSINA STATE, NIGERIA

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ABSTRACT

Quantification of tree biomass in the tropics is a time-consuming activity, especially the measurement of certain biomass components, such as the tree height, diameter at various part of the tree stem. This study assessed the Quantification of aboveground biomass and carbon sequestration potentials of *Eucalyptus cameldulensis* specie at Dayi Plantation, Katsina State, Nigeria. The plantation was stratified into three different age series (1989, 1990 and 1991). In each stratum, a non-destructive approach was adopted and (5) sample plots of 50 x 50m were laid across each of the three (3) age series. All standing trees were marked, numbered and their attribute such as diameter at breast height (DBH), diameter at three different position (bottom, middle and top) and height (HT) were measured and recorded. A constant value of wood density (0.58) was obtained from the web. A total number of 1,349 tree stands were recorded for the entire plantation and the total quantity of 25,295 kg/ha AGB was estimated for the plantation, the estimated carbon stock is 12,647.5 kg/ha and the sequestered carbon, which represents the amount of carbon dioxide absorbed and stored by the ecosystem over time is 46,374.17 kg/ha. Conclusively, it is believed that the result of this study serve as input to forest managers, researchers and policy makers in planning and management of *Eucalyptus camaldulensis* in the state or region with similar environmental conditions.

Keywords: Aboveground biomass, Diameter, Quantification, Wood Density

INTRODUCTION

Plantation forest is one of the world's largest renewable ecosystem providing different products for human demands (Forest Stewardship Council (FSC), 2024). Forest provides income generation, it serves as habitat for animals, watershed protection and climate change mitigation through sequestering atmospheric carbon dioxide (CO_2) and store as a biomass (FSC), 2024). Since the beginning of life, trees have furnished man with two of life's essentials namely food and air (oxygen) (Tree, 2024). As man evolved, trees provided additional necessities such as shelter, medicine and tools. Presently, the values of trees are still increasing as more of their potential are being discovered and their roles are expanding to satisfy the needs created by our present-day lifestyles (Tree, 2024). Plantation forestry is increasingly based on successive rotation of plantations or the establishment of new forests on degraded land (FAO, 2015). This approach distinguishes plantation forests from native forests, which are natural assets with inherent ecological value. In contrast, plantation forests are deliberately grown, often described as tree farms, for specific purposes such as timber production, carbon sequestration, or ecosystem services (FAO, 2021). Plantation forest in Nigeria involves the establishment and management of tree plantations for various purposes, including timber production, pulpwood, and non-timber forest products. Nigeria has a long history of plantation forestry, dating back to the colonial era (FAO, 2020).

Allometric equations provide biomass estimates from tree measurements such as diameter at breast height (DBH), height, and/or wood density (Anthony *et al.,* 2020). Therefore, accurate measurements of biomass and other forest biophysical variables to determine the quantity of biomass in a forest are imperative and it is a useful measure for assessing the changes in forest structure. Widely used allometric equations must be independently evaluated using tree biomass datasets to identify error and bias (Duque *et al.,* 2017). Estimating the stocked carbon in forest trees is very important to assess the mitigation effect of forests on regional and global bases and to predict the potential mechanisms to reduce the emission of carbon that goes into the atmosphere (FSC), 2024). Determining the biomass of forests is a useful way of providing estimates of the quantity and quality of these components. The quantity of biomass in a forest is the net result of production through photosynthesis minus losses due to respiration, mortality, decomposition, and removal through harvest or other disturbances.

The need to estimate forest biomass, carbon stocks and stock changes, has become very important for different or various applications such as timber extraction, estimating the amount of CO_2 that can be absorbed from the atmosphere by the stands, tracking changes in the carbon stocks of the stand and that of global carbon cycle (Alefu *et al.,* 2015. However, limited number of studies is available regarding carbon stock for the different forest types, the soils underneath and plantations of various species of which *Eucalyptus cameldulensis* is the major one (Alefu *et al.,* 2015). Only few activities about carbon sequestration potential have been published recently (Alefu *et al.,* 2015). The accurate quantification of forest attributes, mainly related to biomass are basically determined by the precise measurement at the individual tree level (Altanzagas *et al.,* 2019).

Estimation of Aboveground Biomass and carbon sequestration is important for assessing the productivity and sustainability of the plantation (Liu *et al.,* 2014). Therefore, this study provides insights about the tree volume, estimated biomass carbon sequestration of *Eucalyptus cameldulensis*, for sustainable plantation management in the study area.

MATERIALS AND METHODS

Study site

The study area was Dayi plantation; located along Malumfashi - Gidan Mutum Daya road in Dayi village, Malumfashi Local Government Area, Katsina State Nigeria. The study site has a geographic position at N11^{0}93'486'' - N11^{0}94'469" and E007^{0}67'363'' - E007^{0}68'784" on elevation of 645 m. It has total area of 90ha with several compartments and the plantation established between the years 1989 and 1991 having three different age series by the Katsina State Government of Nigeria presented in Figure 1. The study site experiences a tropical continental climate characterized by distinct wet and dry seasons. The vegetation type of the study site is the West African type which follows the pattern of rainfall distribution. And it falls within Sudan Savanna zone of Nigeria, distinguished by large expanse of grasslands with widely spaced trees of varying heights and diversity.

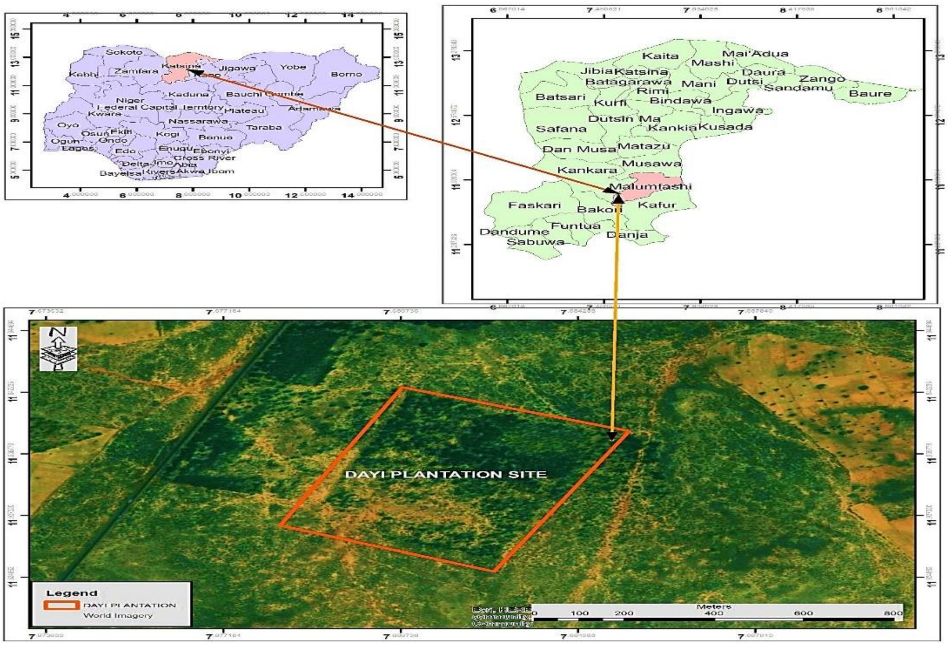

Figure 1: The Study Area
Source: (https://earth.google.com/world/imagery)

A preliminary survey was conducted at the study site in order to obtain general information about the plantation. Subsequently, the reconnaissance survey covered the whole plantation to have an overall impression, plan the methodology and addressed potential challenges. Non-destructive methods was employed in this research as adopted by Ajayi *et al.,* (2012) in which simple random sampling method was used, a sample plot of 50 x 50m was laid, Five (5) in each of the plantation's age series (1989, 1990 and 1991) making a total of fifteen (15) sample plots for whole plantation. The tools used in this research are compass, machete, tally sheets, axe, Global Positioning System (GPS), diameter tape, Haga Altimeter, linear tape, Spiegel-Relaskope, Scientific calculator, work map and stationery.

Data Collection

The number of trees were mark, counted and recorded in each plot, tree attributes such as diameter at breast height (DBH), diameter at the bottom (DB), diameter at the middle (DM), diameter at the top (DT) and height (HT) of each tree in the sample plot were measured and recorded, as adopted by (Henry et. al., 2010),

Data Analysis

The data collected from the field was processed to formulate equations, such as basal area (BA), volume (m^3) and biomass estimation as calculated below

Basal area

$BA = \frac{\pi D2}{4}$ (1)

Where; BA = individual tree basal area (m), D = diameter at breast height (cm) and
π = constant (3.142)

Volume Estimation

The volume of the species was calculated using Newton's formula (Adopted by Saka, 2021)

$v = ((Ab + 4Am + At)H)/6$ (2)

Where; V = Volume, H = Tree height, Ab= Cross sectional area at the base, Am= Cross sectional area at the middle and At = Cross sectional area at the top

While Cross sectional area is $\pi \left(\frac{DBH}{2}\right)^2$

Where; DBH is Diameter at breast height (cm) and π is constant (3.142)

Biomass Estimation

The biomass was estimated by calculating the volume of each standing tree, to obtain the volume, basal area was first calculated by using diameter at breast height and height of tree measurements. As reported by (Chave, 2014). The biomass estimation was then achieved after obtaining the volume of each tree by using the equation below

B = V X ƿ (3)

Where; B = biomass estimation (kg), V = estimated volume (cm^3)
and ƿ = wood-specific density which is 0.58 (t/m^3or g/m^3), adopted by (Akindele 2016).

Above Ground Biomass

$Y = \alpha D^b$ (4)

AGB = $\alpha x(DBH)^b$ (5)
AGB = $\exp(\alpha) \times$ Ꝑdbh^2H (6)
Where; AGB = the total above-ground biomass, DBH = the diameter at breast height, a = intercept of allometric relationship and b = Slope allometric relationship

Estimation of Carbon Stock
Generally, for any plant species 50% of its biomass is considered as carbon. The carbon of trees will be calculated using following equation
Carbon store = Biomass×50% or Biomass average i.e. Biomass/2

Estimation of Carbon dioxide sequestered
The weight of carbon dioxide sequestered (CO_2 is composed of one molecule of Carbon and 2 molecules of Oxygen and the atomic weight of Carbon is 12.0. The atomic weight of Oxygen is 16.0. Hence, weight of CO_2 is C + (2 X O) = 44.0, while the ratio of CO_2 to C is 43.0/12.0 = 3.6663. Therefore, to estimate carbon dioxide sequestered in the tree, we multiplied the carbon stored in the tree by 3.667 (Julius *et al.,* 2021).
Carbon dioxide sequestrated in trees = Atomic weight of CO_2 (44/12) × carbon stored

RESULTS AND DISCUSSION

Table 1: The Statistics Summary of Tree Variables used for the Estimation Aboveground Biomass of *E. cameldulensis* In Dayi Plantation

Year of Establishment/ Age	Plot Number	No. of Trees	Mean Dbh (cm)	Mean Basal Area (m^2)	Volume (m^3)	Biomass (kg/ha)	Carbon Stock (kg)	CO_2 Sequestered (Kg)
1989 (35 YRS)	1	83	69.6	0.38	425.4	987	493.5	1809.5
	2	92	72.9	0.418	645.2	1497	748.5	2744.5
	3	107	82	0.528	875.5	2032	1016	3725.333
	4	74	76.2	0.456	534.6	1240	620	2273.333
	5	84	86.1	0.582	698.1	1620	810	2970
1990 (34 YRS)	1	113	101.6	0.811	1252	2905	1452.5	5325.833
	2	79	92.2	0.668	637.5	1479	739.5	2711.5
	3	79	103.4	0.839	805.1	1868	934	3424.667
	4	67	94.8	0.706	544	1262	631	2313.667
	5	69	84.3	0.556	566.6	1315	657.5	2410.833
1991 (33 YRS)	1	106	89.6	0.631	1039	2410	1205	4418.333
	2	115	81.8	0.526	831	1929	964.5	3536.5
	3	78	86.9	0.594	614.4	1425	712.5	2612.5
	4	117	84.7	0.563	876	2033	1016.5	3727.167
TOTAL	15	1,349				25,295	12,648	46,374

Source: Field work (2024)

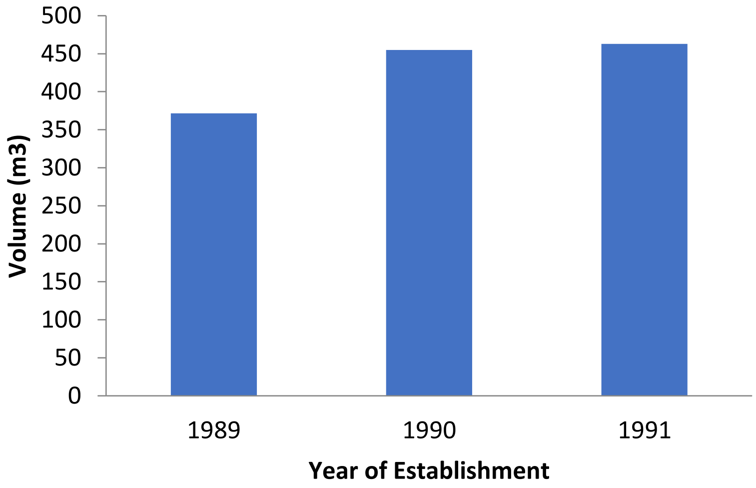

Figure 2: Chart showing Volume of each year series
Source: Field work (2024)

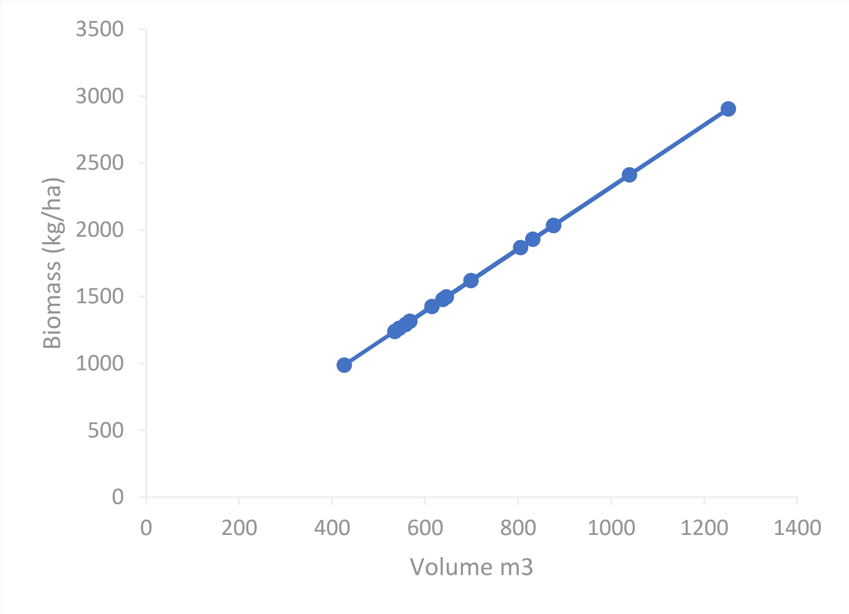

Figure 3: Chart showing relationship between Volume and Biomass
Source: Field work (2024)

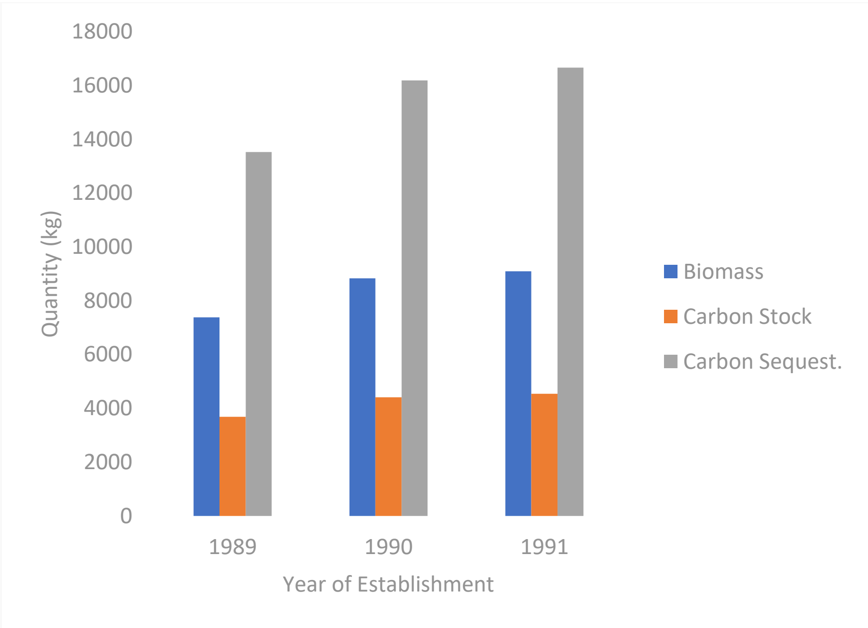

Figure 4: Chart for Biomass, Carbon (CO_2) Stock and Carbon Sequestered
Source: Field work (2024)

Discussion

The statistics summary of tree variables used for the estimation for the aboveground biomass of *Eucalyptus camaldulensis* in Dayi Plantation. The total number of tree stem recorded is 1349, and the highest numbers of tree stem (502 trees) was found in 1991 plantation, while, 1989 and 1990 plantation had a total number of 440 and 407 stems respectively as presented in table 1. The higher number of tree stems obtained in this research is higher than the one recorded by (Saka *et al*, 2020) who recorded a total of 395 tree stems in their research. This variation may be as a result of environmental factor and different in operational management.

In terms of tree volume per hectare, the total tree volume per hectare recorded is (15,674m^3/ha) in the plantation established 1991 and it has the highest total tree volume per hectare, this was followed by plantation established in 1990 with total volume of (15,253m^3/ha), while the least total tree volume per hectare (12,717m^3/ha) was obtained in1989 plantation. Therefore, Volume per hectare varies significantly, this is a reflection of the fact that, plantations tree growth variables varies with age. This is similar to the study by Adekunle *et al.,* (2011) who observed an increase in stand growth with different age series in Teak plantation in Omo Biosphere Forest reserve, this process has been described inevitable especially where there are favourable environmental conditions and all other factors that support tree growth.

The value of specific wood density used in this research was obtained from the web (0.58 t/m^3), this value is consistent with the range of specific wood density values reported by Kumar *et al*., (2017); Sanquetta *et al*., (2020), for *Eucalyptus* species, which typically vary between 0.55 - 0.65 g/cm³. The wood density value of 0.58 t/m³ also correspond with the constant wood density value used (0.58 t/m³) by Akindele (2016).

The total estimated aboveground biomass for *Eucalyptus camaldulensis* in Dayi plantation was 25, 294 kg/m³ across the three age series. The plot biomass ranges between 987 to 2032 kg/m³ in 1989 plantation, in 1990 and 1991, the estimated tree biomass ranges between 1,262 to 2,905 kg/m³ and 1,293 to 2,410 kg/m³ respectively. While the total estimated biomass in plantation 1989, 1990 and 1991 were 7376, 8828 and 9090 kg/m³ respectively, the biomass per hectare increases from 7376 Kg/ha in 1989 to 9090 Kg/ha in 1991, indicating a significant increase in forest biomass over the three-year period. The biomass was higher than the mean of above ground biomass and carbon stock of trees in lower, middle and upper elevations in *Eucalyptus* plantations along elevation gradients in Minjarn Distrct, Northern Ethiopia reported by Tegene, (2018), which was 342.09 kg/ha, 339.03 kg/ha and 257.44 kg/ha respectively.

However, the mean above-ground biomass obtained in this research were higher than 114.48kg/ha obtained in the assessment of aboveground biomass and carbon pools in Ethiopia) reported by Metz *et al*. (2007). The variation with other findings might be from difference in management of the forest plantations and differences in environmental conditions (Kaewkrom, *et al*., 2011).

The study revealed significant insights into carbon storage and sequestration dynamics. According to the findings, the total stored carbon in the study area currently stands at 12,647.5 kg/ha. Meanwhile, the sequestered carbon, which represents the amount of carbon dioxide absorbed and stored by the ecosystem over time, is substantially higher at 46,374.17 kg/ha. The carbon stored and the carbon sequestered are higher than the findings of the mean carbon stocked, carbon dioxide sequestered of 359.69 kg and 1318.70 kg respectively in the study, Carbon sequestration potentials of selected tree species in University of Maiduguri campus, Maiduguri, Nigeria. Reported by Mohammed *et al*., (2025). This variation may be as a result of factors such as plot size and number, climatic condition and the specie.

Age is an important factor on which carbon stock and carbon sequestration rate are dependent, estimates from the study show carbon stocks of 3,688 kg/ha in 1989, increasing to 4,414.5 kg/ha in 1990, and further rising to 4,545 kg/ha in 1991. These numbers suggest a pattern of growing carbon storage capacity over the years, likely due to factors such as ecosystem maturity, human activities, changes in land use, or shifts in climate conditions. In addition, area under 1991 year plantation is more stocking density and they have larger biomass, so, they are sequestering more CO_2 as compared to all other age series of the plantation.

CONCLUSION

Dayi plantation is important for storage of carbon, soil and environmental protection/conservation and different ecological services. The estimated total biomass for 1989, 1990 and 1991 are 7376, 8828 and 9090 kg/m³ respectively and the estimated total above ground biomass for the study was 25294 kg/m³. The estimated carbon stock is 12,647.5 kg/ha. Meanwhile, the sequestered carbon, which represents the amount of carbon dioxide absorbed and stored by the ecosystem over time, is substantially higher at 46,374.17 kg/ha. This study can help in climate change mitigation.

Based on the findings, the study provide support for research and development of new technologies and methods for estimating aboveground biomass and promote sustainable forest management practices to maintain ecosystem services and biodiversity.

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