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Evaluation of Aboveground Biomass and Carbon Stock Content of Seven Most Abundant Tree Species in Oluwa Forest Reserve, Ondo State, Nigeria

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ABSTRACT: Climate change has become a topical issue in the recent time. Hence, several research efforts are geared towards mitigating the effects especially in Nigeria where deforestation rate is alarming. Carbon sequestration potentials of different tree species has been suggested as mitigating factor of climate change. Hence, the objective of this paper is to evaluate the aboveground biomass (AGB) and carbon stock (CS) content for seven most abundant trees species in Oluwa forest reserve, Ondo State Nigeria using systematic line transact, twenty temporary sample plots (25m x 25m) were demarcated. All tree species (diameter at breast height ≥ 10cm) were identified to species level and the seven most abundant (*Funtumia elastica, Celtis zenkeri, Ricinodendron heudolotti, Diospyros crassiflora, Berlinia grandiflora, Picralima nitida* and *Buchholzia coriacea*) selected. The tree height, diameters at the base, middle and top of each selected species were measured. Tree Volume (TV), AGB and CS were estimated and Wood Density (WD) determined following standard procedures. It was observed that *Ricinodendron heudolotti* had the least WD (360kg/m^3) but highest TV, AGB and CS (4.7547 m^3, 1711.683kg and 855.8415kg), respectively. *Diospyros crassiflora* had the highest WD (670kg/m^3) but the least TV, AGB and CS (0.1480 m^3, 99.191kg and 49.5953kg), respectively. This revealed that TV is an important determining factor of AGB. This study shows that high WD alone does not result in high AGB but the TV must equally be high. The more a forest tree is left to mature, the more the AGB and consequently, the amount of carbon that can be sequestered from such forest.

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Carbon stock in tropical forests has been identified as one the highest (Malhi *et al*. 1999). Carbon exists in the earth's atmosphere primarily as the gas-carbon dioxide. It constitutes about 0.04% of atmospheric gases (Vashum and Jayakumar, 2012). However, it plays an important role in supporting life on earth. During photosynthesis, plants take up carbon dioxide from the atmosphere, convert it into carbohydrate and releases oxygen into the atmosphere. When these plants or trees die or are burnt, the carbon stored in them are released back into the atmosphere. Aboveground biomass are the living vegetation above the soil, which include stems, stumps, branches, bark, wildlings/saplings, litters, seeds and foliage (Céline *et al*., 2022). Biomass is also considered a useful indicator of structural and functional attributes of forest ecosystems across a wide range of environmental conditions (Brown *et al.*, 1999). According to Oladoye *et al*. (2018), tree biomass is a function of stem volume and wood density. Sterck *et al*., (2001) opined that wood density varies across species, tree age (Fujimoto *et al*., 2006), life-history strategy (King *et al*., 2005) and environmental factors such as topography and slope aspect (Hultine *et al*.,

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2005). Forests play an important role in global carbon cycling, since they are large pools of carbon as well as potential carbon sinks and sources to the atmosphere (Oladoye *et al*., 2018). Estimating the biomass of a forest ecosystem enhances estimation of the amount of carbon dioxide (CO_2) that can be sequestered from the atmosphere by the forest. It is also required for greenhouse gas inventories and terrestrial carbon accounting. The accurate assessment of biomass estimate of a forest is important for many applications like timber extraction, tracking changes in the carbon stocks of forest and global carbon cycle.

Several researches have been done on above ground biomass estimation (Ige, 2018, Odiwe *et al.*, 2017, Vashum and Jayakumar, 2012,) but studies that have been carried out in Oluwa forest reserve talked about the Ecological implications of land use in Nigerian forest reserve (Orimoogunje and Ekanade, 2010), Agbor *et al*. (2021) worked on the prediction of forest loss in Oluwa forest reserve using satellite based method. However, there is inadequate research recorded on above ground biomass in the forest reserve. Adequate information on the estimated above ground biomass of Oluwa forest reserve will enable stakeholders to estimate the amount of CO_2 that can be sequestered from the atmosphere by Oluwa forest reserve. Hence, this study aimed to estimate the aboveground biomass and carbon stock of seven most abundant tree species in Oluwa forest reserve, Ondo State, Nigeria.

MATERIALS AND METHOD

*Study Area***:** This study was carried out in Oluwa forest reserve, Ondo State, Nigeria. It is located approximately between latitudes 6˚37' and 7˚20' North and longitudes 4˚27' and 5˚05' East (Fig 1). The reserve has been separated from the Omo and Shasha reserves and covers about 1012 km^2. The forest reserve is characterized by undulating topography and a mean elevation of 90 m above sea level, mean relative humidity of 80%, and a daily temperature of 25˚C, characterized by a moist semi-evergreen rainforest (Udoakpan, 2013). Oluwa forest reserve has an annual rainfall which exceeds 2000 mm with two distinct seasons: the rainy season which starts mostly in February and ends in October and a dry season that starts in November and ends in January. The natural vegetation of the area is the tropical rainforest characterized by emergent with multiple canopies and lianas.

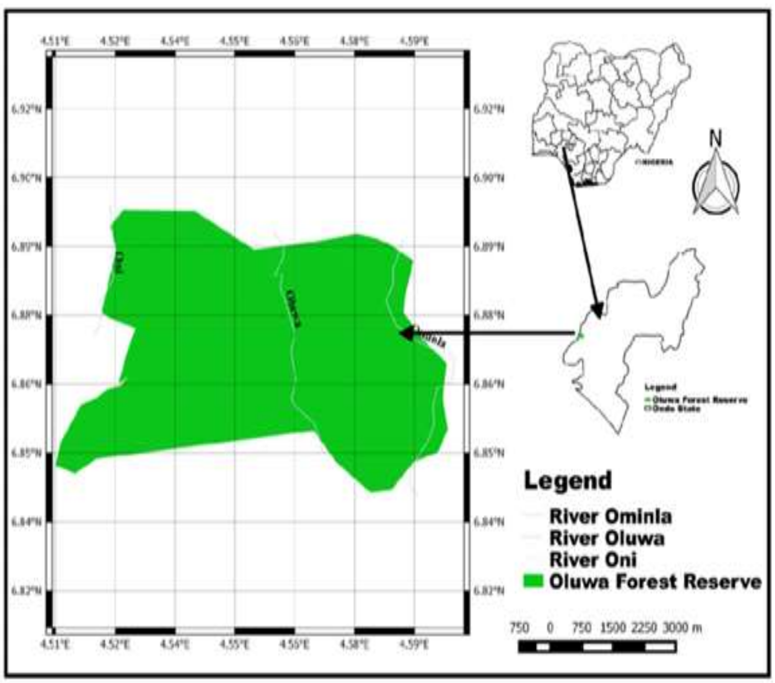

Fig 1: Oluwa forest reserve (Source: Ige and Silas, 2022).

Sampling Technique: Simple systematic line transect was used to lay Temporary Sample Plots (TSP) for this study. A total of 20 TSPs were laid. In laying of TSP for data collection, five parallel transects of 100m apart were laid and four sample plot of equal size of 25m x 25m were laid alternatively on each transect at 50 meter interval distance offset away from each TSP.

Data Collection: On each TSP, all trees with Diameter at Breast Height (DBH) $\geq$ 10 cm were identified to species level. Seven most abundant tree species namely *Funtumia elastica*, *Celtis zenkeri*, *Ricinodendron heudolotti*, *Diospyros crassiflora*, *Berlinia grandiflora*, *Picralima nitida* and *Buchholzia coriacea* were selected for use in this study. The diameter at the base (Db), diameter at breast height (Dbh), diameter at the middle (Dm), diameter at the top (Dt) and height of all selected trees were measured using diameter tape and spiegal relascope. Wood densities of these species were obtained from literatures (FAO, 2020).

Data Analysis: Result of the growth variables were subjected to descriptive statistics and correlation analysis and the result presented in form of tables and charts.

Tree Volume Estimation: The volume of all selected trees was calculated using Newton's formula.

$$\mathrm{T}V = \pi \frac{H}{24}\left(D_b{}^2 + 4D_m{}^2 + D_t{}^2\right) \quad (1)$$

Where, TV = volume (m^3); H= total height; $\pi =$ pi (3.142); D_b = the sectional area at the base (m^2) D_m = the sectional area at the middle (m^2); D_t = the sectional area at the top (m^2)

Aboveground Biomass Estimation: Aboveground biomass for individual trees of each species was determined as a function of stem volume and wood basic density of the tree species (Odiwe *et al*., 2017, Ravindranath and Ostwald, 2008).

$$\mathrm{AGB\ (g) = TV\ (m^3) \times WD\ (k/m^3)} \quad (2)$$

Where, AGB = Above Ground Biomass; TV = Tree stem volume; WD = Wood density

Carbon Stock Estimation: The above ground carbon stock of individual trees of each species was determined as the product of the dry weight and an assumed carbon content of 50% (IPCC 2006). The equation Carbon Stock (kg) = AGB x 0.5 was used to estimate the carbon stock. Where ABG is the Above Ground Biomass

RESULTS AND DISCUSSION

Table 1 shows the summary of the tree species captured for this study. From the results, *Funtumia elastica* has DBH ranges from 14.7 to 25.1, Height ranges from 11.5 to 15.2 and Volume range from 0.051 to 0.263. *Celtis zenkeri* has DBH ranges from 10.9 to 41.9, Height ranges from 5.2 to 26.8 and Volume range from 0.0159 to 0.856. *Ricinodendron heudolotti* has DBH range from 20 to 93, Height ranges from 9.2 to 53.2 and Volume range from 0.164 to 11.428. *Diospyros crassiflora* has DBH range of 10.9 to 24, Height range of 7.2 to 15.3 and Volume range from 0.0380 to 0.364. *Berlinia grandiflora* has DBH range of 11.9 to 41, Height range of 7.1 to 36.8 and Volume range from 0.0686 to 2.615. *Picralima nitida* has DBH range of 14.2 to 24.2, Height range of 6.3 to 13.7 and Volume range from 0.114 to 0.268 while *Buchholzia coriacea* has DBH range of 12 to 26.1, Height range of 6.5 to 33.6 and Volume range from 0.0269 to 1.254.

Table 1 Summary of the Tree Species captured in the Study Area

Species	Dbh range (cm)	Height range (m)	Volume range (m^3)
Funtumia elastica,	14.7 – 25.1	11.5 – 15.2	0.051 – 0.263
Celtis zenkeri	10.9 – 41.9	5.2 -26.8	0.0159 – 0.856
Ricinodendron heudolotti	20 – 93	9.2 – 53.2	0.164 – 11.428
Diospyros crassiflora	10.9 – 24	7.2 – 15.3	0.0380 – 0.364
Berlinia grandiflora	11.9 – 41	7.1 – 36.8	0.0686 – 2.615
Picralima nitida	14.2 – 24.2	6.3 – 13.7	0.114 – 0.268
Buchholzia coriacea	12 – 26.1	6.5 – 33.6	0.0269 – 1. 254

Table 2: Wood Density, Mean Volume, Aboveground Biomass and Carbon Stock (CS) of Selected Species.

Species	W D (g/ cm^3)	W D (kg/ m^3)	Mean V (m^3)	AGB (kg)	CS (kg)
Funtumia elastica,	0.51	510	0.198513	101.2414	50.62069
Celtis zenkeri	0.66	660	0.522004	344.5225	172.2613
Ricinodendron heudolotti	0.36	360	4.754674	1711.683	855.8415
Diospyros crassiflora	0.67	670	0.148046	99.19051	49.59525
Berlinia grandiflora	0.76	760	0.720587	547.6461	273.8231
Picralima nitida	0.72	720	0.196346	141.3692	70.6846
Buchholzia coriacea	0.50	500	0.378643	189.3216	94.66078

WD = wood density, AGB= Above Ground Biomass, CS= Carbon Stock

From Table 2, the Wood density of *Funtumia elastica* is 510, mean volume is 0.1985, AGB is 101.2414 and the carbon stock is 50.6207. The wood density for *Celtis zenkeri* is 660, mean volume is 0.5220, AGB is 344.5225 and the carbon stock is 172.2613. *Ricinodendron heudolotti* has a wood density of 360, mean volume is 4.7547, AGB is 1711.683 and carbon stock is 855.8415. *Diospyros crassiflora* has wood density value of 670, mean volume of 0.148, AGB of 99.190 and carbon stock of 49.595. The wood density of *Berlinia grandiflora* is 760, mean volume of 0.720, AGB is 547.646 and carbon stock is 273.82. *Picralima nitida* has wood density of 720, mean volume of 0.196, AGB of 141.369, and carbon stock of 70. 685. Lastly, *Buchholzia coriacea* has wood density of 500, mean volume of 0.379, AGB of 189.322 and carbon stock of 94.661.

The result of the correlation obtained from this study as shown on Table 3 reveals that almost all the variables showed positive correlation with one another excluding wood density. The DBH had positive correlation with Total height (0.95508), mean Volume (0.98307), aboveground biomass (0.986323) and carbon stock (0.986323). This means that as the DBH of the tree increases, its Total height, Volume, Aboveground biomass and carbon stock values all increases as well. On the other hand, wood density correlated negatively with all the other tree variables like Diameter at breast height (-0.63167), total height (-0.56176), mean volume (-0.68998), above ground biomass (-0.59441) and carbon stock estimation (-0.59441). This implies that wood density decreases as other tree variables like DBH, total height, volume, AGB and CS increases.

Table 3 Correlation Analysis of the Variables

	DBH	THt	V	WD	AGB	CS
DBH	1					
THt	0.95508	1				
V	0.98307	0.950986	1			
WD	-0.63167	-0.56176	-0.68998	1		
AGB	0.986323	0.984189	0.986611	-0.59441	1	
CS	0.986323	0.984189	0.986611	-0.59441	1	1

DBH = Diameter at breast height, THt = Total height, V = mean volume, WD = wood density, AGB = Aboveground Biomass, CS = Carbon Stock

Tree volume is simply the product of the diameter and height of a tree. Trees with higher DBH and height tend to have higher volume, such as, *Ricinodendron heudolotti.* Wood density is one of the major variables required for the estimation of aboveground tree biomass and forest carbon stock. The wood density measurements vary among tree species, and within the individuals of the same species. This variation might be as a result of differences in ecological zones, for example Williamson (1992) and Wiemann *et al.* (2002), where differences in densities between species were reported to be higher in the tropics compared to the values in the temperate region. The wood density for *Funtumia elastica* (510 kg/m^3) reported in this study was higher than the values of other species namely *Funtumia africana (*400 kg/ m^3) and for *F. latifolia (*450 kg/ m^3) reported in the global database (Ryes *et al.*, 1992). Biomass allocation in plants was also reported to be functions of tree volume and wood density (Egbe and Tabot 2011). The biomass production by a plant community is the reflection of its capacity to assimilate solar energy under some set of environmental conditions (Ige, 2018). From the result of this study *Ricinodendron heudolotti* with wood density of 360 kg/m^3 which is also the lowest had the highest aboveground biomass (1711.683). This result disagrees with the findings of Odiwe *et al*., (2017) who attested that the high AGB of *Celtis zenkeri* was as a result of the high wood density value. Therefore, the high AGB of *Ricinodendron heudolotti* was as a result of the high volume recorded in this study. This also goes contrary to the findings of Chave *et al.* (2004) and Kenzo *et al.* (2009) who noted that lower wood density usually shows lower biomass estimate while a higher wood basic density shows a higher biomass estimate. The carbon stock of a forest goes hand in hand with the AGB. That is, the higher the AGB, the higher the CSE while the lower the AGB, the lower the CSE. It can be simply put that the Carbon stock content of a tree species is directly proportional to its aboveground biomass. From the results obtained in this study, the highest value of ABG of *Ricinodendron heudolotti* resulted in highest carbon stock recorded in this study. The other species also follow the same trend. This result agrees with the report from Rahayu *et al*. (2005) and Vieira *et al*. (2005), who reported more carbon stock in rubber plantation trees with increased rates of volume and wood densities (Aboveground biomass).

Conclusion: The study revealed the potential capacity of the most abundant tree species in Oluwa forest reserve to sequestered carbon. This study is therefore important in that the trees be properly managed for continuous provision of their services such as climate change mitigation. It is crucial to protect these tree species against illegal harvesting to allow them mature thereby resulting in high aboveground biomass and also increasing the amount of CO_2 that can be sequestered from the forest.

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