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Full Length Research Article

DETERMINATION OF ABOVE GROUND BIOMASS ACCUMULATED IN NIMBIA FOREST RESERVE OF KADUNA STATE, NIGERIA

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ABSTRACT

Despite the importance of forests, most forest carbon stocks are poorly defined, and knowledge gaps obstruct efforts to estimate above-ground biomass across Nigeria. Descriptive research design was employed in estimating the amount of above ground biomass stored in the forest. A single hectare plot was sampled and used as a representative of the entire forest due to the homogeneity of the forest. Data were collected using, Diameter at Breast Height (DBH), maximum tree height, number of trees within sampled plot and plot size. Allometric equations was employed to analyze the DBH and trees height to estimate the; weight of stem, weight of branch, weight of leaves and finally the accumulated AGB (Above Ground Biomass) within the sampled plot, which was also treated as AGB density in this study. Estimation of forest area covered by tree was done by analyzing a satellite image of the forest using Arc GIS software and finally the Total Aboveground Biomass (TAGB) of the forest was extrapolated from the estimated values. The finding suggest that Nimbia Forest Reserve covers significantly land area of 1,909.72 hectares and 81.12% (1549.24 hectares) with Teak trees planted three metres apart and an AGB density of 53,279,932.02 tons per hectare. These conclude that the Nimbia Forest Reserve is worth over eight billion tons of accumulated AGB and four billion tons of CO_2, furthermore, any tree cutting will release a significant amount of CO_2 into the atmosphere, posing a climate change concern.

Keywords: Biomass, Breast height, Carbon, Forest, Tropical

INTRODUCTION

Biomass is any organic matter-wood, crops, seaweed, animal wastes-that can be used as an energy source. Biomass is probably our oldest source of energy. For thousands of years, people have burned wood to heat their homes and cook their food.

Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. During a process called photosynthesis, sunlight gives plants the energy they need to convert water, carbon dioxide, and minerals into oxygen and sugars. The sugars called carbohydrates, supply plants (or the animals that eat plants) with energy. While carbon is being stored as biomass (carbon stock) which accounts for 40 to 60 percent of above ground biomass.

Above-ground biomass includes all biomass in living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds and foliage. Above-ground biomass is the most visible of all the carbon pools, and changes in it are an important indicator of change or of the impact of an intervention on benefits related to both carbon mitigation and other matters. Above-ground biomass is a key pool for most land-based projects. Carbon exists in the earth's atmosphere primarily as the gas-carbon dioxide. It constitutes a very small percentage of the atmosphere about 0.04% approximately. However, it plays an important role in supporting life on earth, as plants make themselves from it. During photosynthesis, plants take up carbon dioxide from the atmosphere, converting it into carbohydrate and releasing oxygen into the atmosphere. When these plants or trees die or are burnt, the carbon stored in them are released back into the atmosphere. This natural cycling of the carbon is maintained and controlled by a dynamic balance between biological and inorganic processes since the geological history of earth (Kuimi and Jayakumar, 2012).

Forest is the main terrestrial biotic reservoir for above-ground carbon stock. For this reason, accurate estimates of forest above-ground biomass (AGB) are required to understand the global carbon cycle, thereby to implement climate change mitigation policies, and support project activities such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation in developing countries + conservation of forest carbon stocks, sustainable management of forest and enhancement of forest carbon stocks). Globally, substantial effort has been made to develop robust and cost-effective above-ground biomass estimation methods, including field measurements and remote sensing. However, the accuracy in the estimation of AGB still lags behind the required level, and uncertainties in the terrestrial carbon storage are particularly large in the tropical areas. In comparison to other regions of the world, the AGB estimates of the African forests and woodlands, however, remain scarce. In terms of REDD+, large areas of savanna woodlands, shrub lands and agroforestry parklands qualify as forests. Biomass typically constitutes the largest fraction of the primary energy consumption in these areas, and hence AGB estimates are important part of fuel-wood resource assessments (Ruben *et al*. 2016).

In a tropical forest ecosystem, the living biomass of trees, the understory vegetation and the deadwood, which includes the standing deadwood and the fallen deadwood like fallen stems and fallen branches, woody debris and soil organic matters constitute the main carbon pool. Among the above-mentioned carbon pools, the above-ground biomass of the tree is mainly the largest carbon pool and it is directly affected by deforestation and forest degradation. The change in the forest areas and the changes in forest biomass due to management and regrowth greatly influence the transfer of carbon between the terrestrial forest ecosystem and the atmosphere (Ruben *et al*. 2016).

The live biomass density of a tropical forest is the sum of the biomass of all living organisms per unit area. This is determined by both the rate of fixation of carbon into root, stem, branch and leaf material per unit area, and how long that fixed material is resident as living mass in each of those biomass pools. Hence, both the net primary productivity (NPP) and the biomass residence time (τW, 1/biomass turnover rate) determine a forests' AGB. In practice, for old-growth forests the turnover times of fine root and leaf material are much shorter (approx. 1–2 years) than that of woody biomass

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(approx. 50–100 years), and hence total AGB is almost entirely determined by the rate of production of woody biomass (NPPWOOD; some 20–40% of NPP) and its residence time. Thus, all other things being equal, a forest with higher NPPWOOD should have greater AGB.

Estimation of the accumulated biomass in the forest ecosystem is important for assessing the productivity and sustainability of the forest. It also gives us an idea of the potential amount of carbon that can be emitted in the form of carbon dioxide when forests are being cleared or burned. Biomass estimation of the forest ecosystem enables us to estimate the amount of carbon dioxide that can be sequestered from the atmosphere by the forest. The accurate assessment of biomass estimates of a forest is important for many applications like timber extraction, tracking changes in the carbon stocks of forest and global carbon cycle. Forest biomass can be estimated through field measurement and remote sensing and GIS methods.

MATERIALS AND METHOD

Study Area

Nimbia Forest Reserve is located in the Southern Guinea Savanna Zone of Nigeria. It lies between longitudes 8° 30' and 8° 35'E and latitudes9° 29' and 9° 31'N with an elevation of about 600m above sea level (Fig 1).

The forest reserve is located in Jema'a Local Government Area of Kaduna State, Seventy Kilometers South East of Jos along Jos – Kafanchan road. Nimbia Forest Reserve covers an area of about 2,282.4 hectares. It is long and narrow in shape, bounded on the South by Gimi River and on the North by the Lioc Stream (Vivan *et al.* 2015).

In 1957, the then Jema'a Native Authority destroyed the natural vegetation and replaced it with mostly Teak (Tectonagrandis) and a few gmelinaarborea stands. According to Howard (1963), the first teak trial plantation began in 1957, and 98.42 hectares of teak were planted between 1958 and 1966. The planting continued until the 1970s, with the final planting taking place in 1991.

Teak (Tectonagrandis Linn. F) is a tropical and subtropical tree native to India and Southeast Asia. It can withstand a broad range of climatic conditions, with annual rainfall ranging from less than 762mm to more than 3,810mm, and temperatures ranging from 130°F to 370°F. The igneous and metamorphic rocks dominate the Nimbia Forest Reserve, which is located inside the Jema'a platform.

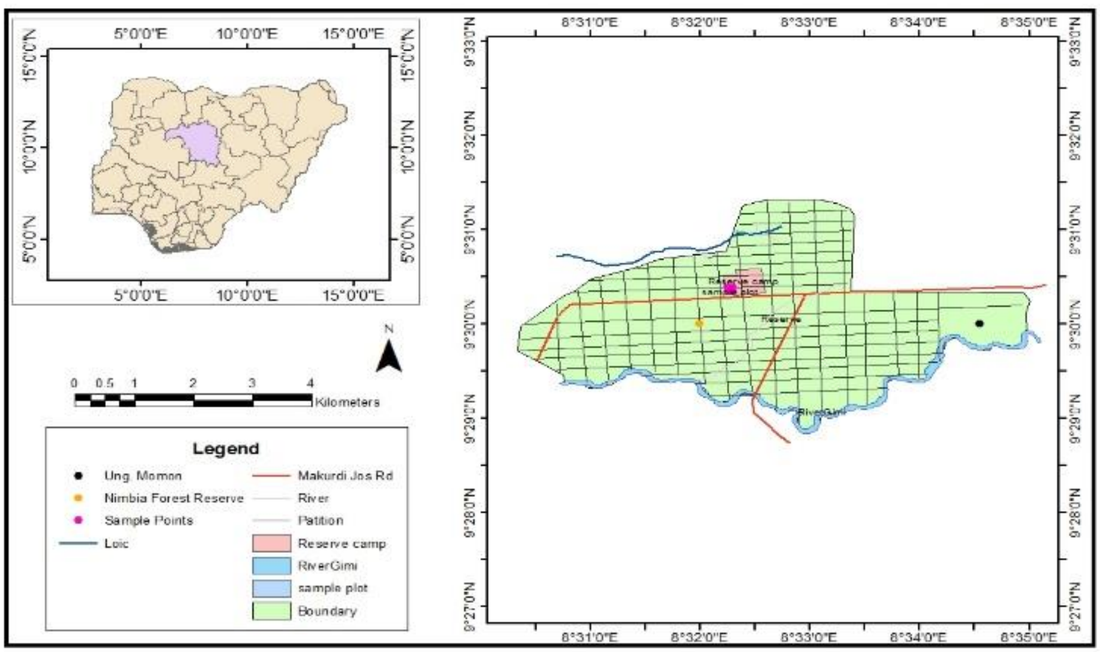

Figure 1: Nimbia Forest Reserve
Source: Author, 2021.

RESEARCH DESIGN

The investigation was carried out using a standard method for estimating biomass, which included selecting a suitable sample plot with a standard size of 100*100 meter, measuring and recording DBH of trees within the sampled plot from the field, and analyzing the data obtained using the allometric equation to estimate the above ground biomass stored in each tree, plot, and the Nimbia Forest as a whole. In this study, data was collected by measuring and recording DBH of 858 trees in the field using a non-destructive method of estimating AGB, and these data were analyzed using well-established allometric equations to obtain useful information such as the amount of AGB stored in each tree, the live above ground density, and the total AGB stored within the Nimbia forest. (Mande *et al,* 2014).

Sample

A single plot sampling was done and this was because of homogeneity of the study area with the same tree species, planted in the same year. A good site was selected within the study area

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where a single hectare plot containing trees that have met the needed requirements could be found. The tree diameters were properly measured and recorded immediately to minimize errors.
The major data collected through field measurements from Nimbia Forest Reserve were data on DBH and plot size. The following criteria and rules for DBH measurement from Condit (2008) were followed during the data collection process;

i. Trees must have a DBH greater than or equal to 100mm
ii. The height of measure (HOM) is always 1.3m on the uphill side. An HOM on the downhill side will be lower.
iii. DBH is taken along the lower side of a leaning tree.
iv. When an otherwise cylindrical stem has an obvious swelling or constriction at 1.3m, the diameter is taken 20mm below the lowest point of the irregularity.
v. For trees with buttresses or silts, DBH must be measured at least 80cm above the top end of the highest buttress.
vi. Majority of the stems must have identified to species in question.
vii. Plot size must be greater than or equal to 0.2ha.
viii. The tree must be of old growth and must be structurally intact, that is it was not impacted by recent selective logging or fire.
ix. Prostrate stems should always be paint-marked, since it is often not clear where 1.3m along the trunk is.
x. When a trunk is extremely irregular at all heights, an HOM must be chosen as best as possible, the marked and recorded so the tree can be re-measured at the same spot in the future.

DATA COLLECTION

Data used for this study were collected in the month of November, 2021. Data collected through field measurements were recorded as DBH, number of sampled trees, plot size and number of plots. Basically the data collection process was carried out on the field following these procedures; A single hectare (100m*100m) plot was marked out as a sample for the entire Forest.

i. Every tree within the sampled plot that has a diameter greater than 10cm were measured and recorded.
ii. Already measured trees were marked with a tag so that they are not measured and recorded again.
iii. The portal GPS device was also used to check and record the geographical coordinates of the plot's four angles.
iv. A total of 858 trees were measured and recorded.
v. Satellite images were used within the Arc GIS program to estimate the current land mass covered by trees in the forest.

Estimation of Forest Biomass

The Estimation of forest biomass was carried out using allometric relationships obtained in the forest according to the International Biological Programme (Kettering *et al*. 2001) and a diameter at breast height (DBH) of 858 trees were measured. Using the DBH tape, tree diameter was measured at 1.3 m (breast height) above the forest floor for each tree within the confirmed plot. All the trees > 10 cm in DBH were identified, mapped and tagged, for measurement. If a tree had a large buttress, it DBH was measured just above the buttresses (Mande, 2014). The DBH was estimated to ascertain the total above ground biomass (TAGB) based on Mande (2014) model. According to the studies conducted by Vielledent *et al.* (2012).

RESULTS

Tree Height (H)

The height of each tree whose DBH were measured on the field were calculated or estimated using an equation that required DBH and Hmax (maximum height of tree) as key parameters. The major AGB component were computed using the estimated height of each tree and recorded on a contingency table (table.1). For this study 40m (forty metres) was used as the value for Hmax. This is the maximum height of the teak specie recorded in the Nimbia forest reserve inventory. The results computed from DBH data shows that the branches of trees holds a higher proportion of biomass while the leaves holds the lowest proportion of biomass (fig.2).

Table 1: Summary of results from analysed DBH of trees in sampled plot.

AGB Component	Biomass Accumulated (Tons)	Percentage (%)
Weight of stem (Ws)	16366698.97	69.17
Weight of branch (Wb)	36854067.87	30.72
Weight of leaves (Wl)	59165.17	0.11
Above Ground Biomass (Ws + Wb + Wl)	53279932.02	100

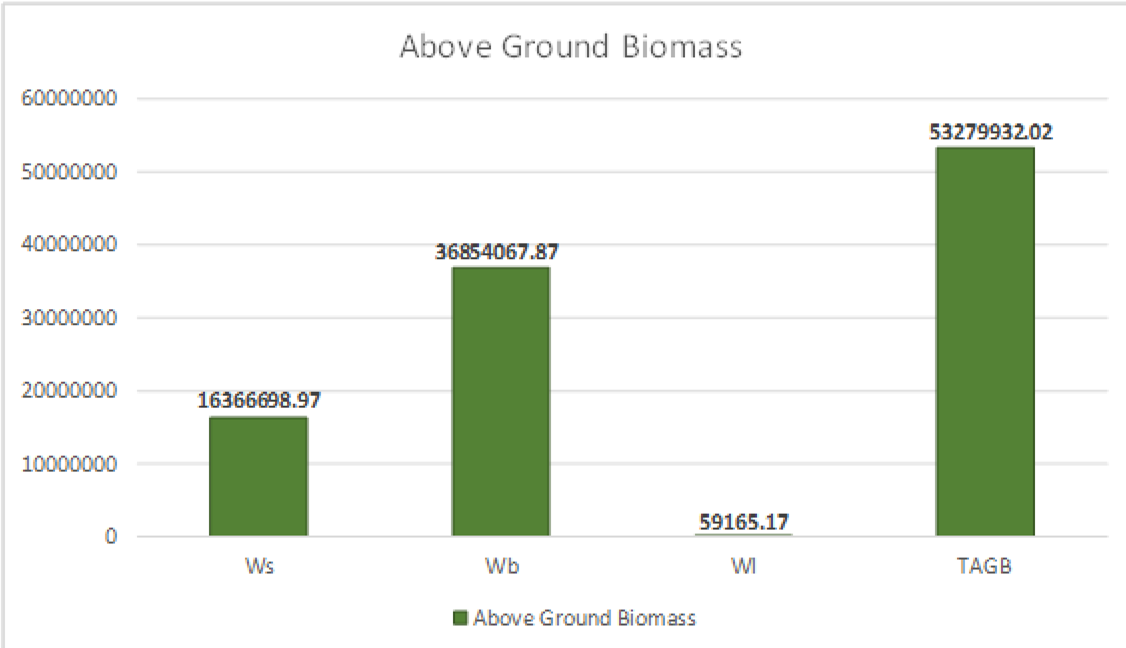

Figure 1: Biomass of stem, branch, leaves and total AGB for sampled plot
Source: Author, 2021.

AGB Within Sampled Plot (Live AGB Density)
The approximate value for total above ground biomass (TAGB) accumulated within the sampled plot also referred to as the live AGB density for this study is 53,279,932.02 ton/ha (Fig 2) which was computed as the summation of weight of stem (Ws), weight of branch (Wb), and weight of leaves (Wl). The plot AGB result presented in this study is well related to the estimated plot AGB of the Sungai Menyala forest of Port Dickson, Malaysia, Mande *et al.* (2014).

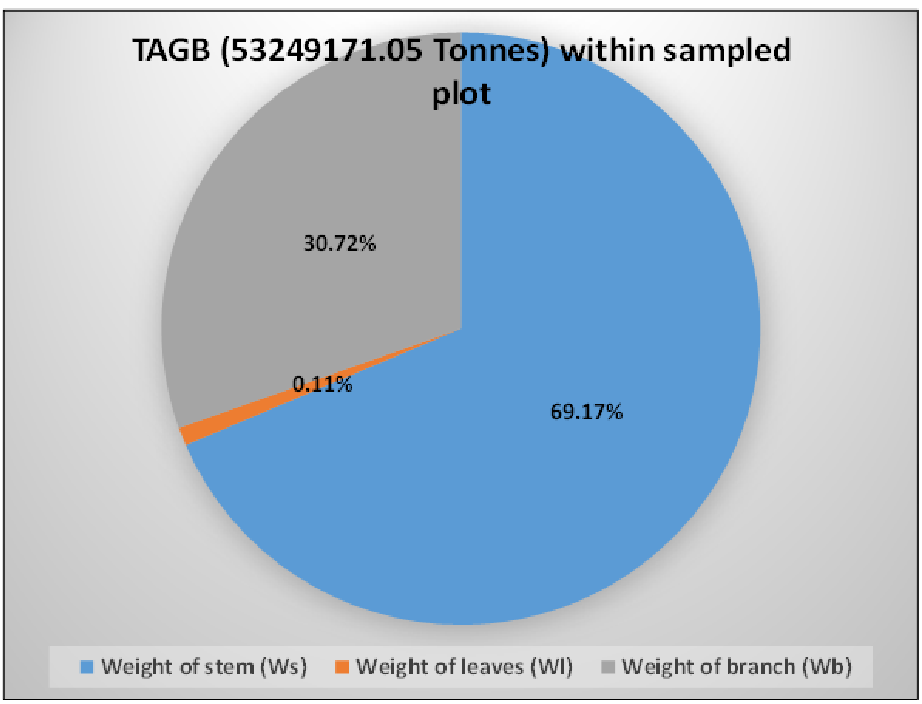

Figure 2: Total Above Ground Biomass within sampled plot.
Source: Author, 2021.

Total Above Ground Biomass Accumulated in Nimbia Forest Reserve

The Total Above Ground Biomass Accumulated (TAGB) in Nimbia Forest Reserve was finally estimated from simple arithmetic as a function of area of forest covered by trees measured in hectares multiplied by above ground biomass density as proposed by Condit (2008); if all the tree species existing in a forest are represented in the estimation of AGB density expressed in ton/hec, the TAGB of the entire forest could be extrapolated as a product of AGB density and forest land area covered by trees. Equation 1 below simplifies the calculation of TAGB.

TAGB = TC × AGBD. .... (equation 1)

Where;
TC is Total Land Area Covered by Forest Trees (hectares) and
AGBD is Above Ground Biomass Density (tons)
TAGB = 1,549.236468 × 53,279,932.02
TAGB = 82,543,213,697.94 tons.

Descriptive Statistics

The descriptive statistics for the whole tree components analysed at the sample plot have been summarized in table 2. The table presents more vividly a total of the mean, standard deviation, standard error, median, mode, maximum value, minimum value, and range.

Table 2: Descriptive Statistics for Tree height, DBH and AGB Components

Components	N	Mean	Std deviation	Std error	Median	Mode	Maximum	Minimum	Range
DBH	858	44.96	26.81	0.92	43	13	176.5	10	166.5
TREE HEIGHT	858	25.50	5.83	0.20	27.25	15.76	38.65	13.33	25.32
WEIGHT OF STEM	858	19063.72	25092.42	857.14	11832.35	675.35	241537.2	344.30	241192.9
WEIGHT OF BRANCH	858	42929.38	61047.95	2085.36	24630.37	1151.94	620151.5	560.39	619591.11
WEIGHT OF LEAVES	858	68.87	30.83	1.05	78.71	18.62	118.64	11.62	107.01
AGB	858	62061.97	86142.57	2942.57	36541.44	1845.91	861807.4	916.320	860891.08

DISCUSSION

The net carbon balance for the forest ecosystems remain uncertain the global carbon budget (Brown *et al*, 1993; Melillo *et al*, 1995) due to an absence of accurate estimations of forest biomass (Tian *et al.* 2000).

The estimated values of the AGB was found to be 53,279,932.02 ton/ha varies with tropical forest of Malaysia recorded Mande *et al.* (2014) to have 992.35 tons, 1621.64 tons, 1878.10 tons, and 2893.57 tons of various plot size, trees age and species. The difference in the value of AGB is due to the facts that both forests exist in different climatic zones. The TAGB of the Nimbia forest was estimated to be 82,543,213,697.94 tons similar to the moist tropical forest in South-Western Cameroon of about 78,644,415,786.55 having similar climatic condition Djomo *et al.* (2011).

CONCLUSION

The study was carried out to analyse the amount of Above Ground Biomass (AGB) accumulated within Nimbia Forest Reserve. Results of the study proved that the forest is worth a lot in terms of accumulated AGB and play many socio-economics, and ecological roles like; noise reduction, wind break, fuel, furniture making, roofing, poles for electric wires, habitat for birds, rodents, insects and other non-consumptive uses. The use of field measurements alone in estimating forest above ground biomass is expensive, time consuming and even hold a lot of errors. Therefore, for more accuracy GIS has been brought in to aid field measurement in estimating forest biomass and possibly on the long run, with more upgrades, GIS alone may be used for this purpose as it will be more accurate because human errors will be reduced and estimating forest biomass will become cheaper and less time consuming.

Nimbia Forest Reserve holds above eight billion tons of AGB. Vashum and Jayakumar (2012) clearly stated that ABG is made up of 40% to 60% carbon, this signifies that about 4 billion tons of carbon is being stored in the forest presently and will be liberated into the atmosphere if the forest were to be destroyed as at the time of this study.

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