PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (7) 1509-1514 July 2023

Assessment of Tree above Ground Biomass and Total Carbon Content Sequestered by Indigenous Tree Species in Sakponba Forest Reserve in Edo State, Nigeria

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ABSTRACT: It is widely known that forest contain more carbon than the entire atmosphere. This study assessed tree above ground biomass (AGB) and total carbon content (TC) sequestered by indigenous tree species in Sakponba forest reserve in Edo State using non-destructive ground base survey. Tree growth data such as Diameter at breast height (Dbh) and Tree height (Th) were collected using a cluster-nested plot design. Information on individual trees' Dbh of ≥ 5 cm was collected from a total of 18 plots of 6 clusters using lacer ace hypsometer and diameter girth tape. Aboveground Biomass and carbon sequestered by each trees were estimated using allometric equations while Number of tree species per hectare, species composition and diameter class size distribution were all evaluated. Results revealed *Funtumia elastica* (9 species/ha), *Ricinodendron heudoletii* (8 species/ha) and *Strombosa postulata* (8 species/ha) and *Trichilia monodelpha* (7 species/ha) as part of the tree species found in the reserve while *Meliacae, Leguminoseae, Apocynaceae, Euphorbiaceae and Sterculiacea were the most dominant families identified in the forest.* A total AGB and carbon of 462.35 Mg Ha-1 and 231.16 Mg Ha-1 were sequestered respectively in the Sakponba forest reserve. The results revealed that, like plantation, natural forests also have great potentials for carbon sequestration. Therefore, it is suggested that establishing more plantations and keep them for longer period of time will be helpful in carbon sequestration for global climate change mitigation.

DOI: https://dx.doi.org/10.4314/jasem.v27i7.25

Cite this paper as: ADEOTI, O. O; ANIMASHAUN, Z. T; OSUNDUN, O. O; MURTALA, O. Z. (2023). Assessment of Tree above Ground Biomass and Total Carbon Content Sequestered by Indigenous Tree Species in Sakponba Forest Reserve in Edo State, Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (7) 1509-1514

Dates: Received: 12 June 2023; Revised: 21 June 2023; Accepted: 04 July 2023 Published: 30 July 2023

Keywords: Biomass; carbon sink; growth study; tree species

Forest ecosystems are critical to the biosphere's functioning and conservation, as well as are the origin of many plants and animals (Onilude *et al.*, 2020). Tropical forests store 25% of global carbon and are home to 96% of the world's tree species, demonstrating the value of forests in carbon sequestration (Ajayi and Adie 2018). Carbon stock assessment plays a crucial role in understanding the carbon sequestration potential of different ecosystems and is essential for effective climate change mitigation strategies. Forests, in particular, are recognized as significant carbon sinks, absorbing and storing substantial amounts of carbon dioxide from the atmosphere. Among the various types of forests, indigenous tree species have been identified as important contributors to carbon sequestration due to their adaptability to local environments and their potential for long-term carbon storage. Global warming is currently considered one of the most significant global issues. The increase in greenhouse gases, particularly carbon dioxide, in the atmosphere contributes to the rise in the Earth's average temperature. The importance of reducing greenhouse gas emissions was emphasized during the third formal meeting of the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan, in

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December 1997 (Pragasan, 2015).To achieve the goal of reducing greenhouse gas emissions, the majority of industrialized countries have signed the Kyoto Protocol. Additionally, countries like Sweden, Finland, Norway, and the Netherlands have implemented carbon taxes and subsidies in their energy sectors since the early 1990s (Pragasan, 2015). Carbon sequestration refers to the process of capturing CO_2 gas from the atmosphere and storing it in liquid or solid form. This process occurs naturally through trees, oceans, soil, and live organic matter (Salem Issa *et al.,* 2020).Carbon pools are carbon reservoirs or stores, where CO_2 is stored in plants and soil (terrestrial sequestration), underground (geological sequestration), and deep in the oceans (ocean sequestration) (Salem Issa *et al.,* 2020). Forest biomass contains the largest portion of carbon sequestered on land. The amount of carbon in a tree depends on its biomass. It is estimated that the world's forests alone contain 283 gigatonnes (gt) of carbon in their biomass and 638 gt in the overall environment (up to a soil depth of 30 cm). This means that trees hold more carbon than the entire atmosphere (Ponthep Meunpong *et al.,* 2010). Around half of the Earth's carbon is present in the oceans. Estimating biomass accurately is challenging, particularly in areas with complex stands, varying environmental conditions, and low vegetation cover density, such as arid lands (Salem Issa *et al.,* 2020). Accurate and consistent measurement methods are required for both types of ecosystems. Quantifying or estimating plant biomass can be done using direct (destructive) and indirect (non-destructive) methods (Salem Issa *et al.,* 2020). The most accurate methods for measuring biomass and calculating carbon stock are direct methods. These methods involve collecting all plants destructively, separating them into different components (e.g., stems, branches, leaves, flowers, fruits, roots), and then analyzing the carbon content of each component either analytically or indirectly as a fraction of the measured biomass (Salem Issa *et al.,* 2020). However, these destructive methods are limited in terms of the area they can cover due to their destructive nature, as well as the time, cost, and labor involved. It is a cruel method of assessing carbon stock, where tree species have to be cut down before several parts assessed. The methods can harm forests and have associated environmental consequences (Salem Issa *et al.,* 2020). Sakponba Forest Reserve is an important ecological enclave in the region, known for its rich biodiversity and valuable ecosystem services. However, the extent of carbon sequestration potential and carbon stock of the indigenous tree species in this forest reserve remains largely unexplored. This study focuses on Assessment of Tree above Ground Biomass and Total Carbon Content Sequestered by Indigenous Tree Species in Sakponba Forest Reserve in Edo State, Nigeria.

MATERIALS AND METHODS

Study Area: Sakponba Forest Reserve is situated in Orhionmwon Local Government Area of Edo State, in the humid tropical rainforest zone of Nigeria (Fig. 1). It lies on latitude 6°04′N and longitude 5°32′E. The forest occupies an area of 50,250 hectares. It is divided into area BC29 with 101 compartments and BC32/4 with 75 compartments. The geologic time scale is of tertiary age of the post middle eolian period, called the Benin Sands (Oguntala, 1980). The topsoil is fine sandy loamy which is reddish in colour and less than 30 cm in depth. Down the profile at depths greater than 30 cm, the soil becomes coarser and darker reddish chrome and becomes brick red as the depth increases (Oguntala, 1980). The mean annual rainfall is 2162 mm. The wettest period is between July and September while the driest is between December and January; the relative humidity is generally high, averaging approximately 71%.

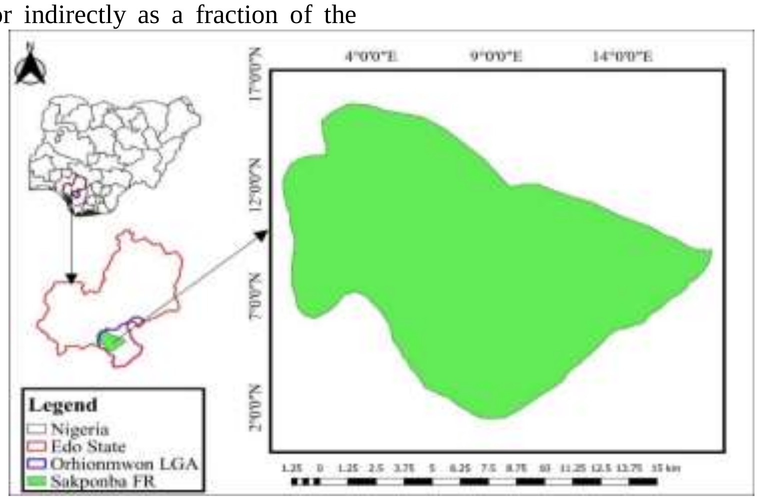

Fig 1: Map of Sakponba forest reserve

Sampling Technique and Data Collection: A ground-based inventory was conducted to gather information about the structural characteristics of individual tree species in the forest. The inventory utilized a cluster design with nested plots (Figure 2). Each cluster consisted of three square plots: a 35 m × 35 m plot enclosing a 25 m × 25 m plot, which in turn enclosed a 7 m × 7 m plot. The clusters were arranged in an elbow-like shape, with corresponding clusters positioned 100m apart (Figure 2). A total 6 clusters making 18 Temporary Samples Plots were used for the data collection. The Spiegel relascope was used to collect data on various parameters of the trees, including total height (THT) and diameter at breast height (Dbh), as well as diameter at the base (Db), middle (Dm), and top (Dt) of the trees. A taxonomist identified all tree species based on their biological nomenclature. However, for trees that could not be identified on the field, the part specimens were collected and sent to the Forestry Research Institute of Nigeria (FRIN) herbarium for proper identification.

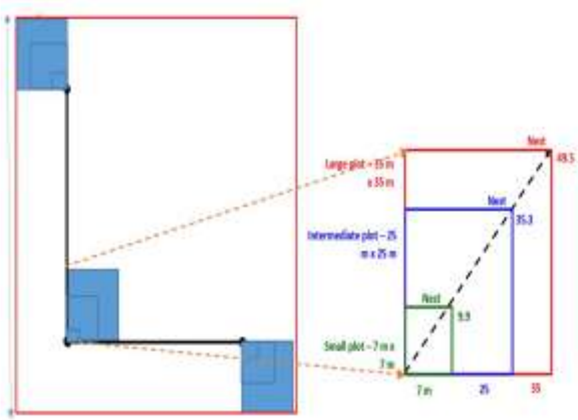

Fig 2: Diagram Showing Cluster design with nested plots for the study areas

Basal Area Estimation: The Basal Area (BA) of each tree was estimated using the formula (Husch *et al.*, 2003):

$$BA = \frac{\pi D^2}{4} \qquad (Eq. 1)$$

Where BA = Basal area (m^2), D = Dbh (cm).

Slenderness Coefficient Estimation: The slenderness coefficient (SC) is the ratio of tree height to its Dbh. It shows the firmness of a tree to withstand wind throw. It is given as:

$$SLC = \frac{THT}{D} \qquad \text{(Eq. 2)}$$

Where THT = Total height (m) and D = Dbh (m).

Tree Volume Estimation: Stem volume for individual tree species were computed using the processed Newton-Simpson's formula (Ige, 2018, Adeoti, 2019) expressed as:

$$V = \pi \frac{H}{24}(D_b^2 + 4D_m^2 + D_t^2) \qquad \text{(Eq. 3)}$$

Where V = merchantable volume, overbark (in m3), H = merchantable height (in m), Db = diameter at the base (in m), Dm = diameter at the middle position measured overbark along the stem (in m) and Dt = diameter at the top (in m).

Above Ground Biomass Estimation: In this study, the allometric model developed by Chave et al. (2014) for tropical forests was utilized to estimate above-ground biomass (AGB). This particular model has been widely employed by various researchers for AGB modeling. For instance, Sharma *et al.*, (2020) utilized this model to estimate AGB for Pinus roxburghii (Sarg.) plantations in Central Nepal. The model is represented as follows:

$$\text{AGB (in kg)} = 0.0509 \times \rho D^2 H \qquad \text{(Eq. 4)}$$

Where ρ is wood density (gcm^{-3}), D is Dbh of the tree (cm), and H is the height of the tree (m).

This model was chosen because it was developed for moist tropical forest trees, unlike the other widely used functions (e.g. Brown 1997). Specific wood density values for the indigenous species were obtained from Reyes *et al.*, (1992) and the global wood density database developed by Zanne *et al.*, (2009). In cases where the wood density for a species was not listed, an average value of 0.5 was used, as recommended by Chave *et al.*, (2005) for trees from tropical areas.

Estimation of Carbon Sequestration by the forest: According to Ajayi and Adie (2018), the carbon content of woody biomass in any forest is typically 50% of the total volume of the trees. As a result, the carbon weight in the tree was determined by multiplying the dry weight of the tree by 50%. Thus, equation 4 was adopted in the calculation of amount of carbon sequestered (Sharma *et al*., 2020).

$$C_s = WX\,0.5 \qquad \text{(Eq. 5)}$$

Where: C_s = sequestered carbon in tons/ha, W = above ground dry biomass in tons/ha

Percentage carbon stock of individual Tree species tree in the stand was determined using equation 5 as described by Bhatta *et al*. (2018).

$$Carbon\ stock\ (\%) = \frac{CCPTS}{SCCS}\ x\ 100 \qquad \text{eq. (6)}$$

Where; CCPTS = carbon content of particular tree species; SCCS = sum of carbon content in the tree sttand

RESULT AND DISCUSSION

Statistics of stand growth for Sakponba Forest Reserve: A statistical summary of the growth variables assessed in the forest is presented in Table 1. The total number of trees (Dbh ≥ 5 cm) in the forest reserve was 126 stems Ha^{-1}. These were distributed among 54 species (Table 1). The Dbh ranges from 4.20 cm to 57.00 cm while the average Dbh recorded in the forest was 21.93 ± 0.76 cm. The mean total height was 17.13±0.47 m while the height ranges between 5.50 m and 35.20 m (Table 1). Also, the range of the basal area was between 0.001 m^2 and 0.255 m^2 and a mean Basal area of 0.38 ±0.02 m^2 ha^{-1}. The observed range of total tree volume was 0.033 m^3 Ha^{-1} and 26.18 m^3 Ha^{-1} with a mean total volume of 4.88±0.37 m^3 Ha^{-1}. The Slenderness Ratio ranges from 27.6 to 471.43, the Above Ground Biomass (AGB) was measured as 462.35 Mg Ha^{-1} while Carbon was 231.18 Mg Ha^{-1} (Table 1).

Tree species and family composition in the forest: The most occurring tree species at the study site was observed to be *Funtumia elastic*, having a frequency 9 stems ha^{-1} while *Ricinodendron heudoletii* and *Strombosia postulata* followed this specie with a frequency of 8 stems ha^{-1}. *Trichilia monadelpha, Entandrophragma angolenses, Guarea cedrata* each had a frequency of 7 stems ha^{-1} while *Khaya grandfoliola, streculia rhinopetala* each had a frequency of 5 stems ha^{-1}. *Annonidium mannii, Anthonatha macrophylla* and *Celtis zenkeri*, on the other hand, each had a frequency of 4 stems ha^{-1} (Figure 3).

Table 1: Descriptive Statistics of Sakponba Forest Reserve

Variable	Total	Mean	Standard Error	Minimum	Maximum
Dbh (cm)	-	21.936	0.765	5.200	57.000
THT (m)	3239.100	17.138	0.470	5.500	35.200
BA (m^2Ha^{-1})	71.929	0.380	0.023	0.011	2.092
Total volume (m^3Ha^{-1})	922.379	4.880	0.377	0.033	26.185
Merchantable volume (m^3Ha^{-1})	520.119	2.751	0.237	0.000	20.600
SLC	17884.000	94.624	3.820	27.600	471.430
AGB (Mg Ha^{-1})	462.350	2.440	0.220	0.020	119.110
Carbon (Mg Ha^{-1})	231.176	1.223	0.110	0.014	9.557

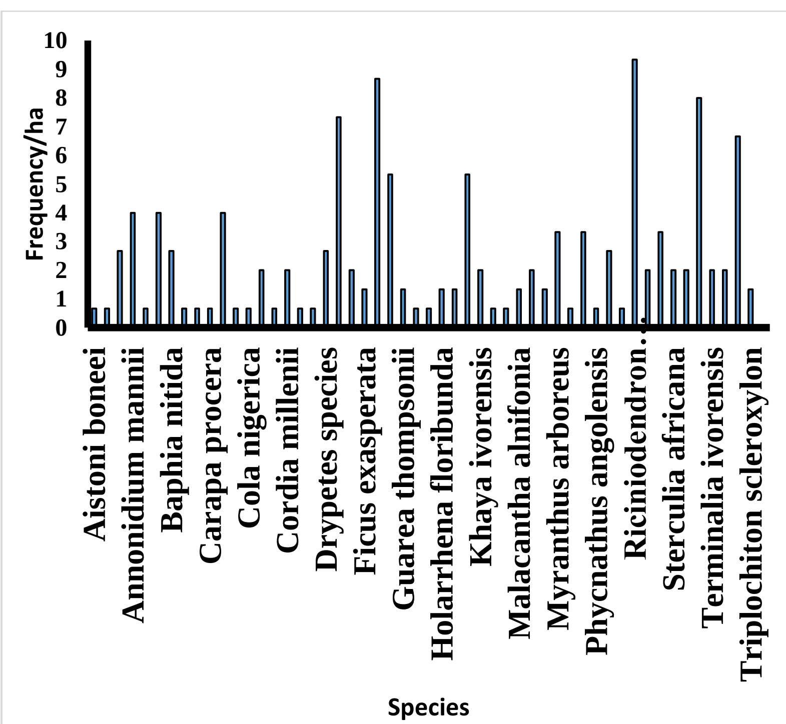

Fig 3: Frequency distribution of tree species in Sakponba Forest Reserve

The five most dominant family of tree species were the *Meliacae, Leguminoseae, Apocynaceae, Euphorbiaceae and Sterculiacea* families. Species of trees from the *Meliacae* family were observed the most occurring at Sakpoba Forest Reserve. This was followed by species from the Leguminoseae family. This families were then followed by species from the *Apocynaceae, Euphorbiaceae* and *sterculiaceae* families (Figure 4).

Diameter class distribution of trees in Sakponba Forest Reserve: The diameter size classes for the tree species in Sakpoba Forest Reserve is presented as a bar chart on Figure 4. The Figure revealed that the majority of the sampled tree species had diameter at breast height in the 20.10 – 30.00cm class.

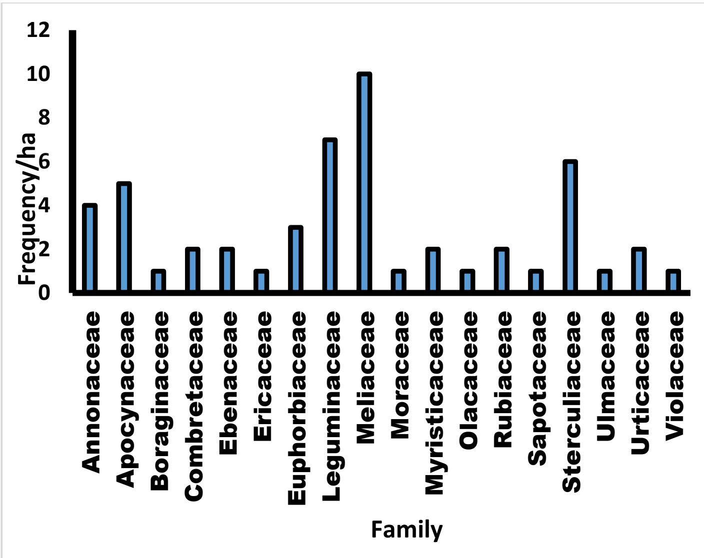

Fig 4: Frequency distribution of Families in Sakponba Forest Reserve

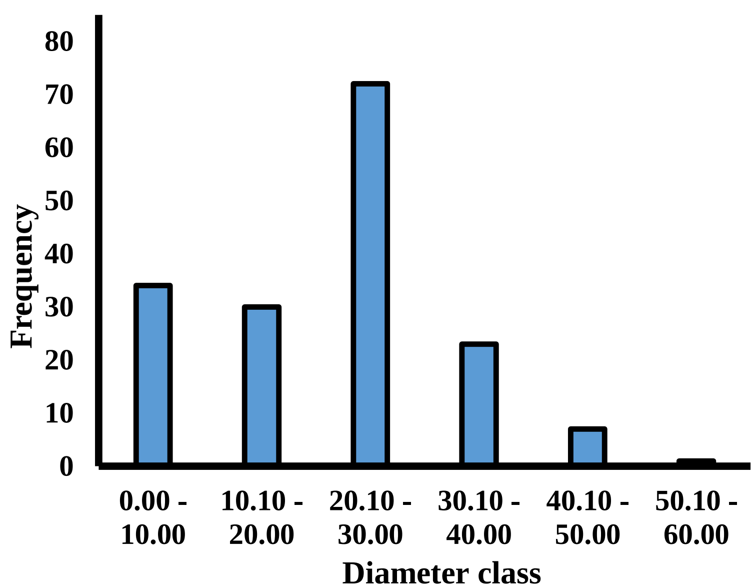

Fig 5: Diameter class distribution of tree species Sakponba Forest reserve

This class was followed number of trees falling within the ≤ 10cm and 10.10 – 20.00cm classes, respectively. The least tree diameter class per hectare observed on the study site belonged to the 50.10 – 60.00cm class. This study therefore indicates that most of the tree species on the study site belonged to a Dbh class of ≤ 30cm, consequently below the minimum merchantable size of 48cm as stipulated by the logging policy of southwestern Nigeria (Adekunle, 2007). These patterns of forest structure have been reported for different types of forest community in Nigeria and outside the country (Fashing *et al.*, 2004, Kalaba *et al.*, 2013) and generally interpreted as a sign of relatively good health of the ecosystem. Since the structural growth of a tree is positively related to the rate of sequestered carbon (that is, the bigger the size of a tree the more carbon it stores) (Mildrexler *et al.*, 2020) and since the observed population structure of the trees in this reserve is characterized by a large population of small trees, this forest reserve has a good potential of sequestering carbon if properly managed.

Conclusion: This study revealed the current status of tree species in Sakponba Forest Reserve in terms of tree species and families composition, above ground biomass and carbon sequestration potentials using a non-destructive method. This study is crucial to improving the current estimations of above ground biomass, carbon stock and sequestration potentials and better estimations of these variables are urgently needed to improve the knowledge on carbon budgets in order to improve the potentials of the indigenous trees to contribute to mitigating global climate change.

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