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Estimation of above ground bole biomass and carbon stock of trees in Urhonigbe Forest Reserve, Edo State, Nigeria

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Abstract

Carbon storage in forest biomass is an important factor of a stable forest and a recentlink in the global carbon cycle. The objective of this study was to determine the above ground bole biomass and carbon stocks of trees in Urhonigbe forest, Edo State, Nigeria. The sampling technique adopted for this study was the cluster sampling. 15 plots of size 25m by 25m were randomly laid and 128 trees encountered and measured. The variables measured for each species of trees were diameter at breast height (cm), diameter at the top (cm), diameter at the middle (cm), diameter at the base (cm) and tree height (m). The above ground bole biomass was obtained with the product of wood density (kg/ha) and tree volume (m^3/ha), while the carbon stock of trees was calculated by multiplying the biomass by the biomass expansion factor which is a constant (0.45). The results showed that tree species have a great influence on the amount of carbon stored in a tree. *Entandrophragma cyclindrium* had the highest amount of above ground bole biomass and carbon stock content, which were 751.8099kg/ha and 338.3145t/ha respectively while *Irvingia gabonesis* had the least amount of biomass and carbon stock of 17.5770kg/ha and 7.9097t/ha respectively. This study has shown that the Urhonigbe forest area is a regenerating forest filled with young stand of trees and they have a great potential to sequester and store carbon at a high rate.

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Introduction

Forest ecosystem provides a number of provisioning, regulatory, supporting and cultural services that are important to the lives and livelihoods of humans and they play an important role in maintaining habitats that support important global diversity (Raich *et al.,* 2014, Escobeda *et al.,* 2011). Compared to other terrestrial ecosystems, forest ecosystems to remore of carbon (Pan *et al.,* 2011). Larger part of sequestered carbon are held in the woody biomass of trees (Scott *et al.,* 2011).Forest ecosystem play a vital role in the mitigation of global climate change (Millar *et al.,* 2007). Forest carbon stock is the amount of carbon that has been sequestered from the atmosphere and is now stored within the forest ecosystem, mainly within living soil and biomass, and to a lesser extent also in dead wood and litter. It can further be defined as the amount of carbon contained in a "pool".

Pools of carbon can be soil, litter and coarse woody debris pools, the oceans are sinks or pools of carbon (kayannal *et al.,* 2014).Carbon depository in the forest biomass is a major factor of a stable forest and a key link in carbon cycle globally. The forest as a carbon sink absorbs millions and tons of CO_2rendering the atmosphere clean and habitable for human race (FAO, 2011). The capability of estimating biomass accurately is paramountin accessing the function or roles played in carbon cycle globally by the forest, confidentially when defining its contribution toward sequestering carbon (Brown, 2002).

The estimation of above ground biomass is the most critical step in quantifying carbon stocks and defuses from tropical forests. In carbon trading and marketing, it is very important to measure and estimate carbon stocks and changes in various pools. It requires transparent and verifiable methods, quantification of uncertainties and appropriate monitoring systems for carbon stocks (Zerihun *et al.,* 2012).

There is a dearth of information on carbon stock in Urhonigbe Forest Reserve, Edo State; therefore, the estimation of above ground bole biomass is a very critical step in quantifying carbon stocks available in the forest.

Materials and methods

Study area

This study was conducted at Urhonigbe Forest Reserve, Edo state, Nigeria. It is located in Orhiomwon Local Government Area of Edo State. The Forest Reserve lies between latitude 5^o $57^1 59^{11}$ and 5^o $59^1 31^{11}$N and longitudes 6^o 05^1 38^{11} and 6^o 06^1 45^{11}E with an initial land area of 3,079/hectares. It is located to the South – East of the Sakponba Forest Reserve in Edo State (Erhenhi *et al.,* 2015). The slope of Urhonigbe Forest Reserve is quite gentle elevation of an average of 60m and an altitude of 75m above the sea (Shell, 2006).

Cluster sampling technique was used for this study. A hectare from the entire population was selected and 15 sample plots were randomly laid. Each plot size was 25m by 25m (0.04ha). The following tree variables were measured.

- diameter at the base(cm) and diameter at breast height{dbh}(cm) were obtained using the diameter girth tape
- diameter at the middle(cm) and top(cm) and height were obtained using the Spiegel relaskop

Data analysis

The data collected was analyzed and the following input variables computed.

Tree bole volume estimation

The volume was calculated using the Newton's equation as stated below;

$$V = h\left(\frac{Db + 4Dm + Dt}{6}\right)$$

Where:

V = Volume over bark (cm^3)

h = Stem height (m)

Db, Dmand Dt were Diameters at the base and middle (cm) and top (cm)

Estimation of density

Tree density for each species was acquired from the standard density database of tropical regions (Gisel *et al.,* 1992).

Above ground bole biomass estimation

This was obtained using the formula stated below;

Biomass = Volume x Density.

The above ground bole biomass was computed by estimating the biomass of the inventoried volume and then expanding the value to take into account the biomass of the other above ground component (Brown, 1999).

Carbon stock estimation

This was obtained by the formula stated below:

Carbon stock = Biomass x 0.45.

Where (0.45) is the biomass expansion factor.

Results and discussion

Results

The summary of all species values were stated below

Table 1 showed the mean values of all trees measured and they include frequency/hectare of species, height (m), dbh (cm), volume (m^3/ha), biomass (kg/ha), density (kg/m^3), carbon stock (t/ha) of trees. The Basal Area values for each specie ranged from 0.0027m^2/ha to 0.0419m^2/ha.

Table 1. Summary of tree species variables measured.

SL	Species	Freq/ha	H (m)	Dbh (cm)	Density (kg/m³)	BA (m²/ha)	Vol(m³/ha)	Biomass (kg/ha)	Carbon Stock (t/ha)
1	*Afzelia Africana*	25	20.00	12.53	670	0.0150	0.3012	201.7738	90.7982
2	*Albizia zyga*	5	20.84	16.63	460	0.0229	0.4349	200.0750	90.0337
3	*Baphia nitida*	1	26.50	20.80	900	0.0340	0.7432	668.8881	300.9996
4	*Berlinia confuse*	3	19.27	11.33	560	0.0102	0.1457	81.6069	36.7231
5	*Ceiba pentandra*	1	20.10	21.05	260	0.0348	0.5552	144.3600	64.9620
6	*Cola millenii*	2	17.80	8.80	700	0.0067	0.1031	72.1748	32.4787
7	*Entandrophragma cylindricum*	8	25.31	19.42	550	0.0419	1.3669	751.8099	338.3145
8	*Irvingia gabonesis*	1	15.50	5.90	710	0.0027	0.0248	17.5770	7.9097
9	*Lophira alata*	19	16.61	9.86	870	0.0096	0.1350	117.4403	52.8481
10	*Nauclea diderrichii*	11	23.54	14.89	630	0.0186	0.3744	235.8581	106.1362
11	*Terminalia superba*	46	21.74	13.40	450	0.0173	0.3730	167.8425	75.5291
12	*Triplochiton scleroxylon*	26	27.27	23.73	320	0.0502	1.2910	413.1245	185.9060

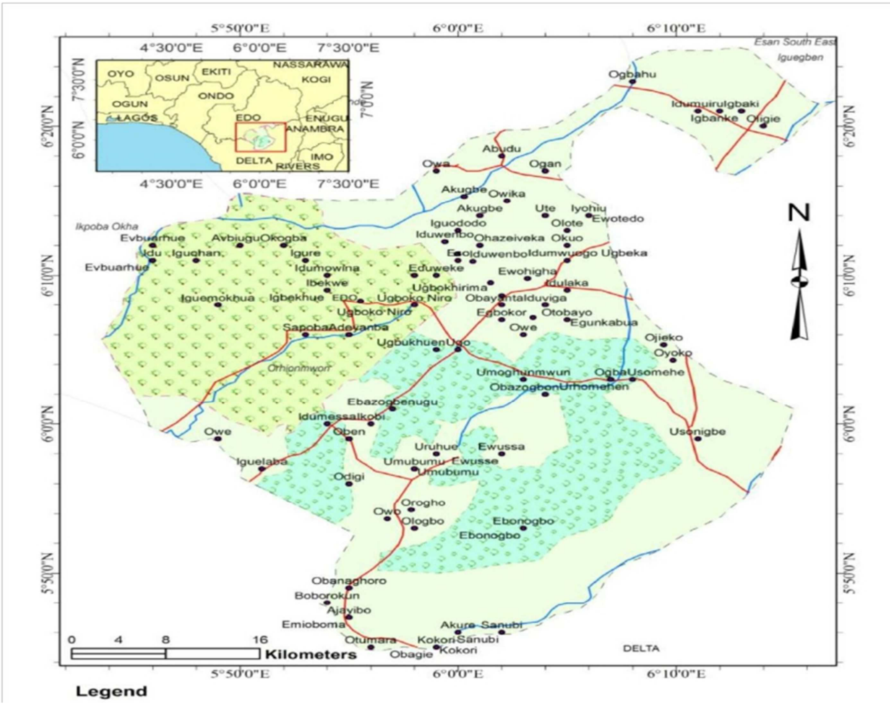
The frequency/hectare of species ranged from 1 to 46 freq/ha. Tree height and dbh of all trees ranged from 15.50m to 27.27m and 5.90cm to 23.73cm respectively. The volume of trees ranged from 0.0248m^3/ha to 1.3669m^3/ha, the density of tree species ranged from 260kg/m^3 to 900kg/m^3 while the carbon stock and biomass of all the species ranged from 7.9097t/ha to 338.3145t/ha and 17.5770kg/ha to 751.8099 kg/ha respectively.

Mean values of the stand, standard error, Kurtosis, skewness, minimum, maximum, total/ha for height, dbh, density, basal area, volume biomass and carbon stock were presented in Table 2 above.

Table 2. Summary of stand variables statistics for the species.

Statistics	H (m)	Dbh (cm)	Density	BA	Vol	Biomass	Carbon Stock
Mean	21.93041	15.10541	546.4865	0.023175	0.540623	247.0743	111.1834143
Standard Error	0.584363	0.674419	14.42591	0.002191	0.073465	33.65037	15.14266872
Kurtosis	1.214722	1.875412	-0.73655	11.66705	26.69435	53.59596	53.59596251
Skewness	0.717042	1.116898	0.48798	2.922872	4.42748	6.216702	6.216701846
Minimum	4.70	4.00	260	0.001257	0.008118	5.439155	2.447619964
Maximum	50	47.8	900	0.179474	7.447358	4096.047	1843.221162
Total/ha	3245.7	2235.6	80880	3.429898	80.01215	36566.99	16455.14532
Freq/ha	148						

The diameter distribution curve displayed in Fig. 2 below showed the diameter distribution classes of trees which ranged from <10cm (which is less than 10cm), 10.1cm to 20cm, 20.1cm to 30cm, 30.1cm to 40cm, 40.1cm to 50cm, and then 50cm and above respectively. It showed a right skewed distribution of the trees species.



Town ●

Road

River

Orhionmwon LGA Boundary

Fig. 1. Showing the map of Urhonigbe Forest Reserve, Edo state Nigeria.

Source: Adopted from Shell (2006).

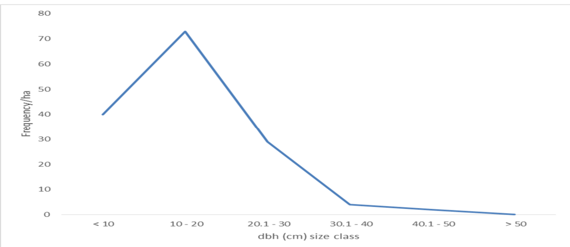


Fig. 2. Diameter distribution curve of the trees.

Fig. 3, showed a bar chart on distribution of tree height classes, which ranged from 0 – 50m and above respectively.

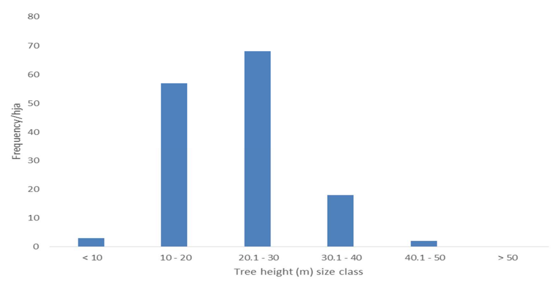


Fig. 3. Tree height (m) size class distribution of the tree species.

Discussion

A number of 128 trees were enumerated in the study area. Twelve species were identified and recorded. It was observed that species of trees was a key determinant of the quantity of carbon stock available in the forest. *Terminalia superba* had the highest occurrence of trees but was among the trees with the lowest content of carbon stock; while species like *Entandrophragma cylindericum* occurred just 8 times but had a very high carbon stock content and biomass as shown in table 1;this showed that the ability to sequester more carbon does not necessarily depend on the number of times species occurred but rather it depends on the species of tree itself. The rate of carbon sequestration also depends on species of a tree (genetic, climatic and edaphic factor).High species richness can have great influence on carbon stock and biomass productivity (Loreau, 1998).

The diameter distribution curve showed the proportion of smaller diameter classes to larger diameter classes, which indicates that trees of smaller diameter were the highest and this showed the condition of regeneration in the forest. Trees with DBH classes less than 10cm had percentage of 25%, 10 – 20cm had 50%, while 20.1 – 30cm had 15%, then 30.1-40cm had 10%, 40.1-50cm had 5%, and>50cm had 0%. DBH distribution revealed a right skewed distribution, which indicated that the forest had younger trees. Sedjo, (2001) stated that a forest of young stand of trees had a great ability to sequester so much carbon proportionate to the biomass in the forest, while additional carbon may not be sequestered by an old forest. The changes in the diameter distribution of trees was also observed and these may be due to factors that affect tree growth such as species, human activities and soil nutrients (Navratil *et al.*, 1994).

This is in line with Mckinley *et al.* (2011) who stated that carbon stocks in the forest are closely tied to biomass in the forest, so factors that increase tree growth rates such as soil, topography, and species of tree and climate of an area will subsequently increase rates of carbon storage within the forests.

Skewness of the height distribution of trees shows a positive (right skewed distribution of tree height). It also indicates that a larger number of young trees were available in the forest. The mean standard error revealed that the samples are true representative of the overall population. This was due to the low value of the standard error obtained.

The kurtosis of the distribution indicated that it has positives values. The distribution is thick and possesses thick tails. To quantify tree biomass is a time consuming activity especially certain biomass components such as the bole, foliage and branches. The biomass expansion method was used to compute the forest carbon.

It has been assumed that 50% of biomass found aboveground is repo sited in the bole of a tree (Whittaker and Linkens, 1973). The quantity of carbon content and biomass recorded in Table 1 varies with species.

The diameter at breast height and the tree height variables were necessary for the estimation of biomass.

The above ground biomass was high and correlated with the high stand density in the area under study. Therefore, this method was solely aimed at estimating carbon without destructing the trees using the destructive approach because conservation and protection of biological diversity, is a driving force to sustain the environment.

Conclusion

Trees play key role in alleviating the diverse effects on environmental deterioration and CO_2 increase in the atmosphere, which leads to climate change; tree also helps to sequestrate carbon into the soil and plant biomass. Therefore, the basic findings of this research showed that tree species had a great influence on the quantity of carbon repo sited in the tree biomass, due to the factors that affect species of trees such as genetic makeup, climatic and edaphic factors.

The results also revealed that the forest under study has a high potential to sequester carbon due to the young nature of tree stands found there.

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