Journal of Forestry Research and Management. Vol. 16(1).18-30; 2019, ISSN 0189-8418

www.jfrm.org.ng

CARBON SEQUESTRATION POTENTIAL AND ABOVE GROUND BIOMASS OF *Triplochiton scleroxylon* K Schum. IN GAMBARI FOREST RESERVE, NIGERIA

Adedokun, S.A., *Agbo-Adediran, O.A. and Adenuga, D.A

Federal College of Forestry, P.M.B. 5087, Jericho Ibadan, Oyo state
*Corresponding author- agboadediranadewale@gmail.com, 08035782049

ABSTRACT

Climate change is a contemporary harmful challenge threatening the existence of man, and is characterized by a consistent unfavourable climate exemplified in the rising earth temperature known as global warming and trees have a major role to play in the mitigation of this dangerous phenomenon because of their ability to absorb and store billion tons of carbon per year from the atmosphere which can help in mitigating the effect of global warming. This study assessed the carbon sequestration potentials and above ground biomass of *Triplochiton scleroxylon* in Gambari forest reserve, Oyo state. The assessment was based on total enumeration of trees which consisted of dbh and height in fifteen temporary sample plots of 20 m x 20 m established through simple random sampling techniques. The above-ground biomass was estimated using allometric equation. Above-ground carbon stock was calculated by multiplying the estimated biomass by a conversion factor of 0.5. The results showed mean diameter at breast height (dbh) of *Triplochiton scleroxylon* was 34.14 cm, mean height was 14.67 m, the above-ground biomass and carbon stock were 1.13 and 0.65tC/ha respectively. The carbon stock in the trees did not depend on the density of tress but rather on the size because major part of the carbon stock was sequestered by the bole of the trees indicating that trees with larger diameter and height have more carbon stock than the smaller trees. It was concluded that smaller trees have higher potential to sequester more carbon because as they continue to increase in size they have the tendencies to stock away more carbon. It was therefore recommended that trees with small size should be conserved to have mitigating impact on the climate warming of the globe.

Keywords: Above-ground biomass, carbon sequestration, allometric equation, carbon stock.

Introduction

There is an increase in the earth's temperature by 0.76^o C since the last century and this is expected to increase by 2^o C by year 2050 (IPCC, 2007). This has resulted into a phenomenon known as climate change which is a contemporary harmful challenge threatening the existence of man, and is characterized by a consistent unfavourable climate exemplified in the rising earth temperature which is referred to as global warming. Forest ecosystems have a major role to play in the mitigation of this dangerous phenomenon because the forests are estimated to store about 650 billion tons of carbon and absorb 8.5 billion tons of CO_2 per year from the atmosphere (Nabuurs, 1998) – which is a major culprit among the principal gases causing global warming. Anthropogenic activities – principal among which is deforestation - release excessive amount of CO_2 into the atmosphere which are trapped from escaping thereby raising the global temperatures. This poses a harmful challenge to humans as it increases the incidence of carcinogenic diseases, flooding as a result of ocean rise and melting of the polar ice in polar regions, aggravates draught in the continental hinterland and loss of bio-resources of food and medicine (Label and Kane, 1989; Odjugo, 2009). According to the Food and Agriculture Organization (FAO, 2008) forests cover over 4 billion hectares or roughly 31% of the earth's surface and sequester and store large quantities of carbon. IPCC (2001) reported that terrestrial ecosystems sequester annually 1.4±0.7 Pg 1C yr – 1, or 22.2% about the flux of fossil fuels globally. Forests also account for 48% of the total carbon storage capacity of worldwide terrestrial ecosystems (Watson *et al*., 2000). According to Akbari (2002) a tree in a forest removes 4.5 – 11 kg of carbon per annum simply by growing and using carbon dioxide in the process of photosynthesis. Despite the role of forest ecosystems as important global carbon sinks, only a portion of the carbon absorbed by the trees are retained in the trees, understory vegetation, in the forest floor and the soil (FAO 2003; Mokany *et al*., 2006; Nelson *et al*., 1999; Niklas, 1997), the remaining are lost through the respiration of the forest. However, the forest remains a major reservoir of carbon (FAO, 2008) as a result of its capacity to sink large amount of carbon from the atmosphere (IPCC, 2007; Ullah, and Amin, 2012).

The rate of increase in atmospheric CO2 concentration can be reduced through the process of Carbon sequestration which is the uptake of Carbon containing substances, in particular CO_2, into a long-lived reservoir (IPCC, 2007). More specifically, carbon sequestration can be defined as the transfer and secure storage of atmospheric CO_2 into the other long-lived pools that would otherwise be emitted or remain in the atmosphere (Lal, 2008). Carbon sequestration in forest ecosystems occurs primarily by uptake of atmospheric CO_2 during tree photosynthesis and the subsequent transfer of some of it into vegetation, detritus and soil pools for secure Carbon storage. Estimates of Carbon uptake vary from between 0.49C and 0.72C for the boreal, to 0.37 per year for the temperate, and between 0.72C and 1.3C/year for the tropical forest biome (Lorenz and Lal, 2009).

Trees use the carbon absorbed by leaves during photosynthesis to maintain cellular structures and grow new tissues. Maintenance of existing tissues requires an expenditure of carbon during respiration which reduces the carbon available for new growth. The net carbon available to a tree, along with the nutrients require for new growth, is then allocated to the growth of leaves, roots, stems, flowers, seeds and the production of chemicals for the protection from insects and herbivores.

Long-term forest inventories are most useful in order to evaluate the magnitude of carbon fluxes between aboveground forest ecosystems and the atmosphere (Alvarez *et al*., 2012; Chave *et al*., 2006). Guidelines have been published for censuring trees and for estimating above-ground biomass (AGB) stocks and changes from these datasets (Brown, 1997; Chave *et al*., 2001 and 2006; Brown *et al*., 2004; Folega *et al*., 2010). However, one of the uncertainties in all estimates of carbon stocks in tropical forests is the lack of standard models for converting tree measurements to aboveground biomass estimates (FAO, 1997).

Tropical forests hold large stocks of carbon (Ekoungoulou, 2014; Holmes *et al*., 1999), yet uncertainty remains regarding their quantitative contribution to the global carbon cycle (Basuki *et al*., 2009; Ekoungoulou *et al*., 2014). One approach to quantifying carbon biomass stock consists of inferring changes from long-term forest inventory plots. Regression models are then used to convert inventory data into an estimate of aboveground biomass (Chave *et al*., 2005). The use of allometric equations is a crucial step in estimating aboveground biomass (Brown *et al*., 2000; Killeen *et al*., 2002). Conventionally, the determination of aboveground tree biomass has been conducted to ensure sustainable management of forest resources while fuel wood management has motivated the calculation of biomass equations, whereas timber management has mainly driven volume equations. Today, the estimation of forest biomass is crucial for many applications, from the commercial use of wood to the global carbon (C) cycle (Morgan and Moss 1985, Bombelli *et al*., 2009). Because of interest in the global C cycle, estimating aboveground biomass is necessary to establish the increments or decrements of C stored in the forests. Several allometric equations for estimating biomass or volume of tropical fast-growing trees have been developed. The forms of the equations vary widely, including various polynomials and models incorporating diameter at breast height (Parde, 1980; Crow and Schlaegel, 1988). The allometric method uses allometric equations to estimate the whole or partial (by compartments) mass of a tree from measurable tree dimensions, including trunk diameter and height (Kangas and Maltamo, 2006). Thus, the dendrometric parameters of all of the trees are measured and the allometric equation is then used to estimate the stand biomass by summing the biomass of individual trees. When building allometric equations for an individual tree, sprout or stand, different methods (destructive or not) may be considered. Destructive methods directly measure the biomass by harvesting the tree and measuring the actual mass of each of its compartments, (e.g., roots, stem, branches and foliage) (Kangas and Maltamo, 2006). Indirect methods are attempts to estimate tree biomass by measuring variables that are more accessible and less time-consuming to assess (for instance, wood volume and gravity) (Peltier *et al*., 2007). Weighing trees in the field is undoubtedly the most accurate method of estimating aboveground tree biomass, but it is time-consuming and is generally based on small sample sizes. Species-specific allometric equations are preferred because tree species may differ greatly in tree architecture and wood gravity (Kettering *et al*., 2001). However, in a tropical forest stand, more than 300 tree species may be found (Gibbs *et al*., 2007) and allometric equations should represent the variability of biomass for those species. According to McWilliams *et al.* (1993), destructive harvesting to build allometric models is seldom conducted in the tropics and sample plot sizes have been small compared to the scale of species diversity patterns; therefore, results may not be representative. Grouping all species together and using generalized allometric relationships that are stratified by broad forest types or ecological zones has been highly effective in the tropics (Brown, 2002). However, there are very few allometric equations for sub-Saharan Africa. The objective of this study was therefore to estimate the carbon sequestration potential of above ground biomass of *Triplochoton scleroxylon* tree species in Gambari forest reserve using allometric equation developed for Tropical forests by Terakunpisut *et al*. (2007).

Materials and Methods

Study area

This study was carried out in Gambari Forest Reserve which is located on latitude 7º 25 and 7º 55'N and longitude 3º 50' and 3º 59'E within the low land semi-deciduous rain forest belt of Nigeria and covers a total land area of 17,984 ha. It is situated at the southern part of Ibadan bounded on the west by River Ona and on the east by the main road of Ibadan to Ijebu-ode. The reserve is bounded by Abanla and Odoona settlements in Oluyole local government area of Oyo State in the north and in the south by Mamu and Abatan settlements in Ijebu-ode local government area of Ogun State. The reserve is divided into two types of forest: natural and plantation forests. The natural rainforest of Gambari is made up of indigenous species such as *Terminalia spp* K. Shum (Afara), *Triplochiton scleroxylon* K. Shum (Arere, Obeche), among others while the plantation forest is made up of mainly exotic species such as G*melina arborea* Roxb (Gmelina) and *Tectona grandis* L.f (Teak). The topography of the study area is generally undulating, lying at altitude between 90 m and 140 m above sea level. The annual rainfall ranges between 1200mm to 1300 mm spreading from March to November. The dry season (December-February) is severe and the relative humidity is over 80% and average annual temperature is about 26.4ºC (Larinde and Olasupo, 2011).

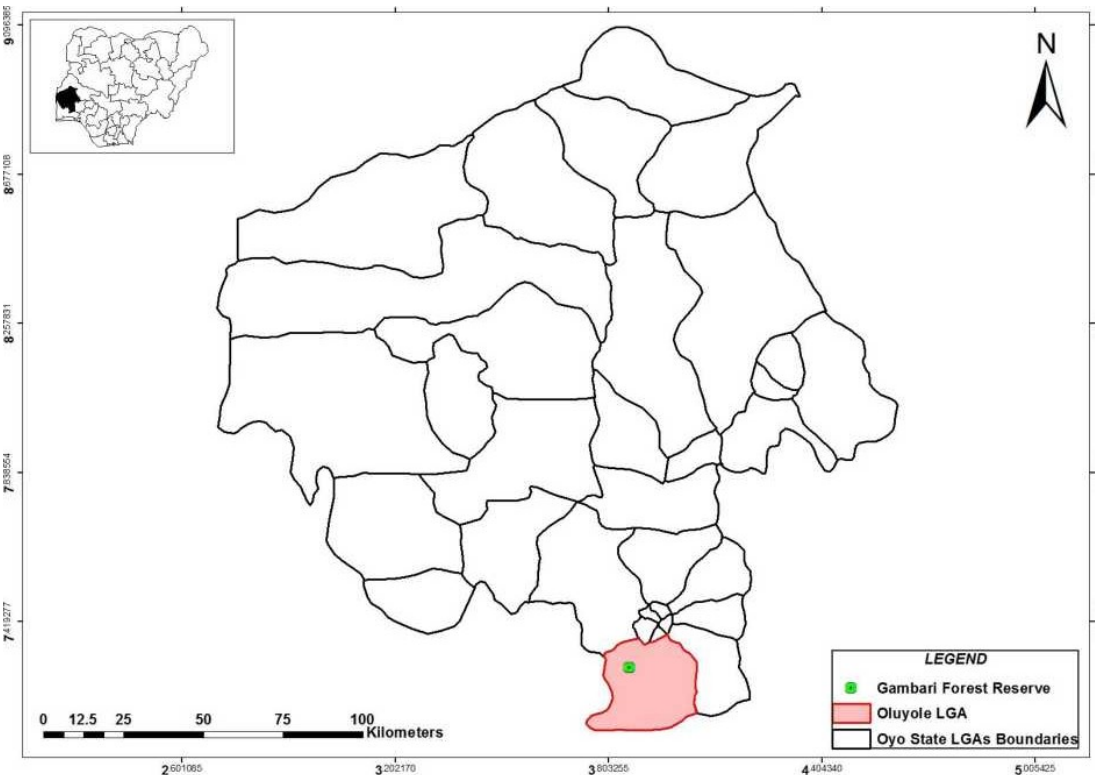

Fig 1: Map of Oyo State showing the study area

Data collection

Simple Random Sampling technique was employed to establish fifteen (15) temporary sample plots of 20 m x 20 m in the *Triplochoton scleroxylon* plantation established in the 1978 in the forest reserve. Total enumeration of all the trees in the sample plots was carried out. Data were collected on dbh (cm), total height (m) and these parameters were used to compute, stem biomass (tons), branch biomass (tons), leaf biomass (tons), basal area (m^2) and volume (m^3).

Estimation of standing biomass and sequestered carbon

The standing biomass of each tree was estimated using the allometric functions of Terakumpisut *et al.* (2007) developed for tropical rainforest. The functions are expressed as follows:

$$Ws = 0.0509*(D^2H)^{0.919} \qquad \text{(eq.1)}$$

$$W_b = 0.00893*(D^2H)^{0.977} \qquad \text{(eq.2)}$$

$$W_l = 0.0140*(D^2H)^{0.669} \qquad \text{(eq.3)}$$

Where,
Ws = Stem biomass (kg/individual tree)
W_b = Branch biomass (kg/individual tree)
W_l = Leaf biomass (kg/individual tree)
D = Diameter at breast height (cm)
H = Height (m^3)

The stem, branch and leaf biomass together constituted the standing biomass of individual tree. The sequestered carbon in the standing biomass of individual tree was estimated by multiplying 0.5conversion factor with the estimated standing biomass which implies that 50% of the standing biomass is the carbon stock (Atjay *et al*., 1979; Brown and Lugo, 1982; Dixon *et. al*., 1994; Chaturvedi, 1994; Cannell and Milne, 1995; Mann *et al*., 1998).

Data analysis

Data obtained were subjected to descriptive analysis

Results and discussion

The mean diameter at breast height (dbh) of *Triplochiton scleroxylon* was 34.14 cm while the mean height was 14.51 m (Table 1). The average stem biomass, branch biomass and leaf biomass were 503, 161.69 and 10.45 kg/tree respectively while the stand biomass was estimated at 0.67tC (1.12 ton C/ha) and sequestered carbon was 0.34tC (0.57tC/ha). The DBH and height of trees were distributed into different size classes and diameter size class of 20-29 cm was dominant (Fig. 2) while height size class of 16-20 m was the dominant class for the tree height (Fig. 3). The frequency distribution of the diameter size class indicated more or less an inverted J-shape (Fig. 2) signifying a growing forest.

Journal of Forestry Research and Management. Vol. 16(1).18-30; 2019, ISSN 0189-8418
www.jfrm.org.ng

Table 1: Descriptive statistics of parameters taken in the study area

Parameters	Minimum	Maximum	Mean	Std. Error
Dbh (cm)	4.78	66.56	34.14	1.86
Height (m^2)	6.00	25.00	14.67	0.57
W_s (kg/tree)	12.86	1864.80	503.00	57.64
W_b (kg/tree)	3.20	635.05	161.69	19.52
W_l (kg/tree)	0.79	29.41	10.45	0.91
Std biomass(tC/ha)	0.02	2.53	1.13	0.08
Seq. carbon(tC/ha)	0.01	1.26	0.65	0.04
Basal (m^2)	0.02	3.48	1.08	0.11
Vol. (m^3)	0.32	72.66	18.09	2.23

W_s, W_b, and W_l are stem biomass, branch biomass and leaf biomass respectively while Std biomass is standing biomass (that is, above ground biomass) and Seq. carbon is sequestered carbon

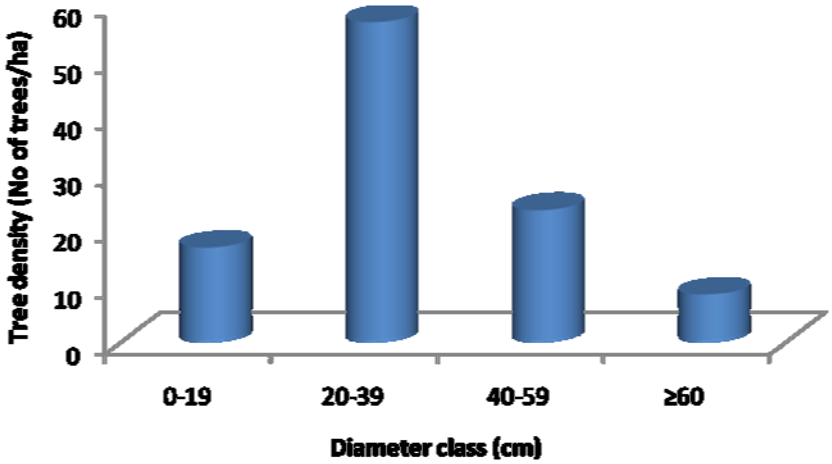

Fig 2: Tree density in each diameter size class of *Triplochiton scleroxylon* species in the study area

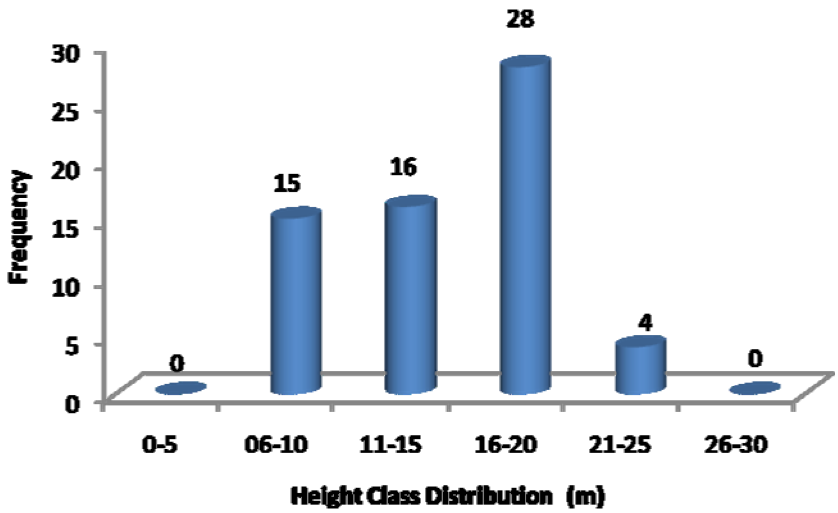

Fig 3: Height class disitribution of *Triplochiton scleroxylon* species in the study area

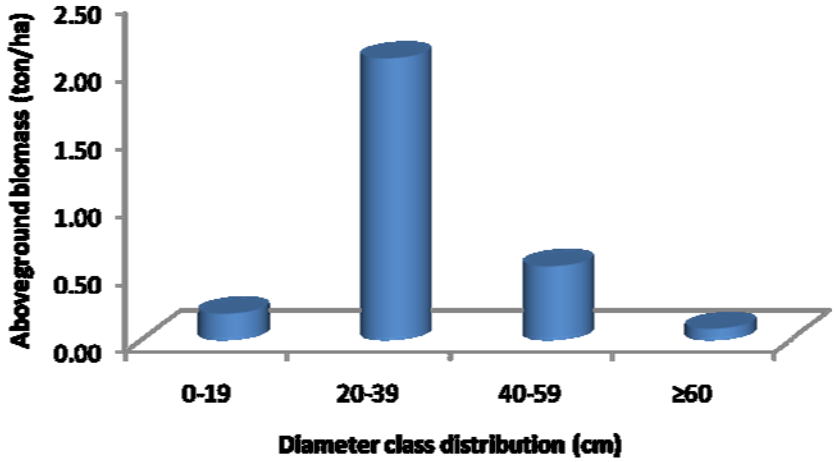

Fig. 4: Aboveground biomass in each diameter size class of *T. scleroxylon* in the study area

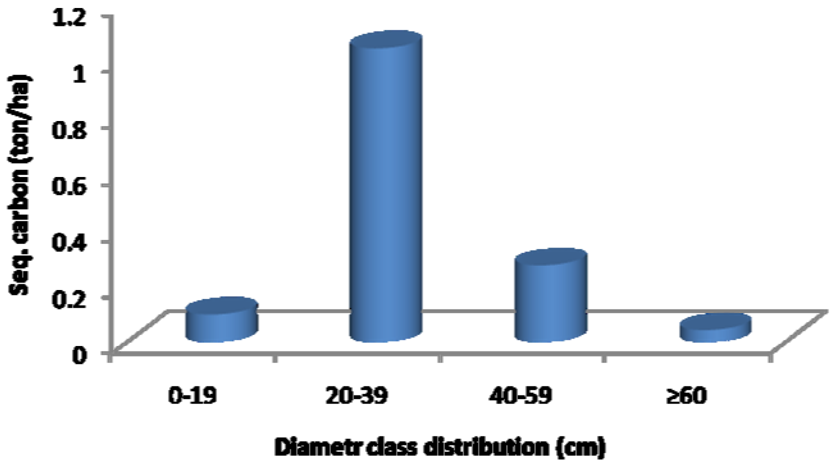

Fig. 5: Sequestered carbon in each diameter size class of *T. scleroxylon* in the study area

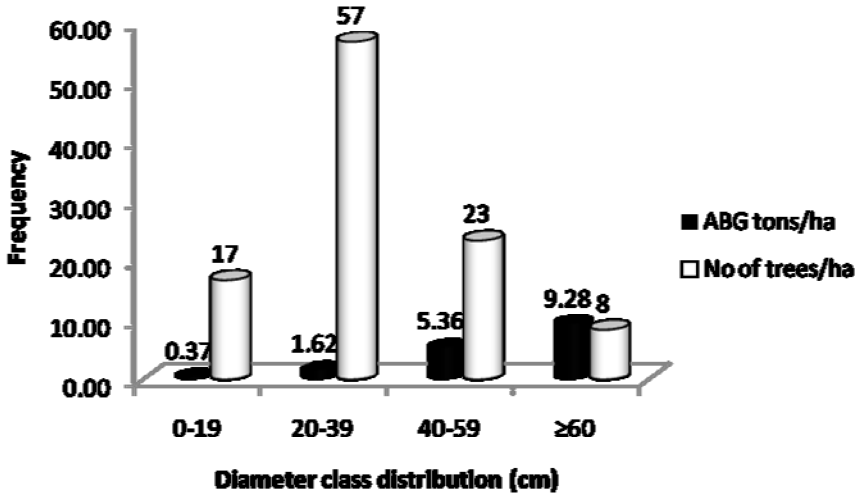

Fig. 6: Aboveground biomass (ton/ha) and tree density of different diameter size classes of *T. scleroxylon* in the study area

Journal of Forestry Research and Management. Vol. 16(1).18-30; 2019, ISSN 0189-8418
www.jfrm.org.ng

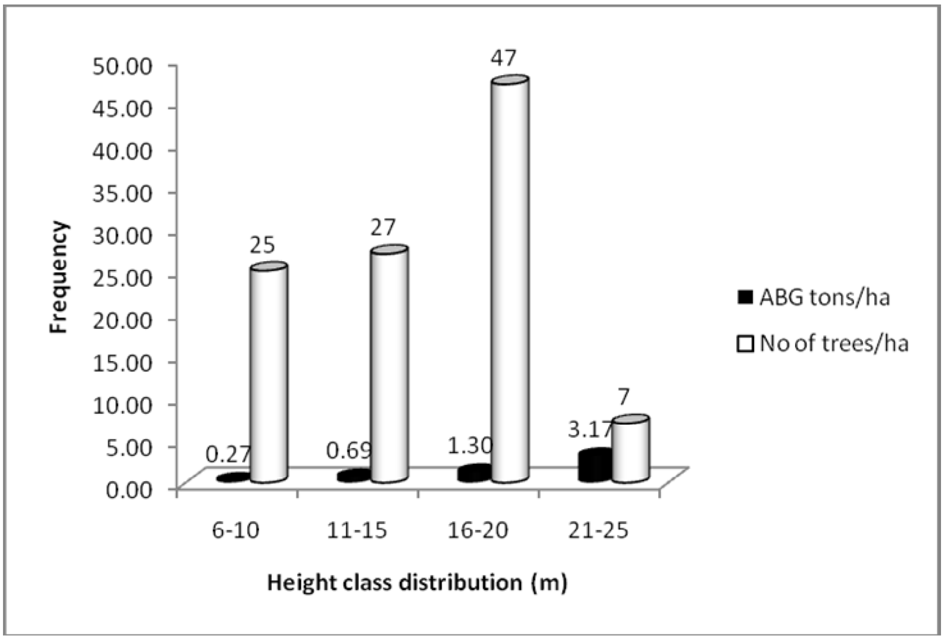

Fig. 7: Aboveground biomass (ton/ha) of different height classes of *T. scleroxylon* in the study area.

According to Olajide (2014), the rate of carbon sequestration by a tree species is a function of its photosynthetic and growth rates and the growth rate is dependent on genetics, climatic and edaptic factors. Forest plantation establishment and protection is an effective and efficient measure to combat global warming and mitigating climate change. Tewari *et al*., (2008) opined that forests are a much cheaper and easier reservoir for storing carbon. There is increasingly convincing evidence which shows that the earth is getting warmer and this could have serious effects on humans, carbon sequestration by forests can potentially reduce the accumulation of greenhouse gases in the atmosphere which is a major culprit in global warming. The above-ground biomass was highest at the diameter class = 60 cm (9.28tC/ha) (Fig. 6) even though this diameter class had the least density of trees with 8 trees/ha. The height class of 21-25 m had the highest carbon sequestration potentials with 3.17tC/ha while also having the least tree density, this is distantly followed by the dominant height class with 1.30tC/ha (Fig. 7). This trend is similar to the findings of Terakunpisut *et al*., (2007) who found out that big trees had the most above-ground biomass accumulation because of their highest stem volume and large diameter despite their low tree densities. According to Flint and Richards (1996), carbon sequestration reported in SE Asia ranged from 17.5 ton C/ha or less in severely degraded tropical dry forests to almost 350 ton C/ha in relatively undisturbed mature tropical rain forest while Brown and Lugo (1982) reported the estimates of carbon sequestration of tropical forest in three countries including Cameroon as ranging from 76.5 ton C/ha undisturbed tropical rain forest to 223 ton C/ha in relatively undisturbed mature tropical rain forest with Cameroon having 119-170.5 ton C/ha. The range of carbon sequestration estimates obtained from this study is lower than the reported cases and this could be as a result of high human pressure around the forest which made it to be highly disturbed reflecting an immature forest. Another factor responsible for low carbon sequestration is that in other studies there were presence of large trees with diameter class greater than 100 cm and height greater than 60 m while in this study the largest diameter and height were 66 cm and 25 m respectively (Table 1). However the potential to sequester more carbon lies in the fact that the trees in the study area are still young and immature, if they are not felled indiscriminately they have the tendencies to store more carbon as they grow older as Terakunpisut *et al*., (2007) noted that carbon sequestration varies from forest types and age of the forest and relied on tree size class because tree diameter class of 40-60 cm in a mixed deciduous forest sequestered more carbon than other class sizes while 20-40 cm diameter class in a dry evergreen forest and tropical rainforest had more carbon sequestered than other size classes in their study.

Conclusion

From the results obtained in this study, it can be deduced that each size class of the species has a different carbon sequestration potential while small and medium sized trees had a greater potential for carbon sequestration than big trees, the large trees have more carbon stock but as their growth rate reduce, their carbon sequestration potentials will also reduce, protecting the smaller trees from deforestation and illegal felling can considerably sequester more carbon from the atmosphere in the future as they continue to grow. Efforts must be mustered to strictly protect this indigenous trees especially the smaller ones from indiscriminate felling in the forest because of their atmospheric carbon sequestration potentials.

References

Akbari, H. (2002): Shade Trees Reduce Building Energy use and CO_2 Emissions from power Plants. *Environmental Pollution* 116: 119-126.

Alvarez, E., Duque, A., Saldarriaga, J., Cabrera, K., De-Las-Salas, G., Del-Valle, I., Lema, A., Moreno, F., Orrego, S. and Rodríguez, L. (2012): "Tree above-ground biomass allometries for carbon stocks estimation in the natural forests of Colombia", *Forest Ecology and Management* 267: 297-308.

Atjay, G.L., Ketner, P., and Duvignaed, P. (1979): Terrestrial primary production and phytomass.- In B. Bolin, E.T. Degens, S. Kempe (eds.), The global carbon cycle, pp. 129-182. New York: Wiley and Sons

Basuki, T.M., Van-Laake, P.E., Skidmore, A.K. and Hussin, Y.A. (2009): "Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests", *Forest Ecology and Management* 257 (8): 1684-1694.

Bazzaz, F. A. (1996). Plants in changing environments: linking physiological, population, and community ecology. Cambridge University Press, Cambridge, pp 332.

Bombelli, A., Avitabile, V., Belelli-Marchesini, L., Balzter, H., Bernoux, M., Hall, R., Henry, M., Law, B.E., Manlay, R., Marklund, L.G. and Shimabukuro, Y.E. (2009): Assessment of the status of the development of the standards for the Terrestrial Essential Climate Variables: Biomass. Food and Agriculture Organization – Global Terrestrial Observation System. 18 p.

Brown, S. (1997): Estimating biomass and biomass change of tropical forests: a primer UN FAO Forestry Paper 134, Food and Agriculture Organization of United Nations (FAO), Rome, Italy.

Brown, S. (2002): Measuring carbon in forests: current status and future challenges. *Environmental Pollution* 116: 363–372.

Brown, S. and Lugo, A.E. (1982): The storage and production of organic matter in tropical forests and their role in the global carbon cycle. *Biotropica* 14: 161-187

Brown, S., Burnham. M., Delaney, M., Vaca, R., Powell, M. and Moreno, A. (2000): "Issues and challenges for forest-based carbon-offset projects: a case study of the Noel Kempff Climate Action Project in Bolivia" *Mitigation and Adaptation Strategies for Climate Change* 5 (1): 99-121.

Brown, S., Pearson, T., Slaymaker, D., Ambagis, S., Moore, N., Novelo, D. and Sabido, W. (2004): Application of Multispectral 3- Dimensional Aerial Digital Imagery for Estimating Carbon Stocks in a Tropical Pine Savanna, Report to the Nature Conservancy Conservation Partnership Agreement.

Cannell, M.G.R. and Milne, R. (1995): Carbon pools and sequestration in forest ecosystems in Britain. *Forestry* 68: 361-378

Cannell, M. G. R. and Dewar, R. C. (1994): Carbon allocation in trees: a review of concepts in modelling. *Advances in Ecological Research* 25: 59-104.

Chave, J, Muller-Landau, H.C, Baker, T.R., Easdale, T.A., TerSteege, H. and Webb, C.O. (2006): "Regional and phylogenetic variation of wood density across 2,456 neotropical tree species" *Ecological Applications* 16: 2356-2367.

Chave, J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J.P., Nelson, B.W., Ogawa, H., Puig, H., Rie´ra, B. and Yamakura, T. (2005): "Tree allometry and improved estimation of carbon stocks and balance in tropical forests" *Oecologia* 145: 87-99.

Chave, J., Rie´ra, B. and Dubois, M.A. (2001): "Estimation of biomass in a neotropical forest of French Guiana: spatial and temporal variability" *Journal of Tropical Ecology* 17: 79-96.

Chaturvedi, A. N. (1994): Sequestration of atmospheric carbon in India's Forests. *Ambio* 23: 460-467.

Crow, T. R. and Schlaegel, B. E. (1988): A guide to using regression equations for estimating tree biomass. *Northern Journal of Applied Forestry* 5:15-22.

Dixon, R. K., Brown, S., Solomon, R. A., Trexler, M. C. and Wisniewski, J. (1994): Carbon pools and flux of Global forest ecosystems. *Science* 263: 185-190.

Ekoungoulou, R. (2014): Carbon Stocks Evaluation in Tropical Forest Congo; Carbon Stocks in Forest Ecosystems. Lambert Academic Publishing. Ed. Megan Moore, Saarbrucken, Germany.

Ekoungoulou, R., Liu, X., Loumeto, J.J., Ifo, S.., Bocko, Y.E., Koula, F.E. and Niu, S. (2014): "Tree Allometry in Tropical Forest of Congo for Carbon Stocks Estimation in Above-Ground Biomass", *Open Journal of Forestry* 4 (5): 481-491.

F.A.O. (1997): Forest harvesting in natural forests of the Republic of Congo, Forest Harvesting Case Studies-07, Food and Agriculture Organization of United Nations (FAO), Rome, Italy.

F.A.O. (2003): State of the World's Forests, Food and Agriculture Organization of United Nations (FAO), Rome, Italy.

F.A.O. (2008): Les forêts du Bassin du Congo, Etat des Forets. Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), Rome, Italy.

Flint, P.E. and Richards, J. F. (1996): Trends in carbon content of vegetation in South and Southeast Asia associated with change in land use. In V.H.Dale (ed), Effects of Land-Use Change on atmospheric CO_2 concentations, South and Southeast Asia as a case study, pp. 201-300. Berlin: Springer-Verlag

Folega, F., Zhao, H., Zhang, Y., Wala, K. and Akpagana, K. (2010): "Ecological and numerical analysis of plant communities of the most conserved protected area in North-Togo", *International Journal of Biodiversity and Conservation* 2 (10): 359-369.

Gibbs, H. K., Brown, S., Niles, J. O. and Foley, J. A. (2007): Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environmental Research Letters* 2: 1-13.

Holmes, T. P., Blake, G. M., Zweede, J. C., Pereira, R., Barreto, P., Boltz, F. and Bauch, R. (1999): Financial costs and benefits of reduced impact logging relative to conventional logging in the eastern Amazon, Tropical Forest Foundation, Arlington, VA, USA.

IPCC (2001): Third Assessment Report of IPCC on Climate Change. The Scientific Basis, Contribution of Working Group1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK.

IPCC (2007): Intergovernmental panel on Climate Change's Fourth Assessment Report. Climate Change Synthesis.

Jarvis, P. G., Ibrom, A. and Linder S. (2005): Carbon forestry: managing forests to conserve carbon. Taylor and Francis *Oxon* pp 331-349

Kangas, A. and Maltamo, M. (2006): Forest inventory, Methodology and Applications. *Managing Forest Ecosystems* 10: 179-194

Ketterings, Q. M., Coe, R., Noodrdwijk, M., Ambagau, Y. and Palm, C.A. (2001): Reducing uncertainity in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management* 146:199–209.

Killeen, T. J., Siles, T. M., Grimwood, T., Tieszen, L. L., Steininger, M. K., Tucker, C. J. and Panfil, S. (2002): Habitat herterogeneity on a forest-savanna ecotone in Noel Kempff Mercado National Park (Santa Cruz, Bolivia): implications for the long-term conservation of biodiversity in a changing climate, In: How Landscapes Change: human disturbance and ecosystem fragmentation in the Americas, (Eds) Bradshaw, G.A. and Marquet, P.A, Springer-Verlag, Heidelberg, Germany.

Label, G. G. and Kane, H. (1989): Sustainable Development: A guide to our common future. The Report of the World Commission on Environment and Development. Global Tomorrow Coalition, Washington, U.S.A.

Lal, R. (2008): Carbon sequestration in soil. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources Pp 1-54

Larinde, S. L. and Olasupo, O.O. (2011): Socio-economic importance of fuel wood production in Gambari forest reserve area, Oyo state, Nigeria. *Journal of Agriculture and Social Research* (JASR) Vol. 11, no. 1, Pg 203.

Mann, M. E., Brafley, R. S. and Hughes, M. K. (1998): Global-scale temperature patterns and climate forcing over the past six centuries. *Nature* 392: 779-787

McWilliam, A. L. C., Roberts, J. M., Cabral, O. M. R., Leitao, M. V. B. R., De Costa, A. C.

L., Maitelli, G. T. and Zamparoni, C. A. G. P. (1993): Leaf area index and aboveground biomass rain forest and adjacent clearings in Amazonia. *Functional Ecol*., 7: 310-317.

Mokany, K., Raison, R. J. and Prokushkin A.S. (2006): "Critical analysis of root: shoot ratios in terrestrial biomes", *Global Change Biology* 12 (1): 84-96.

Morgan, W.B. and Moss, P.A. (1985): Biomass energy and urbanisation: commercial factors in the production and use of biomass fuels in tropical Africa. *Biomass* 6: 285–299.

Nabuurs, G. J. (1998): Kyoto Forests. Change. Research and Policy Newsletter on Global Change from the Netherlands, 43, RIVM/NRP, Bilthoven.

Nelson, B. W., Mesquita, R., Pereira, J. L. G., De-Souza, S. G. A., Batista, G. T. and Couto, L. B. (1999): "Allometric regressions for improved estimate of secondary forest biomass in the central Amazon" *Forest Ecology and Management* 117: 149-167.

Niklas, K.J. (1997): "Mechanical properties of black locust Wood", Size- and age-dependent variations in sap- and heartwood. *Annals of Botan*y 79: 265-272.

Odjugo, P. A. O. (2009): Quantifying the cost of climate change impact in Nigeria: Emphasis on wind and rainstorm. *Journal of Human Ecology* 28(28): 93-101.

Olajide, O. (2014): Comparative assessment of carbon sequestration in standing biomass of planted forests of *Pinus caribaea* and *Nauclea diderrichii* in Southeastern Nigeria. *Nigerian Journal of Agriculture, Food and Environment* 10(2):45-47

Parde, J. (1980): Forest biomass. *Forestry Abstracts* 41:343-362.

Peltier, R., Njiti, C. F., Ntoupka, M., Manlay, R., Henry, M., and Morillon, V., (2007): Evaluation du stock decarboneet de la productivité en bois d'un parcà Karités du Nord-Cameroun. *Bois etforêt destropiques* 294: 39–50.

Terakunpisut, J., Gajaseni, N. and Ruankawe, N. (2007): Carbon sequestration potential in aboveground biomass of Thong Pha Phum National Forest, Thailand. *Applied Ecology and Environmental Research* 5(2): 92-102.

Tewari, A., Singh, V. and Phartiyal, P. (2008): Potential of community managed forests for carbon trade. *Low External Input and Sustainable Agriculture* (LEISA) 24(4): 32-33.

Ullah, M.R. and Amin, M. (2012): "Above- and below-ground carbon stock estimation in a natural forest of Bangladesh", *Journal of Forest Science* 58 (8): 372-379.

Watson, R.T., Noble, I.R, Bolin, B., Ravindranath, N.H., Verardo, D.J. and Donken, D.J, (2000): *Land Use, Land-Use Change and Forestry*, Special Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK.