DIAMETER AT BREAST HEIGHT: AN INDEX OF TREE VOLUME ESTIMATION IN BLOCK A FOREST OF INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE (IITA), IBADAN, OYO STATE, NIGERIA

[1*]Ariyo, O. C., [2]Usman, M. B., [2]Emeghara, U. U. and [3]Ariyo, M. O.

[1]Department of Entrepreneurship and Innovative Agriculture, Federal College of Forestry Mechanization, Afaka, Kaduna, Kaduna State, Nigeria. Forestry Research Institute of Nigeria, Ibadan, Oyo State, Nigeria*
[2]Federal College of Forestry Mechanization,, P. M. B. 2273, Afaka, Kaduna State, Nigeria. Forestry Research Institute of Nigeria
[3]Department of Horticulture and Landscape Management, Federal College of Forestry Mechanization, , Afaka, Kaduna State, Nigeria.
Forestry Research Institute of Nigeria, Ibadan, Oyo State, Nigeria

[1*]Corresponding author: ask4ariyo@yahoo.com

Ariyo, O. C., Usman, M. B., Emeghara, U. U. and Ariyo, **M. O.** (2019): Diameter at Breast Height: An Index of Tree Volume Estimation in Block a Forest Of International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria *Nigerian Journal of Forestry, 49 (2)* 110 - 119

Abstract
Tree volume is one of many parameters that are measured to document the size of individual trees. Tree volume measurements serve a variety of purposes, some economic, some scientific, and some for sporting competitions. This study was based on the relationship between tree volumes (V) and diameter at breast height (dbh). The volume equation of tree developed by FORMECU was adopted for this study. The study was conducted in the Block A forest of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria to estimate the volume of trees in the forest using dbh. Data were collected by identifying; enumerating and measuring all the trees with dbh ≥ 10 cm in 30 plots laid along 3 transect D, E (0^0N) and F (180^0W). The data were analysed using descriptive statistics, basal area analysis and volume equation. The result revealed 389 trees and shrubs per 0.3 hectare, belonging to 68 species and 27 families were recorded in the forest. The most abundant family are Fabaceae sub families of Caesalpinoideae, Mimosoideae and Papilinoideae represented by 12 species (17.64%). *Newbouldia laevis* (33), *Lecaniodiscus cupanioides* (28), *Antiaris toxicaria var. africana* (26) and *Sterculia tragacantha* (22), *Albizia zygia* (19), *Cola millenii* (18), and *Trichlla monadelpha* (16) were the most abundant trees in the forest. *Daniellia orgea* had the highest basal area and volume of 14.03 m^2 ha−1 and 1.87 m^3/ ha, followed by *Lannea welwitchii*, *Cleistopholis patens* and *Ficus mucoso* with 10.61 m^2 ha−1, 8.59 m2 ha−1 and 6.07 m2 ha−1 basal area and 1.81 m3/ ha, 1.76 m3/ ha, 1.68 m3/ ha volume respectively. The study concludes that tree volumes could be computed from diameter at breast height without actual felling of the trees and without causing indelible damage to the tree or nearby understory.

Keywords: Abundant, Basal area, Plots, Transects, Tree species, Volume

Introduction

Diameter at Breast Height (DBH) of a tree is one of the most important variable of consideration in forest management. It is not only used to estimate the volume of the tree, but also as a way of describing the stand structure and to select an inventory sample (Elias et al, 2016). Effective forest management requires estimates of growing stock. Such information guide forest managers in timber valuation as well as in allocation of forest areas for harvest. The determination of the volume of timber at a given time is one of the concerns of forest managers. To obtain inventory information for the purpose of planned management of the forest and also to meet with the full objective of timber production, one of the principal parameter is the determination of volume of standing trees (Ero, 1974, Aigbe and Oyebade, 2014). For timber production, an estimate of growing stock is often expressed in forms of timber volume, which can be estimated from easily measurable tree dimensions (Akindele and LeMay, 2006). The most common estimate of a growing stock is to use volume equations based on relationships between volume and variables such as diameter and height.

The accurate estimation of tree growth in the tropical forest is crucial for many applications from the commercial exploitation of timber to the global carbon cycle. Complex inventories of forests require accurate estimates of the total and merchantable volume of each tree and to improve inventory efficiency, tree variable attribute of diameter at breast height (dbh) and stump diameter should be inclusive. For several decades, forest science focused much attention on modelling individual tree height and volume functions of individual tree attributes. Traditionally, relationships between predictor variables and tree biomass, height and volume have been described based on regression models (Salazar *et al.,* 2008; Zianis *et al.,* 2005).

The volume content of a tree is normally estimated using traditional volume tables or equation which requires the measurement of both tree dbh and merchantable height. In a situation where tree height was not taking into consideration during measurement, tree volumes can still be estimated by using volume equation developed by FORMECU (1999). Previous studies have been conducted to determine relationships between tree volume and dbh and stump diameter (Bylin, 1982; Curtis and Arney 1977; Aigbe and Oyebade, 2014).

Tree volume is one of many variables that are measured to document the size of individual trees. Tree volume measurements serve a variety of purposes, some economic, some scientific, and some for sporting competitions. Measurements may include just the volume of the trunk, or the volume of the trunk and the branches depending on the detail needed and the sophistication of the measurement methodology. The estimation of merchantable tree volumes is essential for understanding of allowable cut cycle and for establishing sustainable forest management in forest estate. Non-linear regression was more efficient than linear regression for estimation of merchantable tree volume. According to Aigbe and Oyebade, (2014), dbh can be very useful in estimation of volume if the stand has not been cut because dbh is easier to measure and it saves time.

The Block A forest of IITA has an area of about 50 hectares and is a unique forest in the sense that it serves as a buffer zone for villagers living around the perimeter fence of IITA. It is a repository of useful timber and non-timber forest products which are useful for food, medicine, cooking, and wrapping or preservation of food items (Ariyo *et al*., 2018). The forest is serving as a source of livelihood for villagers living in adjoining villages of the perimeter fence of IITA for over forty years. The villagers are allowed into the forest to collect NTFPs such as *Adenopus breviflorus*, *Bambusa vulgaris*, leaves of *Cordia millenii*, fruits and kernels of *Elaeis guineensis*, *Pentaclethra macrophylla*, *Talinum triangulare*, *Tetrapleura tetrapetra* and firewood are collected from Block A forest. Some of these non-timber forest products were collected illegally along with dried firewood, fruits and kernels of *Elaeis guineensis*, and *Talinum triangulare* which they have the permission to collect. Part of the forest was also used for arboretum and experimental plot (Fig. 2), this gives opportunity to IITA staff to collect pegs, poles and stakes for the experimental field. Most of the research in forestry at IITA has focused on West bank forest and only very little studies has been carried out from Block A forest. To the best of my knowledge, no study has estimated the volume of trees in Block A forest. Against this backdrop, this study was carried out to estimate the stem volume of trees in the forest using non destructive approach method (Diameter at Breast Height- DBH) as provided in the volume equation for trees developed by FORMECU (1999).

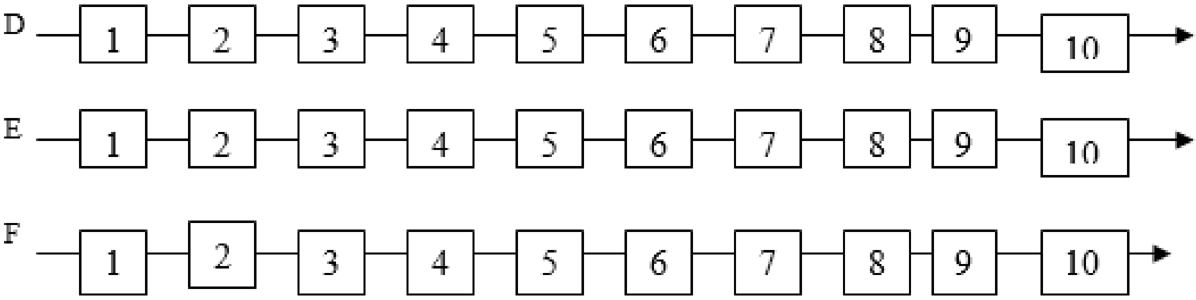
Materials and Method

Study Area

The study was carried out in the Block A forest of International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria. IITA is located on longitude $7^{0}30'8''$N, latitude $3^{0}54'37''$E and 243 m above sea level. The vegetation is within the Forest-Savanna Transition Zone and the soil is an Alfisoil and slightly acidic (Tenkouano and Baiyeri, 2007, Ariyo, 2020a, 2020b). The site falls within humid tropical lowland region with two distinct seasons: the longer wet season and shorter dry season. The wet season lasts for eight months, and it extends from March to October while the dry season lasts for four months from November to February. The rainfall pattern is bimodal with an annual total which ranges from 1,300 to 1,500mm most of which falls between May and September (Ariyo, 2018; 2020a; 2020b). The average daily temperature ranges between 21°C and 23°C, while the maximum is between 28°C and 34°C. Radiation is about 5285 MJ/m2/year. Mean relative humidity is in the range of 64% to 83% (Tenkouano and Baiyeri, 2007, Ariyo, 2020a, 2020b). The natural vegetation in this area could be classified as tropical semi-deciduous forest with various pockets of vegetation types ranging from derived savanna, secondary forest and riparian types. According to Ezealor (2002), the area resembles mature Guinea-Congo lowland rainforest with scattered emergence of trees which include *Ceiba, Milicia* and *Terminalia* spp. Large clumps of bamboo (*Bambusa vulgaris)* are common; stands of *Raphia farinifera* are found along watercourses while scattered oil-palms *Elaeis guineensis* grow in both low-lying and the relatively better-drained upland areas.

Data Collection Techniques

The data that was used for this study were collected by vegetation survey using transect and plot sampling techniques (Onyekwelu *et al*., 2005; Lawal and Adekunle, 2011, Ariyo, *et al.*, 2011, 2012, Onefeli, *et. al*., 2013; Ariyo, 2018, 2019, 2020a 2020b). Three transects {D, E (0^{0}N) and F (180^{0}W)} were constructed with the aid of prismatic compass in Block A forest of IITA. The transects were established with minimal disruption to the environment and marked with flagging tape at every 10 m. Each transect was 500 m long. 10 sampling plots of 10 m by 10 m each were demarcated along each of the transect. A total number of 30 sampling plots (3 transect by10 plots) were used for the study. A distance of 40 m was left between each of the plot to minimize repetition of tree species while 20 m was left at the beginning and at the end of each transect as the border row to minimize edge effects (Fig. 1). In each plot, all trees and shrubs with diameter at breast height (dbh) greater than or equal to 10 cm (DBH ≥ 10 cm) were identified with their scientific and family names. The trees and shrubs were enumerated and measured. Samples of trees that cannot be identified on the field were coded and taken to the Forestry Research Institute of Nigeria, Ibadan (FRIN) herbarium for proper identification. The species of trees and shrubs, number of individual of each species and total number of each species were recorded from each plot and the data pooled together per transect. The coordinate of the plots and transects was taken with Geographical Positioning System (GPS) and plotted on the GPS arc view to locate the exact position of each transect within the forests and to obtained the study location map (Fig, 2).



Legend: - Each line D, E and F are 500m long transect while 1, 2, 3, --------10 are plots of 10 m by 10 m each.
Figure 1: Transects and plots design

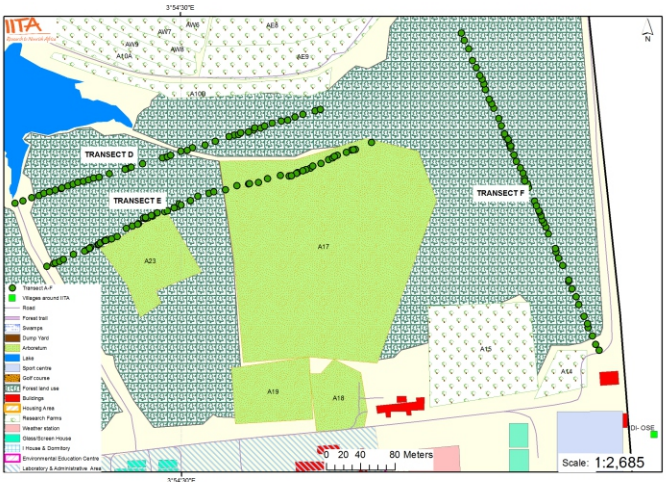


Figure 2: Map of Block A forest showing the location of transect D, E and F

Data Analysis

The data collected were analysed with descriptive statistics such as tables, frequency counts, percentages and mean. Analysis of basal area and volume estimation using volume equation developed by FORMECU (1999) were carried out following Ariyo, (2020b).

Estimation of the Basal Area

The determination of basal area of all individual trees belonging to a particular species was achieved using basal area formula: $BA = D^2/4$

Where: BA = Basal area in m^2 per hectare

= 3.142

D = Diameter at breast height in meter.

In this study the diameter measurement was obtained from the circumference (d = c/)

All the individual trees basal area within the three transects (0.3 ha) were added together and converted to hectare to obtained the basal area of a specie

Trees Volume Estimation

Individual tree volume was estimated using volume equation for trees developed by FORMECU (1999) is expressed as:

$$V = e^{-8.433+2.331 \ln(D)}$$

Where V is volume (m^3) and D is diameter at breast height in meter

Results and Discussion

The result showed that 389 trees and shrubs per 0.3 hectare, with diameter at breast height (dbh) ≥ 10 cm belonging to 68 species and 27 families were recorded in the forest. The forest contains both indigenous and exotic tree species. This could be as a result of tree arboretum which covers about 5.87 ha of the entire area of the forest. The distribution of the woody plants into tree and shrubs on Table 1 showed that tree had 69.12% species with relative frequency of 82.52% while shrub had 30.88% species with 17.48% relative frequency. This implies that trees dominated the forest in terms of the number of species and individual species. This corroborate with the findings of Ariyo (2018, 2020b) which found 581 trees and shrubs with the (dbh) ≥10 cm belonging to 65 species and 28 families in West bank forest ecosystem found in the same environment as Block A forest in IITA, Ibadan Nigeria.

The major families according to Table 2 are Fabaceae sub families of Caesalpinoideae, Mimosoideae and Papilinoideae represented by 12 species (17.64%). This was followed by Euphorbiaceae by 7 species (10.29%), Moraceae and Rubiaceae had equal representation of 6 species each (8.82%), Apocynaceae and Malvaceae by 5 species each (7.35%), Sapindaceae by 4 species (5.88%). Families that were represented with 2 species (2.94%) are Anacardiaceae, Annonaceae, Bignoniaceae, Bombacaceae and Tiliaceae. Other families such as Capparidaceae, Dichapetalaceae, Ebenaceae, Lamiaceae, Leaceae, Lecythidaceae, Meliaceae, Myristicaceae, Myrtaceae , Olacaceae , Palmae , Pandaceae and Ulmaceae were represented with 1 species (1.47%) respectively.

The most abundant trees in the forest are *Newbouldia laevis* (33), *Lecaniodiscus cupanioides* (28), *Antiaris toxicaria var. africana* (26), *Sterculia tragacantha* (22), *Albizia zygia* (19), *Cola millenii* (18), and *Trichlla monadelpha* (16). *Lonchocarpus sericeus* and *Celtis zenkeri* had equal abundant of (14) while *Ficus exasperata* has (10) abundant. Three species; *Trilepisium madagascariense*, *Holarrhena floribunda* and *Elaeis guineensis* had equal abundant of 9. Other tree species had abundant ranging from 8 to 1. Species which occurs once in the forest are considered rare, they includes *Albizia adianthifolia*, *Allophyllus africanus*, *Alstonia boonei*, *Psydrax parviflora*, *Cassia siamea*, *Ceiba pentandra*, *Cleistopholis patens*, *Euadenia trifoliolata*, *Kigelia africana*, *Lannea welwitschii*, *Leea guineensis*, *Mallotus oppositifolius*, *Morinda lucida*, *Nesogordonia papaverifera*, *Gmelina arborea*, *Rauvolfia vomitoria*, *Rothmannia hispida*, *Rytigynia umbellulata* and *Triplochiton scleroxylum*. Generally it can be inferred that the abundance of the trees in the forest is very low. This could be due to removal of poles, stakes and pegs for experimental fields by IITA staff.

Form	NOS	% NOS	SF	SRF %
Shrubs	21	30.88	68	17.48
Trees	47	69.12	321	82.52
Total	68	100	389	100

Source: Computed from Vegetation Survey Data, 2018

NOS: Number of species, **SF**: Species frequency, **SRF**: Species relative frequency

Basal Area Computation

Basal area is the cross-sectional area of all of the stems in a stand at breast height (1.3 m above ground level). This basal area per unit area is used to explain the crowdedness of a stand of forests. A stand of large trees is more stocked than with the same number of trees of smaller diameter (Martin, 1989). The basal area of individual tree species encountered in the forest was presented on Table 3. It revealed that *Daniellia ogea* had the highest basal area of 14.03 m^2 ha−1. This was followed by *Lannea welwitchii*, *Cleistopholis patens*, *Ficus mucoso* and *Ricinodendron heudelotii* having 10.61 m^2 ha−1, 8.59 m^2 ha−1, 6.07 m^2 ha−1 and 5.76 m^2 ha−1 respectively. Species such as *Gmelina arborea*, *Elaeis guineensis*, *Alstonia boonei*, *Senna siamea* and *Bombax buonoposence* had 5.12 m^2 ha−1, 3.60 m^2 ha−1, 3.57 m^2 ha−1, 2.41 m^2 ha−1, and 2.27 m^2 ha−1 respectively. Other species had basal area between 2.11 m^2 ha−1 to 0.03 m^2 ha−1. The forest recorded a total basal area of 89.69 m^2 ha−1 and average basal area of 1.32 m^2 ha−1. According to Dawins (1959) cited in Lamprecht (1989) the normal basal area of virgin tropical forest in Africa is 23-37m^2 ha^{-1}. Alder and Abayomi (1994) recommended a basal area of about 23m^2 per hectare for a fully stocked forest for timber. Egor *et al* (2014) recorded a basal area of 29.78m^2 per hectare. Based on these reports, the basal area of Block A forest is higher and the forest is considered to be fully stocked with trees. Aigbe and Oyebade, (2014) obtained the mean basal area per hectare of 32.13 m^2/ha from average of 300 trees in their study of Comparison of stump diameter and diameter at breast height for tree volume estimation of *Terminalia ivorensis* in Sakpoba forest reserve, Nigeria. However the value of the total basal area and average basal area recorded in the forest was less than the total basal area of 98.22 m^2 ha−1 and average basal area of 15.11 m^2 ha−1 recorded by Ariyo (2018, 2020b) in the West bank forest found in the same environment as Block A forest in IITA, Ibadan Nigeria. This may be due to the fact that the West bank forest is under active protection by forest rangers day and night while the block A forest is open to villagers to collect non- timber forest products (NTFPs) and IITA staff to collect pegs, poles and stakes for the experimental field. It was reported by Cain and Castro (1959), cited in Tamrat Bekele (1994) that basal area provides a better measure of the relative importance of the species than simple stem count. Species with the largest contribution in basal area can be considered as the most important woody species in the forest. Accordingly, the most important woody species of Block A forest were *Daniellia orgea*, *Lannea welwitchii*, *Cleistopholis patens*, *Ficus mucoso* and *Ricinodendron heudelotii*. These were the top 5 dominant tree species in the forest.

Estimation of Trees Volume in the Forest

The volume of individual tree species estimated from the forest presented on Table 3 showed that *Daniellia orgea* had the highest volume of 1.87 m^3/ ha. *Lannea welwitchii*, *Cleistopholis patens*, *Ficus mucuso*, *Ricinodendron heudelotii* and *Gmelina arborea* had 1.81 m^3/ ha, 1.76 m^3/ ha, 1.68 m^3/ ha, 1.67 m^3/ ha, and 1.65 m^3/ ha volume respectively. *Elaeis guineensis* and *Alstonia boonei* recorded equal volume of 1.57 m^3/ ha. *Senna siamea* had 1.48 m^3/ ha, *Bombax buonoposence* (1.47 m^3/ ha), *Albizia zygia* (1.46 m^3/

ha), *Cassia siamea* (1.45 m^3/ ha) and *Albizia ferruginea* (1.44 m^3/ ha). Other tree species of tree had volume ranges between 1.40 m^3/ ha to 0.52 m^3/ ha. The total volume of 74.50 m^3/ ha and average volume of 1.10 m^3/ ha were obtained from the forest. Aigbe and Oyebade, (2014) obtained a mean volume of 450 m^3/ ha from average of 300 trees in their study of Comparison of stump diameter and diameter at breast height for tree volume estimation of *Terminalia ivorensis* in Sakpoba forest reserve, Nigeria. The total and average volume obtained in this forest was lower that the total (68.19 m^3/ ha) and average (1.05 m^3/ ha) volume of tree species obtained in West bank forest of IITA in the same environment. According to Ariyo (2018, 2020b), volume distribution among tree species had similar trend with basal area. This similarity is an indication of the relationship between basal area and volume. The higher the diameter, the higher the basal area and thus the higher the volume of tree species. Trees with high dbh contribute more to volume than the undersized trees, this agreed with the finding of Akinsanmi and Akindele, (2002), Ariyo (2018, 2020b).

Table 2: Family Distribution of Trees in the Forest

S/n	Family	No of species	Percentage
1	Anacardiaceae	2	2.94
2	Annonaceae	2	2.94
3	Apocynaceae	5	7.35
4	Bignoniaceae	2	2.94
5	Bombacaceae	2	2.94
6	Capparidaceae	1	1.47
7	Dichapetalaceae	1	1.47
8	Ebenaceae	1	1.47
9	Euphorbiaceae	7	10.29
10	Fabaceae- Caesalpinioidea	5	7.35
11	Fabaceae- Mimosoideae	4	5.88
12	Fabaceae- Palpilinoideae	3	4.41
13	Lamiaceae	1	1.47
14	Leaceae	1	1.47
15	Lecythidaceae	1	1.47
16	Malvaceae	5	7.35
17	Meliaceae	1	1.47
18	Moraceae	6	8.82
19	Myristicaceae	1	1.47
20	Myrtaceae	1	1.47
21	Olacaceae	1	1.47
22	Palmae	1	1.47
23	Pandaceae	1	1.47
24	Rubiaceae	6	8.82
25	Sapindaceae	4	5.88
26	Tiliaceae	2	2.94
27	Ulmaceae	1	1.47

S/n	Woody Plant Species	Family	Form	TD	TE	TF	Total	Diameter (m)	BA/0.3 ha (m^2)	BA/ha	V(m^3)/ ha
1	*Albizia ferruginea (*Guill. & Perr.) Benth.	Fabaceae- Mim.	Tree	1	2	4	7	27.33	586.53	1955.08	1.44
2	*Albizia adianthifolia var. adianthifolia*	Fabaceae- Mim.	Tree	.	1	.	1	5.09	20.37	67.90	0.71
3	*Albizia zygia* (DC.) J.F. Macbr.	Fabaceae- Mim.	Tree	3	14	2	19	28.41	633.98	2113.28	1.46
4	*Alchornea cordifolia* (Schumach. & Thonn.) Mull.Arg.	Euphorbiaceae	Shrub	2	.	1	3	6.68	35.09	116.96	0.83
5	*Alchornea laxiflora* (Benth.) Pax & K.Hoffm.	Euphorbiaceae	Shrub	2	3	3	8	6.88	37.21	124.03	0.84
6	*Allophyllus africanus*	Sapindaceae	Shrub	.	.	1	1	19.10	286.44	954.81	1.28
7	*Alstonia boonei* De Wild.	Apocynaceae	Tree	1	.	.	1	36.92	1070.66	3568.85	1.57
8	*Anthonotha macrophylla* P.Beauv.	Fabaceae- Caes.	Tree	2	2	2	6	8.17	52.42	174.72	0.91
9	*Antiaris toxicaria var. a fricana Scott-Elliot ex A.Chev.*	Moraceae	Tree	6	13	7	26	14.16	157.56	525.21	1.15
10	*Blighia sapida* K.D. Koenig	Sapindaceae	Tree	2	2	2	6	19.36	294.45	981.51	1.29
11	*Blighia unijugata* Baker	Sapindaceae	Tree	1	.	1	2	6.21	30.26	100.85	0.80
12	*Bombax buonoposence* P. Beauv.	Bombacaceae	Tree	3	.	2	5	29.47	682.27	2274.23	1.47
13	*Brachystegia eurycoma* Harms	Fabaceae- Caes.	Tree	.	2	.	2	8.43	55.88	186.25	0.93
14	*Bridelia micranthra* (Hochst.) Baill.	Euphorbiaceae	Shrub	.	1	2	3	8.17	52.42	174.72	0.91
15	*Psydrax parviflora* (K. Schum.) Bullock	Rubiaceae	Shrub	.	.	1	1	10.50	86.65	288.83	1.02
16	*Cassia siamea* Lam.	Fabaceae Caes.	Tree	.	.	1	1	28.17	623.19	2077.30	1.45
17	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	Tree	.	.	1	1	7.96	49.73	165.76	0.90
18	*Celtis zenkeri* Engl.	Ulmaceae	Tree	4	7	3	14	17.41	238.20	793.99	1.24
19	*Cleistopholis patens* (Benth.) Engl. & Diels	Annonaceae	Tree	1	.	.	1	57.29	2577.98	8593.25	1.76
20	*Cola gigantean* A. Chev.	Malvaceae	Tree	.	.	2	2	10.72	90.18	300.62	1.03
21	*Cola millenii* K. Schum	Malvaceae	Tree	3	2	13	18	10.36	84.38	281.27	1.02
22	*Daniellia ogea* (Harms) Holland	Fabaceae- Caes.	Tree	1	.	1	2	73.20	4209.10	14030.34	1.87
23	*Dichapetalum madagascariense* Poir	Dichapetalaceae	Shrub	3	.	.	3	3.29	8.50	28.32	0.52
24	*Diospyros monbuttensis* Gurke	Ebenaceae	Shrub	2	3	.	5	9.55	71.61	238.70	0.98
25	*Elaeis guineensis* Jacq.	Palmae	Tree	3	4	2	9	37.06	1078.58	3595.27	1.57
26	*Euadenia trifoliolata* (Schumach. & Thonn.) Oliv.	Capparidaceae	Shrub	.	.	1	1	3.82	11.46	38.19	0.58
27	*Ficus exasperata* Vahl	Moraceae	Tree	3	2	5	10	17.05	228.21	760.71	1.23
28	*Ficus mucuso* Welw. Ex Ficalho	Moraceae	Tree	2	2	.	4	48.14	1820.22	6067.41	1.68
29	*Funtumia elastic* (Preuss) Stapf	Apocynaceae	Tree	3	2	2	7	14.72	170.20	567.33	1.17

30	*Glyphaea brevis* (Spreng.) Monach.	Tiliaceae	Shrub	2	.	1	3	5.09	20.37	67.90	
31	*Grewia pubescens* P. Beauv.	Tiliaceae	Shrub	2	.	.	2	6.84	36.78	122.60	0.84
32	*Holarrhena floribunda* (G.Don) T.Durand & Schinz	Apocynaceae	Tree	3	4	2	9	13.78	149.08	496.94	1.14
33	*Hura crepitans* L.	Euphorbiaceae	Tree	.	.	1	1	16.23	206.95	689.85	1.21
34	*Kigelia africana* (Lam.) Benth.	Bignoniaceae	Tree	.	.	1	1	4.46	15.60	51.98	0.65
35	*Lannea welwitschii* (Hiern) Engl.	Anacardiaceae	Tree	.	.	1	1	63.65	3182.69	10608.95	1.81
36	*Lecaniodiscus cupanioides* Planch. Ex Benth.	Sapindaceae	Tree	3	17	8	28	10.30	83.32	277.73	1.02
37	*Leea guineensis* G. Don	Leaceae	Shrub	.	1	.	1	3.82	11.46	38.19	0.58
38	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae- Mim.	Tree	.	3	3	6	13.23	137.59	458.62	1.12
39	*Philenoptera cyanescens* (Schum. & Thonn.) Benth.	Fabaceae- Pap.	Shrub	2	.	.	2	4.30	14.50	48.34	0.64
40	*Lonchocarpus sericeus* (Poir.) DC.	Fabaceae- Pap.	Shrub	5	7	2	14	25.08	493.89	1646.29	1.40
41	*Mallotus oppositifolius* (Geiseler) Mull. Arg.	Euphorbiaceae	Shrub	.	1	.	1	4.77	17.90	59.68	0.68
42	*Manihot glaziovii* Mull. Arg.	Euphorbiaceae	Tree	.	2	2	4	15.91	198.92	663.06	1.20
43	*Microdesmis puberula* Hook.f.ex Planch	Pandaceae	Shrub	.	2	2	4	4.77	17.90	59.68	0.68
44	*Millettia thonningii* (Schum. & Thonn.) Baker	Fabaceae-Pap.	Tree	.	2	3	5	10.44	85.60	285.34	1.02
45	*Monodora tenuifolia* Benth.	Annonaceae	Tree	2	3	2	7	9.18	66.26	220.86	0.97
46	*Morus mesozygia* Stapf	Moraceae	Tree	.	2	.	2	11.78	108.93	363.09	1.07
47	*Myrianthus arboreus* P.Beauv.	Moraceae	Tree	1	2	1	4	17.58	242.88	809.61	1.25
48	*Napoleona vogelii*	Lecythidaceae	Shrub	8	.	.	8	4.30	14.50	48.34	0.64
49	*Morinda lucida Benth.*	Rubiaceae	Tree	.	1	.	1	7.92	49.23	164.11	0.90
50	*Nesogordonia papaverifera*	Malvaceae	Tree	1	.	.	1	13.37	140.36	467.85	1.13
51	*Newbouldia laevis*	Bignoniaceae	Tree	19	11	3	33	8.70	59.49	198.29	0.94
52	*Gmelina arborea*	Lamiaceae	Tree	.	1	.	1	44.24	1537.32	5124.39	1.65
53	*Oxyanthus tubiflorus*	Rubiaceae	Shrub	.	2	.	2	4.77	17.90	59.68	0.68
54	*Pavetta corymbosa*	Rubiaceae	Shrub	.	3	.	3	3.71	10.83	36.10	0.57
55	*Pisdium guajava*	Myrtaceae	Tree	.	2	.	2	18.46	267.66	892.21	1.27
56	*Pycnanthus angolense*	Myristicaceae	Tree	2	.	2	4	25.06	493.44	1644.80	1.40
57	*Rauvolfia vomitoria*	Apocynaceae	Shrub	1	.	.	1	9.55	71.61	238.70	0.98
58	*Ricinodendron heudelotii*	Euphorbiaceae	Tree	.	.	3	3	46.89	1727.17	5757.24	1.67

59	*Rothmannia hispida*	Rubiaceae	Shrub	.	.	1	1	9.23	66.92	223.05	0.97
60	*Rytigynia umbellulata*	Rubiaceae	Shrub	1	.	.	1	5.09	20.37	67.90	0.71
61	*Senna siamea*	Fabaceae-Caes	Tree	1	.	2	3	30.34	723.14	2410.47	1.48
62	*Spondias mombin*	Anacardiaceae	Tree	2	3	.	5	11.71	107.75	359.18	1.07
63	*Sterculia tragacantha*	Malvaceae	Tree	13	5	4	22	16.78	221.21	737.37	1.23
64	*Strombosia pustulata*	Olacaceae	Tree	.	.	2	2	15.91	198.92	663.06	1.20
65	*Trichlla monadelpha*	Meliaceae	Tree	4	3	9	16	17.74	247.30	824.33	1.25
66	*Trilepisium madagascariense*	Moraceae	Tree	1	3	5	9	21.89	376.38	1254.61	1.34
67	*Triplochiton scleroxylum*	Malvaceae	Tree	.	1	.	1	5.41	22.99	76.65	0.74
68	*Voacanga africana*	Apocynaceae	Tree	2	3	2	7	11.09	96.68	322.25	1.05
	Total			**124**	**144**	**121**	**389**	**1147.01**	**26905.50**	**89685.02**	**74.50**
	Average							**16.87**	**395.67**	**1318.90**	**1.10**

Conclusion and Recommendation

The findings of the study showed that Block A forest of International Institute of Tropical Agriculture contains both indigenous and exotic tree species that are merchantable and fairly stocked considering mean volume and basal area per hectare. A total number of 389 trees and shrubs with diameter at breast height (dbh) ≥ 10 cm belonging to 68 species and 27 families were recorded in the forest. *Daniellia orgea* had the highest basal area and volume. Some tree species were encountered once in the forest. To prevent the extinction of these mono specific ones and their families, adequate and continuous protection of the forest should be given priority. Also removal of poles and pegs for experimental plots by IITA staff should be stopped immediately. It can be concluded from the findings of the study that tree volumes could be computed from diameter at breast height without felling the tree and without causing indelible damage to the tree or nearby understory.

Acknowledgements

The authors acknowledged the assistance of Ms. Deni Bown, the former forest manager of International Institute of Tropical Agriculture (IITA) Ibadan, Oyo State Nigeria and also the efforts of all IITA forest staff, Geo spatial Lab. and Industrial attachments students from Federal College of Forestry, Ibadan and University of Ibadan (U.I) were highly acknowledged.

Competing Interests

Authors have declared that no competing interests exist.

References

Aigbe, H. I. and Oyebade, B. A. (2014): Comparison of Stump Diameter and Diameter At Breast Height For Tree Volume Estimation of *Terminalia Ivorensis* in Sokpoba Forest Reserve, Nigeria. *Journal For Applied Research* 6: 1-14

Akindele, S.O. and LeMay, V.M. (2006): Development of Tree Volume Equations forCommon Timber Species in the Tropical rain Forest Area of Nigeria. *Forest Ecology and Management* 226: 41-48.

Akinsanmi, F. A., and Akindele, S. O. (2002). Timber yield assessment in the natural forestarea of Oluwa forest reserve, Nigeria. *Nigerian Journal of Forestry* 32 (1) 16-22.

Alder, D., Abayomi, J. O., (1994): Assessment of Data Requirements for Sustained YieldCalculations. A Consultancy Report prepared for the Nigerian Tropical Forest Action Plan, FORMECU, Federal Department of Forestry, Ibadan, Nigeria; 76

Ariyo, O. C. (2020a): "Comparative Analyses of Diversity and Similarity Indices of West Bank Forest and Block A Forest of the International Institute of Tropical Agriculture (IITA) Ibadan, Oyo State, Nigeria." *International Journal of Forestry Research*, vol. 2020, p. NA. *Gale Academic One File*, Accessed 14 Oct. 2020.

Ariyo, O. C. (2020b): Tree Stem Volume Estimation from West Bank Forest Ecosystem ofIITA, Ibadan, Oyo State, Nigeria. *Journal of Forestry Research and Management* 17(1): 99-110.

Ariyo, O. C. (2019): Comparison of Woody Plants Population Structure in Two Distinct Forest of International Institute of Tropical Agriculture (IITA) Ibadan, Oyo State, Nigeria. *Journal of Forestry Research and Management* 16(3): 87-103.

Ariyo, O.C (2018). Socio- Economic and Botanic Analysis of West bank forest and Block A Forest of IITA, Ibadan, Oyo State, Nigeria. Unpublished Ph.D. Thesis submitted to the Department of Forestry and Wild life Management, University of Agriculture, Abeokuta, Ogun State, Nigeria. pp. 1-357

Ariyo, O.C, Adedokun, M.O., and Ariyo, M.O (2018): Determinants of the Quantity of Non-timber Forest Products Collected from Forests of the International Institute of Tropical Agriculture in Ibadan, Nigeria. *Asian Journal of Research in Agriculture and Forestry* 1(1): 1-13.

Ariyo, O. C., Oluwalana, S. A., Faleyimu, O. I.,and Ariyo, M. O. (2012). Assessment of Vegetation Structural Diversity and Similarity Index of IITA Forest Reserve in Ibadan, Oyo State, Nigeria. *Agrosearch Journal* 12 (2): 135-157

Ariyo, O. C., Oluwalana, S. A., Akinyemi, O., Ariyo, M. O., and Awotide, O. G., (2011).Structure and Demographics Patterns of Woody Plant Community in IITA forest reserve. *Obeche Journa* 29(2): 259-269.

Bylin, C. V. (1982). Estimating d.b.h. from stump diameter for 15 southern species. U.S.D.A. For. Serv. Res. Note SO-286, South. For. Exp. Stn., New Orleans, LA. 3 p.

Curtis, R. O. and Arney, J. D. (1977): Estimating d.b.h. from stump diameters in second growth Douglas fir .U.S.D.A. Forest Service Research Note PNW-297, Pacific Northwest Forest & Range Experiment Station, Portland, Oregon 7 p.

Egor, B. E., Opeyemi, O., and Enefiok, S. U. (2014): Stand Structure, Density and Yield of Tree Community In Ukpon River Forest Reserve, Cross River State, Nigeria. *Nature and Science* 12(11): 1-8

Elias, M., Kyriaki, G. K., Vasileios, D., Elias, P. (2016): Diameter at Breast Height Estimated from Stumps in Quercus Frainetto in the Region of Evros in North-eastern Greece. *CERNE*, 22(3): 337-344.

Ero, I. I. (1974). A study of Merchantable Timber V olume for Six High Forest species of Southwestern Nigeria. M.Sc. F. Thesis, University of Toronto, Canada. 89 pp

Ezealor, A. U. ed. (2002). Critical sites for biodiversity conservation in Nigeria. Nigeria Conservation Foundation: Lagos, Nigeria. 110pp.

FORMECU (1999). Forest Resources Study, Nigeria. Revised national report Vol. 2.Prepared for

FORMECU by Break and Geomatics International, 224pp.

Lamprecht, H. (1989). *Siliculture in the tropics*. Tropical forest ecosystems and their trees pecies possibilities and methods in the long-term utilization. T2-verlagsgessells Chaft, GmbH,RoBdort, Germany, PP. 296.

Lawal, A., and Adekunle, V. A. J. (2011). Impact of Enrichment Planting on Biodiversity Restoration in Degraded Forest. In Labode Popoola, Kayode Ogunsanwo and Felix Idumah (Eds.). *Forestry in the Context of the Millennium Development Goals. Proceedings of the 34th Annual Conference of the Forestry Association of Nigeria* held in Osogbo, Osun State, Nigeria. Vol. 1, pp 558-571.

Martin, A.J. (1989). Forestry facts, Department of Forestry, UW – Madison.

Onefeli, A. O., Opute, O. H., and Oluwayomi, T. I. (2013). Biodiversity Assessment of Okpe Sobo Forest Reserve, Delta State. *Proceeding of the 36th Annual National Conference of the Forestry Association of Nigeria* held at University of Uyo, Akwa-Ibom State Nigeria. 4th – 9th November, 2013. (Eds.) L. Popoola, O.Y. Ogunsanwo, P.I. Oni, F.O. Idumah, A.O. Akinwole. Volume 2, pp. 490-495.

Onyekwelu, J. C., Adekunle, A. J., and Adeduntan, S. A.(2005). Does Tropical Rainforest Ecosystem Possess the Ability to Recover from Severe Degradation. In. L. Popoola, P. Mfon, and P.I.Oni (Eds.). *Sustainable Forest Managemen in Nigeria: Lessons and Prospects*. *Proceedings of the 30th Annual Conference of the Forestry Association of Nigeria* held in Kaduna, Kaduna State, Nigeria. pp. 145-163.

Salazar, S., Sanchez, L. E., Galindo, P. and Santa-Regina, I. (2008). Above ground tree biomass equations and nutrient pools for a paraclimax chestnut stand and for a climax oak stand in the Sierra de Francia Mountains,Salamanca, Spain. *Scientific Research and Essays*, 5: 1294-1301.

Tamrat Bekele. (1994). Phytosociology and ecology of a humid Afromontane forest on the central plateau of Ethiopia. *Journal of Vegetation Science* 5: 87-98.

Tenkouano A. and Baiyeri K. P. (2007). Adoption pattern and yield stability of banana and plantain genotypes grown in contrasting agro-ecology zone in Nigeria. African Crop Science Conference Proceedings, 8: 377-384.

Zianis, D., Muukkonen, P., Mäkipää, R. and Mencuccini. M. (2005): Biomass and stem volume equations for tree species in Europe. *Silva Fennica Monographs* 4: 1-63.