VOLUME ESTIMATION OF SHELTER BELT STANDS IN USMANU DANFODIYO UNIVERSITY, SOKOTO, NIGERIA WITH THREE ANALYTICAL FORMULA

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Abstract
Three different tree volume estimation formula were compared with the view to determining the most suitable for shelterbelt stands in UsmanuDanfodiyo University, Sokoto. The major difference between the methods lies in the position where the diameter used in the volume estimation was obtained. Data were collected from eight randomly selected sample plots of 25×25m from the shelterbelt stands. The total height, merchantable height, diameter at breast height, diameter at the base middle and top were measured for all trees in each plot. From the data obtained, the volumes were computed using each ofthe three analytical formulas (Huber's, Newton's and Smalian's formula). The volumes were compared using Analysis of Variance (ANOVA) and the results showed significant difference ($p<0.05$) among the formulas. Correlation analysis was also carried out with the view to establish the relationship between the volume computed using the three formula and other measured tree growth variables (Dbh and Height). The result revealed strong positive relationship ($r=0.93$) between volume and Dbh, while a weak positive relationship exists between height and Dbh ($r=0.40$).The Smalian's formula produced significantly ($p>0.05$) higher volume estimates and is therefore, recommended for estimating volume of shelterbelt stands in UsmanuDanfodiyo University, Sokoto.

Keywords: *Tree volume; shelterbelt; traditional formulas*

Introduction

Forest inventories either in plantation or natural forest ecosystem are conducted to estimate the quantity of timber and the condition of the forest estate for proper and efficient management planning and decision. The timber volume in a plot is the sum of the volumes of the trees within it. During forest inventory especially in the tropical natural forest ecosystem characterized by dense canopy closure, lianas and thickets, it is practically difficult, inefficient and costly to measure all predictor variables for every tree in each plot. To overcome this problem, the use of volume equation with dbh and height (merchantable or total height) as predictor variables is developed. This is possible because tree stem volume is a function of dbh, height and form i.e. V = F (dbh, h, f). Volume is linearly related to tree dbh or basal area. This relationship has also been observed to be curvilinear (Akindele and LeMay, 2006).

While dbh could be obtained at little expense in almost any forest type, height measurements are considerably more expensive to collect. Riesco and Diazmaroto (2004) reported that measurement of height in all tall dense stands can be very difficult, therefore plot volumes are generally obtained by measuring all trees in the sample plots for dbh and sub samples for height and other variables (diameter of trees at the base, middle and top) needed to compute volume with Newton's formula (Husch *et al*., 2003).

Standard volume tables are often used to estimate tree volume as a function of tree diameter and height for both routine forest measurement and for forest research purposes. A recognized shortcoming is that a standard volume table may fail to estimate the volume of sample trees in a specific stand as recorded by Evert (1968),Grosenbaugh(1954), Hazard and Berger (1972). This may happen if the actual taper of the sample trees of a stand differs from the average taper of the trees used in construction of the volume equation. Use of these volume equations ignores the variation that occurs because of taper that is formed. One solution is to estimate tree volumes with a standard volume equation, then directly measure the volume of a sample of the population of interest using intensive dendrometry (Turnbull *et al*, 1963).

Tree stem and log volumes depend on tree stem geometry. The most widely known sectional methods (formula method) for volume estimation are: Smalian's, Huber's, and Newton's, methods. All three methods calculate volume based on cross-sectional area measured at the log ends (Smalian's), at the mid-point diameter (Huber's), or at both ends and mid-point (Newton's). Smalian's and Huber's are preferred in the field because they are easier to apply than Newton's method. It's generally known that the Smalian's method is less accurate than Huber's method but it is more frequently used, particularly when logs are stacked in piles where the mid-point diameter is not available for measurement (Avery and Burkhart, 1994).

Shelterbelts are plantings of single or multiple rows of trees or shrubs that are established for environmental purposes. The height of the tallest row and overall density of foliage and branches of an individual planting greatly influence the size of the nearby area that is protected or sheltered. Shelterbelts are generally established to protect or shelter nearby leeward areas from troublesome winds (USDA, 1997). Such plantings are used to reduce wind erosion, protect growing plants (crops and forage), manage snow, and improve irrigation efficiency.

Materials and Methods

Study Area

The study was conducted in some established shelterbelts within the main campus ofUsmanuDanfodiyo University Sokoto. Situated between latitudes 10°N to 13°58'N and longitudes 4°8'E to 6°54'E in Wammako Local Government Area of Sokoto State, Nigeria. The climate of the study area is characterized by a long dry season (October-April) with a short rainy season (May-September/October), (Singh, 1995). Rainfall starts in late May and ends in late September or early October with annual rainfall ranging from 400mm to 700mm (Singh, 1995). The minimum and maximum temperatures are 19°C and 39°C respectively with mean annual temperature of 27°C with relative humidity of 52 to 56%.

The study area experiences harmattan wind, which are dry, cold, and dusty blowing between the months of November to February. The soil of study area is predominantly sandy to sandy-loamy with low fertility level particularly poor in primary nutrients like Nitrogen, Phosphorus and Potassium (Ango*et al.*, 2014). The vegetation of the area falls within the Sudan Savannah vegetation zone characterized by soils that are mostly sandy to loamy in texture with some patches of clayey subsoil. An assortment of various species of grasses and legumes, patches of bushes and sparsely distributed indigenous tree species majority of which are thorny tree species, such trees include *Acacia nilotica*, *Faidherbiaalbida, Zizipusspp, Tamarindusindica, Balaniteaegyptiaca*(Ango *et al*., 2014)

Reconnaissance Survey

Prior to stand enumeration, a reconnaissance survey of the availableshelterbelts within the main campus of UsmanuDanfodiyo University, Sokoto was carried out in order to assess the condition of the stands and to become acquainted with the structure and arrangements of the shelterbelts for easy planning of the full-scale fieldwork.

Sampling Techniques

A list of all available shelterbelts formed the sampling frame and 40% of the available shelterbelts were selected randomly for the study. Each selected shelterbelt was divided into 25 x 25 m sampling plots and two plots were selected within each sampled location.

Data Collection

Data were collected, with the use of Haga altimeter, Measuring tape, Circumference tape and Spiegel Relaskop. The following measurements were carried out on all trees in each selected plot.

i. Merchantable height wasmeasured by the use of Haga altimeter in meters (m)

ii. The middle and upper diameter was measured using Spiegel Relaskop in centimetres (cm)

iii. Diameter at the base and diameter at the breast height (1.3m above the ground) was also measured using measuring tape in centimetres (cm)

Data Analysis

Data obtained from the field were organized and screened. Then stand volume was computed by the use of the three traditional formulas as follows:

Huber's formula (Avery and Burkhart, 1994)

$$V = \frac{\pi Dm^2}{4} X h \quad \text{.....} \quad (1)$$

Smalian's formula (Clutter *et al*., 1983; Avery and Burkhart, 1994)

V = [redacted] ($\overline{Db}^2$ + [redacted] $\overline{Dt}^2$)........ (2)

Newton's formula (Avery and Burkhart, 1994)

$$V = \frac{\pi h}{4} (Db^2 \; Dm^2 + Dt^2) \quad \text{.....} \quad (3)$$

Where;
V is the log volume
Dm is the tree diameter at the middle
Db is the tree diameter at the base.
Dt is the tree diameter at the top.
H is the tree height
Π= 3.124 (which is constant)
Correlation analysis was carried out in order to establish relationship between tree volume and other measurable parameters. Analysis of variance was conducted to determine the significance difference ($p>0.05$) among the three formulas used in cubic volume computation. Duncan's Multiple Range Test was used to separate the means. Statistical package SPSS was used for data analysis.

Results and Discussion
Summary Statistics
The summary of the data obtained from the field and tree volume computed using the traditional formulae are shown in Table 1.The summary statistics shows that, the minimum and maximum dbh recorded ranged from 11.0 to 47.0cm, mean height ranged from 7.5 to 20.0m in the sampled plots. It is evident that all the selected trees in the data set tend to follow similar trend of tapering from base to the top, which confirm the biological validity of the data set as indicated by Husch *et al*. (2003).

The result shows a wide variation in terms of growth pattern. This variation could be due to improper management of the shelterbelt since the time of establishment. There is no proper spacing between the trees, which mayhave been causedby inadequate silvicultural treatments at the early stage of the shelterbelt establishment.

Table1: Summary Statistics of the Field Data

Variables	Min	Mean	Max	SE
Dst (cm)	14	31.32	57	0.879
Dbh (cm)	11	26.53	47	0.740
Dm (cm)	10	22.03	39	0.609
Dt (cm)	6	15.82	30	0.477
H (m)	7.5	13.57	20	0.260
BA (m^2)	0.10	0.60	0.147	0.033
Huber's (m^3)	0.0731	0.583681	2.1530	0.0376346
Smalian's (m^3)	0.0992	0.739007	2.2131	0.0468103
Newton's (m^3)	0.0821	0.635456	2.1594	0.0397982

Relationship between Variables
Correlation analysis was carried out in order to determine the type of relationship that existed between the volume with each of the three formula and the other tree growth variables measured as shown in Table 2. The result shows that there is strong positive relationship between the Dbh, height and volume computed using the three traditional formula, which signifies an increase in the size (Dbh) induces an increase in volume (the more the dbh the more the volume). There was also weak positive relationship between Dbh and height.

The result of this study is in line with Shamaki *et al.* (2016) who reported a weak and positivesignificant relationship between height and Dbh ($r= 0.359$) and strong positive relationship between volume and Dbh ($r= 0.829$) while working with Neem species in Moreh Forest Plantation.

Table 2: Correlation Coefficient

	Dst	Dbh	Dm	Dt	MTH	TH	Huber's	Smalian's	Newton's	BA
Dst	1.00									
Dbh	0.97	1.00								
Dm	0.88	0.89	1.00							
Dt	0.80	0.80	0.82	1.00						
MTH	0.29	0.31	0.34	0.30	1.00					
TH	0.35	0.40	0.40	0.29	0.73	1.00				
Huber's	0.81	0.84	0.93	0.76	0.45	0.60	1.00			
Smalian's	0.93	0.93	0.86	0.81	0.43	0.56	0.91	1.00		
Newton's	0.88	0.90	0.93	0.80	0.45	0.59	0.99	0.96	1.00	
BA	0.96	0.99	0.86	0.78	0.27	0.36	0.83	0.94	0.89	1.00

Volume Comparison

One-way Analysis of variance (ANOVA) was used to compare tree volumes computed using thethree analytical formulas (Huber's, Smalian's and Newton's formula) as presented in Table 3. The result obtained shows significant difference ($p<0.05$) among the three formulas of volume estimation. Smalian's formula differs significantly with Huber's, but is statistically similar with Newton's formula in terms of tree volume estimation. The significantly higher stand volume produced withSmalian's formula may be as a result of the need to estimate volume at both end of the tree bole.

The result of this study is in line with the findings of Nur *et al*. (2015) while working on volume comparison for second growth forest using different formulafor tree volume estimation, and the result obtained shows that there were significant differences between the three analytical formula. The research concluded that the result can be used as a guide to select appropriate formula for estimating the volume of standing trees of a forest.

The significantly higher (0.739007m^3) volume rate recorded by Smalian's formula can be as a result of the requirement to measure diameter at both ends of the tree trunk and also there is less tapering at the merchantable potion of the trees. The Smalian's formula is easy to use due to its practicability.Smalian's formula gives exact result or volume estimates for cylindrical and parabolic stem form. While the least volume computed was obtained by Huber's (0.583681m^3). The lower volume obtained from Huber's formula could be attributed to the single diameter value used in its estimation, which tends to assume that the tree is cylindrical from the base to the top. The deficiency in Huber's formula has been buttressed by Avery and Burkhart (1994).

Even though Newton's formula produced volume that is not significantly different from the one obtained with Smalian's formula, but it has been adjudged the best formula for estimating stand volume of tress. This is because it incorporated diameter measurement at the base, middle and top thus capturing the less tapering nature at merchantable stem of the tree. West (2009) reported that the Newton's formula gives more accurate volume estimates, because it uses more tree growth variables for volume estimation. It is the most flexible for determining volume of a whole stem or portion of it. The formula is applicable to any of the three possible stem forms, be it neiloid, paraboloid or conoid (Chapman and Meyer, 1949).

Table 3: **ANOVA table for comparison of volume from different computation formula**

Formula	Mean volume (m^3)
Huber's	0.583681^{b}
Smalian's	0.739007^{a}
Newton's	0.635456^{ab}
SEM	0.046

Conclusion

The study revealed that stand data collected followed a normal growth pattern of trees (tapers from bottom to top). Positive correlation was noted among the variables measured (dbh, height and volume). Analysis of variance (ANOVA) revealed a significant difference between Smalian's and Huber's but there is no significant difference between the Smalian's and Newton's formula. There was wide variability in terms of spacing and growth performance of the trees within the shelterbelts which implies the need for efficient management plan for the stands because of its environmental conservation roles.

Since there was no significant difference between Smalian's and Newton's formula in volume estimation, the Smalian's formula is recommended for merchantable volume estimation of shelterbelt stands due its ease of application compared with the Newton's formula.

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