Journal of Forestry Research and Management. Vol. 15(3).104-117; 2018, ISSN 0189-8418
www.jfrm.org.ng

STAND GROWTH ASSESSMENT OF SELECTED PLANTATION TREE SPECIES IN BENIN CITY, NIGERIA

Akinyemi, G.O.

Onigambari Research Station, Idi-Ayunre, Ibadan, Nigeria
E-Mail: akinyemigab@yahoo.com. Phone No: 08038185689

ABSTRACT

Stand growth assessment is an important measure of sustainable forest management. Dearth of periodic information on stand conditions of forest plantation species is one the major challenges of sustainable forest management in Nigeria. Hence, the need to assess the stand density and other growth variables with a view to providing the database necessary for the sustainable management of the selected species. Stands of *Gmelina aborea* (0.7ha), *Eucalyptus camadolensis* (0.7ha) and *Tectona grandis* (1.8ha) at Moist Forest Research Station, Benin City, Edo State, Nigeria were assessed for stand density and growth variables. Total enumeration of each stands were done to assess diameters at breast height (dbh), base (db), midlle (dm) and top (dt) and total height of all trees. Stand density was estimated using the number of trees encountered per hectare. Growth variables such as tree basal area, volume, slenderness coefficient and mean annual increment (MAI) were also estimated. Data were subjected to descriptive statistics and correlation matrix. *G. arborea* stands had the highest density of 1102 trees per hectare with MAI value of 2.35±0.01cm/yr followed by *T. grandis* with 1050 trees per hectare but had the highest MAI (2.71±0.01cm/yr) while *E. camadolensis* had the least stand density per hectare (986) and MAI (2.03±1.20cm/yr). The result of correlation matrix reveals that all the growth variables assessed follows the same strength of relationship regardless of the species. DBH was high and positively correlated with total height, basal area and volume for the three species. The result of slenderness coefficient revealed that 50% of the *E. camadolensis* stands are prone to wind throw. It is therefore recommended that re-stocking of gaps should be sustainably done in order to increase the density of trees for optimum utilization of the growth resources.

Keywords: Stand density, growth variables, re-stocking, resources and sustainable

INTRODUCTION

Stand growth assessment represents the basic step of data collection and prediction in forest management (van Laar, 2007). This method is primarily designed to evaluate development of standing volume over time, and it has a high predictive value with respect to ecological balance of the stand (Pretzsch, 2009).

The population of trees is usually evaluated using a set of variables such as diameter at breast height (DBH), tree height, crown projection area, crown length and height of the crown base. This describes all individuals belonging to the population. Classically, the data are evaluated using basic descriptive statistics (such as mean, median, standard deviation). Due to the fact that variables can be more or less related, it is advisable to also use correlation or regression statistics for the description of the population (West, 2009). Known relations are also used for deriving frequently used allometric relationships as described by Fralish (1988), Cerný (1990), Ige and Akinyemi (2016), Akinyemi (2018) and Osawa and Allen (1993). Typical is the relation between tree height and diameter, where a set of models exists (Ige and Akinyemi, 2016)). Such relationships are frequently non-linear. Today, there are entire databases of these relationships (Jenkins *et al*. 2003; Somogyi *et al*. 2008; Henry *et al*. 2013; Ige, 2018). For some tree species, the relationship between dendrometric variables within a large part of their distribution area is known (Wirth *et al*. 2004; Dimitris *et al*. 2005).

Stand density determines the amount of growing space available for individual trees growing on a site and the level of competition among them for light, soil moisture and nutrients (Ige and Adesoye, 2017). It therefore, has great effect on the rate and pattern of tree growth and can be manipulated by the forest manager to maintain a good balance between the site and the trees growing on it for desired economic and silvicultural benefits. According to Nuga and Chima (2010), foresters can influence the growth, quality and health of trees by altering stand density. On its part, growth rates of trees determine the yield of forest stand and the rate of returns on forest investments.

One of the major challenges of forestry development in Nigeria is the dearth of periodic information on stand conditions of forest plantation species. However, sustainable management of forest stands can only be ensured if current and reliable information on growth condition of the stand are available. This could be used by forest managers to provide accurate and timely information on the existing stock. Forestry like other business ventures requires effective management of its resources.

Gmelina aborea, *Eucalyptus camadolensis* and *Tectona grandis* stands in Moist Forest Research Station, Benin City, Edo State, Nigeria have not been assessed for stand density and growth rates. Thus, there had been no data on the stand densities of these stands and the growth rates of the trees for rational decision making and sustainable management. Therefore, the objective of this study was to assess the stand density and other growth variables with the view to providing the database necessary for their sustainable management.

MATERIALS AND METHODS

This study was carried out in Five years old plantations of *Gmelina arborea* (0.7ha), *Eucalyptus camadulensis* (0.7ha) and *Tectona grandis* (1.8 hectares) located in Moist Forest Research Station, Benin City, Edo State, Nigeria. It is located within latitude 6^{o} 32' 20.055'' N and 6^{o} 32' 20.0854'' N and longitude 5^{o} 58' 2.564''E and 5^{o} 58' 2.863''E at 99 m above sea level. It has a mean annual temperature range of 27^{o}C and 32^{o}C and the mean annual rainfall is 2078mm. Total enumeration of each plantation was carried out and the following variables were assessed: Stem height-St (m), diameter at breast height outer bark-dbh (cm) and diameters at the Base (Db), Middle (Dm) and Top (Dt).

Data computation

Stand Density

Stand density of each species was estimated using equation 1

$$N = \frac{h}{a} x\, C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where N = estimated number of trees per hectare, h = One hectare, a = area of plot in hectare and c = number of trees counted in the plot

Basal Area Estimation

The Basal Area (BA) of individual trees was estimated using the formula in equation 2 (Husch *et al*, 2003)

$$BA = \frac{\pi}{4} D^2 \quad \ldots\ldots\ldots\ldots 2$$

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

Volume Estimation

The volume of individual trees was estimated using Newton equation developed for stem volume estimation (Husch *et al*, 2003):

$$V = \pi H \left[\frac{Db^2 + 4Dm^2 + Dt^2}{24} \right] \quad \ldots\ldots\ldots\ldots 3$$

Where V = Stem volume (m^3), H = stem height (m), Db = Diameter at the base, Dm = Diameter at the middle, Dt = Diameter at the top and Π = 3.142 (constant)

Slenderness coefficient (TSC)

$$TSC = \frac{THt}{dbh} \quad \ldots\ldots\ldots\ldots 4$$

According to Navratil*et al*, (1996), slenderness coefficient values were classified into three categories.

TSC values > 99…………… High slenderness coefficient

70 < TSC values > 99……….Moderate slenderness coefficient

TSC values < 70 …………….Low slenderness coefficient

Diameter Growth Rate Mean Annual Increment (MAI)

This was estimated by calculating the Mean Annual Increment (MAI) in DBH using equation 5 as developed by Husch *et al.*, (2003):

$$MAI = \frac{DBH}{A} \quad \ldots\ldots\ldots\ldots 5$$

Where MAI = Mean Annual Increment (cm/yr), A = Tree Age (years) and DBH = diameter at breast height (cm)

RESULT AND DISCUSSION

The *Tectona grandis* had 1050 standing trees per hectare with a total basal area of 0.05±0.01m^2/ha as indicated in Table 1. The *Eucalyptus camadolensis* had 896 standing trees per hectare with a mean basal area of 0.01±0.00m^2/ha. In the *Gmelina arborea* plot, there were 1102 standing trees per hectare with a mean basal area of 0.03±0.00 m^2/ha. According to Table 1, the growth rate of the three tropical tree species assessed in this study follow a similar trend. The highest mean dbh was observed in Teak plantation (13.57±1.35cm) while the least was identified in Eucalyptus plantation (10.15±0.46cm). This corroborated the findings of Etigale *et al*., (2013) on stand density and growth rate of three tree species in Uyo, Nigeria. The diameter size class distribution (Fig 1 – 3) reveals that the plantations are still emerging. The curve follows a normal distribution for tropical plantation tree species as pointed out by Husch *et al*., (2003). If proper management is gear towards the plantations, their growth and yield rate will be highly profitable in terms of merchantable logs and volume expected to be derivable from them.

The trees were planted at the espacement of 3m x 3m, resulting in the initial stocking of 1111 trees per hectare. A comparison of the initial stocking with the numbers of trees per hectare obtained in this study revealed the level of reduction in population of trees in each of the plantation. Nwoboshi (1982) observed that, as a forest stand develops and individual trees grow larger, the number of trees per unit area decreases. Various factors were responsible for the reduction in number of trees in the plots. In *G. arborea* plot, the diminution was only 0.8%. Since there was no visible sign of disturbance, this reduction could be attributed to natural selection arising from competition for growth resources among the trees. This agrees with Smith (1962), who opined that the diminution in number usually sets in as a result of some rigorous natural selection which favours the most vigorous trees that survive the intense competition for light, soil moisture and nutrients within the forest stand. In the *T. grandis* and *E. camadolensis* stands, the reductions in population were 5% and 11.3% respectively.

Values of MAI in DBH calculated for *T. grandis* trees range from 1.59cm/yr to 3.23cm/yr, with an average of 2.71±0.01cm/yr. *E. camadolensis* trees had values of MAI in DBH ranging from 0.83cm/yr to 3.44cm/yr, with an average of 2.03±1.20cm/yr, while those of *G. arborea* trees range from 0.44cm/yr to 3.79cm/yr, with an average of 2.35±0.01cm/yr, as shown in Table 1.

The result of correlation matrix (Tables 2 – 4) reveals that all the growth variables assessed follows the same strength of relationship regardless of the species. DBH was high and positively correlated with Total height, BA and Volume for the three species. This might be as a result of the fact that dbh is good predictor of important growth variables in tropical forest (Ige and Akinyemi, 2016). The tree slenderness coefficient was negatively correlated with dbh. This is an indication that the bigger the dbh of a tree, the more stable it is to withstand wind throw. This result also agrees with Ige and Akinyemi (2016) study on *Triplochiton scleroxylon* plantation in Gambari forest reserve. Hence, proper management on increasing the growth of tree dbh will enhance stable and healthy tree in a forest ecosystem.

Table 1: Summary of stand growth variables

Growth variables	*Tectona grandis*			*Eucalyptus camadolensis*			*Gmelina arborea*		
	Min	**Max**	**Mean±S.E**	**Min**	**Max**	**Mean±S.E**	**Min**	**Max**	**Mean±S.E**
N (ha)			1050			986			1102
DBH (cm)	7.96	16.15	13.57±1.35	4.14	17.19	10.15±0.46	2.22	18.96	11.74±0.00
THt (m)	8.00	20.00	14.04±0.42	4.00	16.00	10.02±0.38	4.50	17.00	9.80±0.25
BA (m^2/ha)	0.01	0.17	0.05±0.01	0.01	0.02	0.01±0.00	0.01	0.07	0.03±0.00
VOL (m^3/ha)	0.32	6.61	1.64±0.12	0.10	1.25	0.55±0.04	0.11	1.74	0.61±0.04
TSC	34.62	116.12	69.04±3.16	66.15	217.52	102.83±3.27	41.43	763.06	94.17±6.71
MAI (cm/yr)	1.59	3.23	2.71±0.01	0.83	3.44	2.03±1.20	0.44	3.79	2.35±0.01

Journal of Forestry Research and Management. Vol. 15(3).104-117; 2018, ISSN 0189-8418
www.jfrm.org.ng

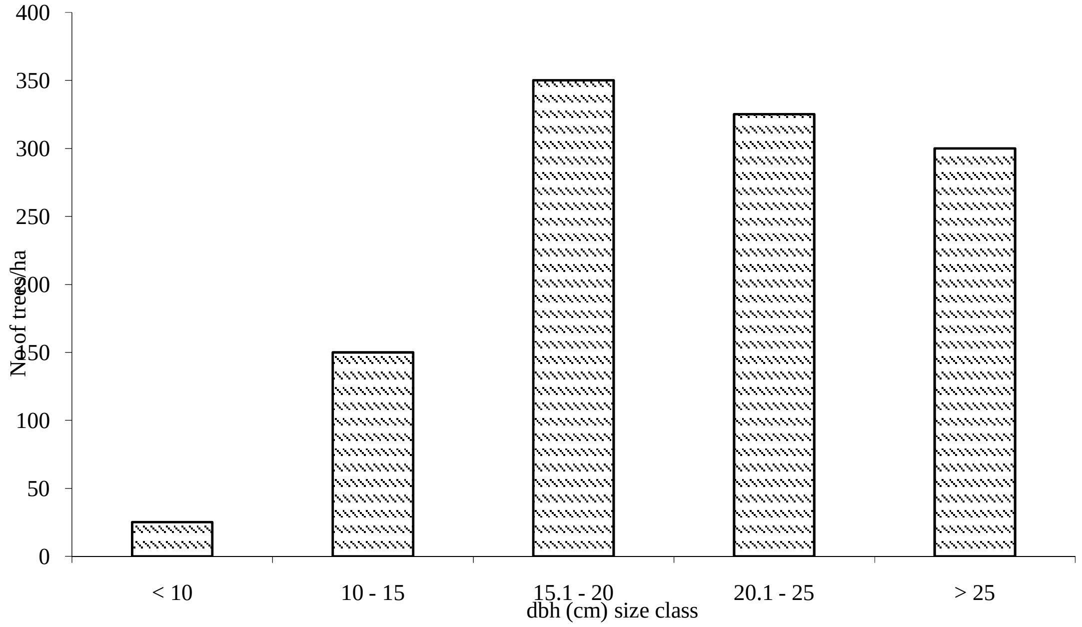

Fig 1: Diameter size class distribution for *Tectona grandis*

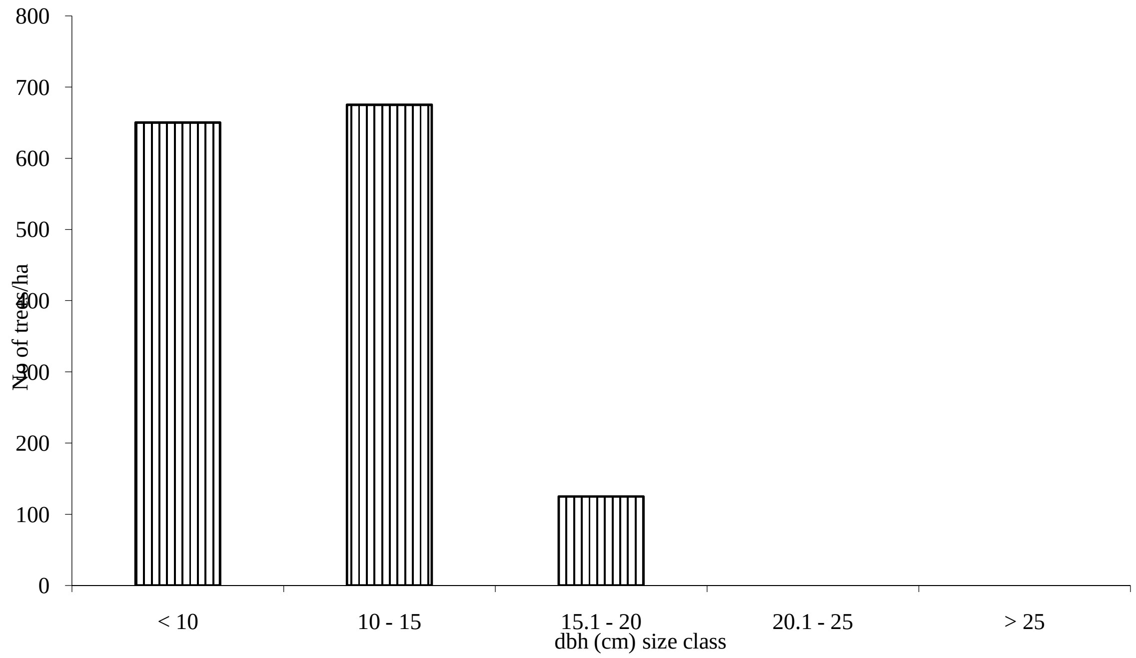

Fig 2: Diameter size class distribution for *Eucalyptus camadolensis*

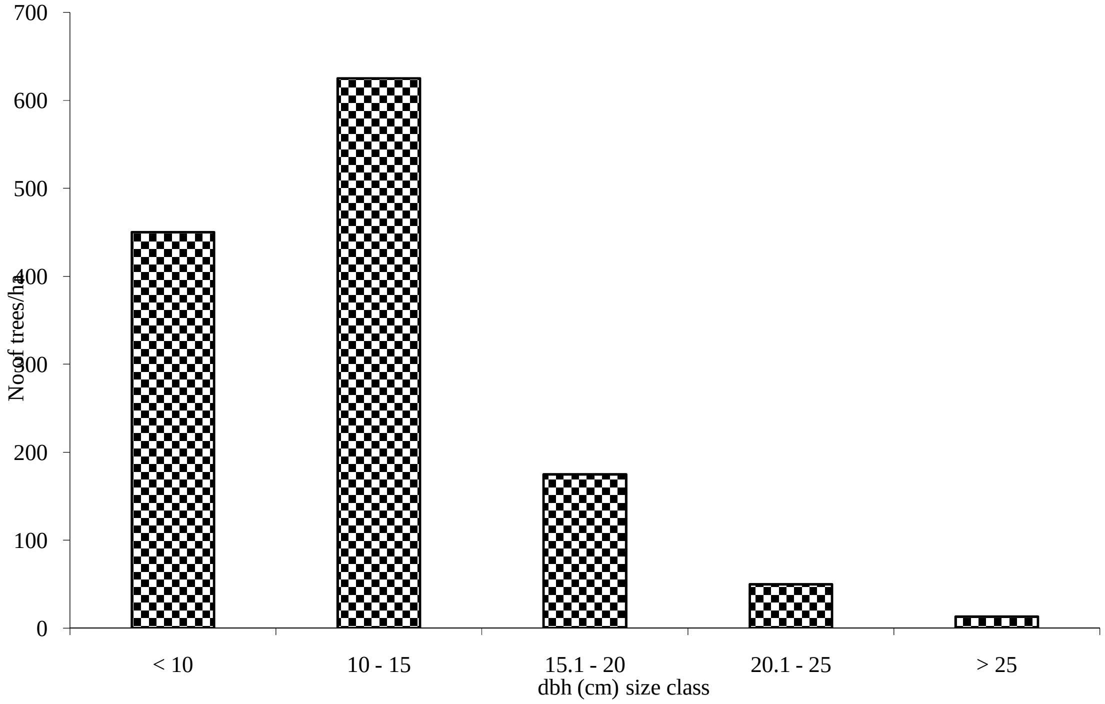

Fig 3: Diameter size class distribution for *Gmelina arborea*

Table 2: Correlation matrix between TSC and growth variables for *Tectona grandis*

	TSC	*DBH*	*THt*	*BA*	*Vol*
TSC	1				
DBH	-0.8025	1			
THt	0.0712	0.4555	1		
BA	-0.7667	0.9829	0.3978	1	
Vol	-0.6111	0.9501	0.6707	0.9409	1

Table 3: Correlation matrix between TSC and growth variables for *Eucalyptus camadolensis*

	TSC	*DBH*	*THt*	*BA*	*Vol*
TSC	1				
DBH	-0.4847	1			
THt	0.0335	0.8229	1		
BA	-0.4761	0.9862	0.7849	1	
Vol	-0.2937	0.9604	0.9218	0.9552	1

Table 4 Correlation matrix between TSC and growth variables for *Gmelina arborea*

	TSC	*DBH*	*THt*	*BA*	*Vol*
TSC	1				
DBH	-0.4012	1			
THt	0.2035	0.6694	1		
BA	-0.3039	0.9661	0.6281	1	
Vol	-0.2661	0.9563	0.8147	0.9388	1

Table 5: Tree slenderness coefficient classification

TSC Range	Value (%/ha)			Implication
	Teak	Euc	Gm	
> 99	6.53	50.00	24.76	Prone to wind throw
70 – 99	41.30	44.82	52.38	Moderate
< 70	52.17	5.18	22.86	Withstand wind throw

The slenderness coefficient value over 99 is considered to be at the high risk of wind throw as suggested by Navratil (1996), the result of this study indicated that 50% of Eucalyptus trees in the sampled stands in Benin City belongs to the high risk category of wind throw. The relationship of wind throw and slenderness coefficient is indirect. Lower slenderness coefficient can be an indicator of larger crowns, lower centre of gravity and a better developed root system. The desirable height/dbh ratios for adequate wind resistance vary according to species and country. In general, trees with a higher slenderness coefficient (low taper) are much more susceptible to damage than trees with low slenderness coefficient (high taper). Since smaller slenderness coefficient is usually indicating a higher resistance to wind throw, the relationships suggest that silvicultural treatments, such as producing long-crowned trees, and maintaining appropriate stand density through spacing, thinning, or gradually harvesting overstory trees, can be helpful in reducing the risk of wind throw (Wang *et al*., 1998; Eguakun and Oyebade, 2015).

CONCLUSION AND RECOMMENDATION

Creation of gaps usually favours diameter growth rate of individual trees. It can cause a reduction in stand growth and yield (measured in basal area or volume per hectare) if it leads to inadequate stocking as it was the case of the *E. camadolensis* stand, which recorded a very low basal area per hectare compared to the other two stands. The variation in stand densities among the tree species indicates natural selection arising from competition for growth resources among the trees. Generally, tree growth increased with more gaps in a stand. It is therefore recommended that restocking of gaps should be sustainably done in order to increase the density of trees for optimum utilization of the growth resources. Thinning should also be done. This will help to reduce the level of competition among the residual trees.

ACKNOWLEDGEMENT

I wish to appreciate Mr. Isebemhe E., Mr. Egberuare G. E and Mr. Osaro J. for technical assistance provided during data collection for this study.

REFERENCES

Akinyemi, G.O (2018). Growth Assessment of Young *Tectona grandis* (Linn F.) Plantation in Benin City, Nigeria. *International Journal of Environmental Sciences* (ISSN: 2277-1948) Vol 8 No 1 2018. Pp 18 – 21

Cerný, M. (1990). Biomass of *Picea abies* (L.) Karst. in Mid-western Bohemia. Scandinavian *Journal of Forest Research*, 5: 83–95

Dimitris Z., Petteri M., Raisa M. and Maurizio M. (2005). Biomass and stem volume equations for tree species in Europe. Silva Fennica Monographs, 4: 1–63.

Eguakun, F.S and Oyebade, B.A (2015). Linear and nonlinear slenderness coefficient models for *Pinus caribaea* (Morelet) stands in southwestern Nigeria. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)* e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 8, Issue 3 Ver. II (Mar. 2015), PP 26-30

Etigale, E.B., Ajayi, S., Udofia, S.I and Moses, M.U (2013). Assessment of stand density and growth rate of three species in an Arboretum within the University of Uyo, Nigeria. *Journal of Research in Forestry, Wildlife and Environmental.* Vol 6 No pp 8 – 16

Fralish J.S. (1988). Diameter-height-biomass relationships for *Quercus and Carya* in Posen Woods Nature Reserve. Transactions of the Illinois State Academy of Science, 81: 31–38.

Henry M., Bombelli A., Trotta C., Alessandrini A., Birigazzi L., Sola G., Vieilledent G., Santenoise P., Longuetaud F., Valentini R., Picard N. and Saint-André L. (2013). GlobAllome-Tree: International platform for tree allometric equations to support volume, biomass and carbon assessment. *iFor-est – Biogeosciences and Forestry*, 6: 326–330.

Husch, B., I. M. Charles and W. B. Thomas (2003). Forest Mensuration. The Ronald

Press Company, New York, U. S. A. pp 120-123.

Ige, P.O and Akinyemi, G.O (2016): Assessment of slenderness coefficient functions for *Triplochiton scleroxylon* K.Schum stands in Onigambari Forest Reserve. In: Forest Management and Challenges of Environmental Sustainability (Adekunle, V.A.J., Oke, D.O and Emehri, E.A. – Editors). Proceedings of the Fifth Biennial Conference of the Forests and Forest Products Society, Delta State University, Asaba Campus, Delta State, Nigeria, 25th – 29th April, 2016, pp 50 – 56

Ige, P.O and Adesoye, P.O (2017). Assessment of Non-Spatially explicit competition indices effects on Diameter Growth of *Gmelina arborea* Roxb. Stands in Omo Forest Reserve, Nigeria. *Forests and Forest Products Journal* 10:106-118

Ige, P.O (2018). Assessment of Site Quality Index for Young *Gmelina arborea* (Roxb.) Stands in Omo Forest Reserve, Ogun State, Nigeria. *International Journal of Applied Research and Technology*. 7(10): 36 – 44. http://www.esxpublishers.com/images/IJRT-1018-0211.pdf

Jenkins J.C., Chojnacky D.C., Heath L.S. and Birdsey R.A. (2003). Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species. General Technical Report NE-319. Newtown Square, USDA Forest Service, Northeastern Research Station: 45

Navratil, S. (1996). Silvicultural systems for managing deciduous and mixedwood stands with white spruce understory. In Silvicultural of temperate and boreal broadleaf-conifer mixture. Edited by P.G. Comeau and K.D. Thomas. B.C. Ministry of Forests, Victoria. Pp. 35–46.

Nuga, O. O. and Chima, U. D. (2010). Tropical Silvilcultural Systems and Practices. In: *Ijeomah, H.M. and Aiyeloja, A. A. (Eds.)Practical Issues in Forest and Wildlife Resources Management*. Green Canopy Consultants, Port Harcourt, Nigeria. pp. 54-85.

Nwoboshi, L. C. (1982). *Tropical Sivilculture*. Ibadan University Press, Ibadan, Nigeria. 333pp.

Osawa A. and Allen R.B. (1993). Allometric theory explains self-thinning relationships of mountain beech and red pine. *Ecology*, 74: 1020–1032.

Pretzsch H. (2009). Forest Dynamics, Growth and Yield. Berlin, Heidelberg, Springer-Verlag: 664

Smith, D. H. (1962). *The Practice of Sivilculture*.7th Edition, John Wiley and Sons, Inc. N. Y. London, 578pp.

Somogyi Z., Teobaldelli M., Federici S., Matteucci G., Pagliari V., Grassi G. and Seufert G. (2008). Allometric biomass and carbon factors database. *iForest – Biogeosciences and Forestry*, 1: 107–113

van Laar A., Akça A. (2007). Forest Mensuration. Dordrecht, Springer-Verlag: 383.

Wang, Y., Titus S. J. and Lemay V. M. (1998). Relationship between Tree Slenderness Coefficient sand Tree or Stand Characteristics for Major species in Boreal Mixed Forest. *Can. J For. Res*. 28: Pp. 1171-1183.

West P.W. (2009). Tree and Forest Measurement 2ndEd. Berlin, Heidelberg, Springer-Verlag: 191.

Wirth C., Schumacher J. and Schulze E.D. (2004). Generic bio-mass functions for Norway spruce in Central Europe – a meta-analysis approach toward prediction and uncertainty estimation. *Tree Physiology*, 24: 121–139.