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Tree Slenderness Coefficient (TSC) and tree Growth Characteristics (TGCS) for *Pinus caribaea* in Omo Forest Reserve, Nigeria

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Abstract: *Tree slenderness coefficient (TSC) remains a fundamental attribute for determining tree and stand stability among exotic coniferous species such as Pinus caribaea in Nigeria. The relationship between the TSC and tree growth characteristics (TGCs) of Pinus caribaea (morelet) were investigated within Fifteen (15) Temporary Sampled Plots (TSPs) of 20m x 20m (0.04ha) of three age series (1990, 1991 and 1997) in Omo Forest Reserve, Nigeria. Five Hundred and Two (502) trees were sampled using random sampling method and tree growth characteristics such as diameter at breast height (DBH), total height (THT), merchantable height (MHT), Stem quality (SQ), crown length (CL) and crown diameter (CD) were measured while other tree characteristics such as basal area (BA), volume (VOL), tree slenderness coefficient (TSC), crown projection area (CPA) and crown ratio (CR) were estimated using their respective empirical formula. The quantitative data collected were subjected to descriptive analysis, correlation and regression-residual analyses to determine the relationship between the TSCs and TGC among the age series. The results of the investigation showed significant differences($P<0.05$) in the TGCs within and across the age series of the Pinuscaribaea, and TSCs varied significantly across the age series with 1990 pine having the minimum mean value of 28.32 ± 0.602 and the TSC maximum mean value of $38.64 \pm 0.464$was found within 1997 pine plantation. The TSCs were found to be negatively correlated with DBH, age and all crown attributes across the three age series. Tree height attributes including THT, MHT and SQ were however found to be positively correlated with TSCs across the study area. Indeed the information of TSC and TGCs among Pinus caribaea in Nigeria proffer reasonable options for solving evolving wind throw potential among many exotic species in Nigeria.*
Keywords: *Tree slenderness coefficient, exotic coniferous, relationship, growth attributes*

I. Introduction

Tree slenderness coefficient (TSC) can be technically defined as ratio of tree total height (THT) to diameter outside bark at 1.3m or 4.5ft above the ground level. This diameter is oftentimes referred to as diameter at breast height (DBH). In recent time, the study on TSC is becoming significant in quantitative forestry following the susceptibility of many exotic species to natural phenomenon such as wind damage, blow down, breaking or uprooting of live tree as a result of high intensity of wind components. This obviously increases the tenor of mortality among some exotic species such as *Pinus caribaea* (Oteng-Amoako and Brink, 2008) across the ecological zones in many sub-saharan African countries including Nigeria.

According to Wang et al. (1998), the susceptibility of a stand to wind throw or damage is largely influenced by the tree slenderness coefficient or taper of the tree and this vulnerability to wind most times is based on a combination of some tree growth characteristics (TGCs), stand conditions, site soil and site quality, topography and wind patterns (Ruel, 2000). These combinations generally substantiate the impact of both biological and physical factors on the individual tree or stand stability among exotic species (Byrne, 2011; Nivert, 2001; Navratil, 1996).

Though several studies and results had been carried out and recorded on slenderness coefficient and stand stability potential in many part of the world (Rudnicki *et al*., 2004; Wang *et al*., 1998; Liu *et al*., 2003; Becquey and Nivert, (1987), the study on TSC with reference to its relationship with the TGCs have not been researched in Nigeria on any conifer stand among which *Pinus caribaea* is the most representative species. However, the current climate changes with series of environmental degradation and desert encroachment in the tropics including Nigeria necessitate critical assessment of the relationship of TSC and TGCs in Nigeria as it relates to evaluation of stand stability of *Pinus caribaea* in Nigeria. Onyekwelu (2001) reported that little emphasis has been given to growth characteristics of many exotic species in Nigeria and where silvicultural intervention had been adopted without good knowledge of growth characteristics, bad management decision are always made with attendance adverse effect on stand productivity. Therefore, this study explored the relationship between tree slenderness coefficient and tree growth characteristics for *Pinus caribaea* plantations in Omo Forest Reserve, Nigeria.

II. Methodology

Data Collection

Fifteen (15) Temporary Sample Plots (TSPs) of size 0.04 ha each were randomly sampled from the three age series where 502 individual trees were measured across the sampled TSPs from Omo Forest Reserve, Ogun State, Nigeria (Fig.1). Quantitative data such as diameter at breast height (cm), diameter at base (cm), diameter at the middle (cm), total height of tree (m), merchantable height of tree (m) of individual tree were collected from three age series of pine located within TSPs. The three age series are 1990, 1991 and 1997.

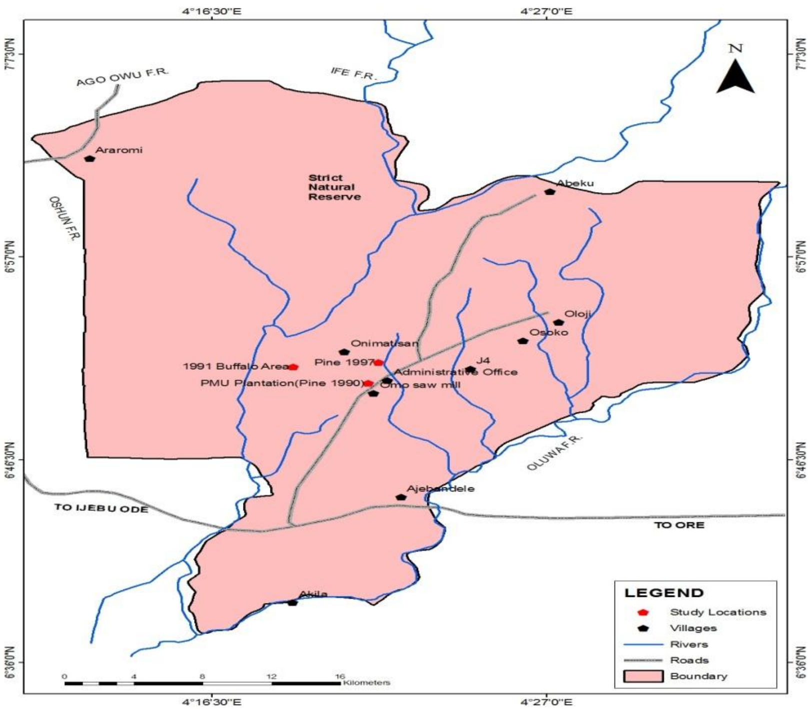

Fig. 1: Map of Omo Forest Reserve in Ogun State, Nigeria

Data Analysis

The data collected from tree measurement was processed into suitable form for statistical analysis while the non-measurable tree growth characteristics (TGC) were estimated for further analysis procedures. The estimated TGCs include basal area (BA), volume estimation (V), crown projection area (CPA) and crown ratio (CR) as shown in the expressions below.

Basal Area Estimation

The basal area for each tree in each sample plot was estimated using formula;

$$BA = \frac{\pi D^2}{4} \quad \text{---------------------------------1)}$$

Where BA = Basal Area (m^2)

D = dbh, $\pi = 3.143$

In each plot, the total basal area of all the trees was computed and used to estimate the basal area per hectare using the formula of (Harrison et al., 2010).

Tree volume estimation

The tree volume for each tree within the TSPs was estimated using Newton' equation

$$V = \frac{(g_b + 4g_m + g_u)L}{6} \quad \text{................(2)}$$

Where V= Tree volume

L= tree height/length

g_b, g_m, g_u=cross sectional area at the base, middle and at the top

Tree Slenderness Estimation

Tree slenderness was estimated for all trees using this formula

$$TSC = \frac{THT}{D} \quad \text{------------------------------------- (3)}$$

Where TS = tree slenderness
THT = height
and D = dbh

Crown Projection Area (CPA)
The Crown projection area for each tree in the study area was estimated from the formula:

$$CPA = \frac{\pi(CD^2)}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where CPA = crown projection area and CD = crown diameter.

Crown ratio
Crown ratio was also computed for each tree in this study using the formula

$$CR = \frac{CL}{THT} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where CR = crown ratio, CL = crown height and THT = total height.

III. Results

The results of tree growth characteristics among the age series are shown in Table 1. There were significant variations among the age series with the varying values of the TSC. Similarly, the correlation matrix between tree slenderness coefficient (TSC) and tree growth characteristics (TGCs) in Pinuscaribaea for measuring association between the TSC and TGCs is shown in Table 2. As a means of verifying the validation of the models, scattered diagrams were plotted for the relationship between tree slenderness coefficient and major tree attributes to show the relationship of the predictor variable and explanatory variables (Figs. 2-7).

Table 1: Summary statistics of growth characteristics for *Pinus caribaea* in Omo Forest Reserve

Growth Attributes	1990			1991			1997		
	Min	Max	Mean ±S.E	Min	Max	Mean ±S.E	Min	Max	Mean ±S.E
DBH(m)	0.24	1.27	0.735±0.017	0.38	1.48	0.819±0.023	0.31	1.06	0.616±0.010
THT(m)	9.00	28.00	19.89±0.347	17.00	26.00	22.04±0.165	14.00	29.50	22.84±0.214
MHT(m)	6.00	23.00	14.90±0.276	12.00	22.00	16.85±0.219	11.00	27.50	19.18±0.246
SQ(m)	4.00	20.00	12.20±0.263	11.00	22.00	16.82±0.208	9.50	26.50	18.77±0.236
CL(m)	2.00	14.00	7.691±0.215	2.00	9.00	5.218±0.133	1.50	17.30	4.066±0.106
CD(m)	1.00	7.80	4.107±0.096	1.50	5.78	3.610±0.091	1.00	7.83	3.712±0.083
BA(m^2)	0.05	1.26	0.453±0.020	0.11	1.72	0.573±0.033	0.08	0.88	0.319±0.010
TSC	12.41	48.91	28.32±0.602	15.38	52.63	28.89±0.695	22.83	64.71	38.64±0.464
VOL(m^3)	0.79	23.84	5.715±0.328	0.95	39.46	8.343±0.569	0.58	19.22	4.669±0.212
CPA(m^2)	0.79	47.79	14.22±0.651	1.77	26.24	10.95±0.506	0.79	48.16	12.22±0.55
CR	0.13	0.72	0.386±0.009	0.10	0.45	0.238±0.006	0.06	0.62	0.182±0.005

DBH(m)- diameter at breast height, THT(m)- total height of tree, MHT(m)- merchantable height of tree, SQ- stem quality, CL- crown length,
CD- crown diameter, BA- basal area, TSC- tree slenderness coefficient, VOL- tree volume, CPA- crown projection area and CR- crown ratio
Source: Field survey 2014

Table 2: Correlation matrix between tree slenderness coefficient (TSC) and tree growth characteristics (TGCs) for *Pinus caribaea* in the study area

	TSC	*THT*	*MTH*	*SQ*	*CL*	*CD*	*DBH(M)*	*BA*	*V*	*CPA*	*CR*	*Age*
TSC	1.000											
THT	0.086	1.000										
MHT	0.148	0.902*	1.000									
SQ	0.247	0.826*	0.881*	1.000								
CL	-0.313	-0.003	-0.244	-0.567*	1.000							
CD	-0.380	0.473	0.446	0.275	0.203	1.000						
DBH(M)	-0.807*	0.427	0.310	0.182	0.300	0.555*	1.000					
BA	-0.761*	0.366	0.258	0.140	0.286	0.503*	0.980*	1.000				
V	-0.618*	0.498	0.395	0.276	0.238	0.512*	0.906*	0.929*	1.000			
CPA	-0.338	0.448	0.443	0.270	0.175	0.976*	0.511*	0.467	0.490	1.000		
CR	-0.341	-0.367	-0.531*	-0.81713*	0.913*	0.050	0.132	0.137	0.039	0.035	1.000	
Age	-0.568*	-0.300	-0.452	-0.559*	0.553*	0.085	0.359	0.352	0.228	0.048	0.623*	1

DBH(m)- diameter at breast height, THT(m)- total height of tree, MHT(m)- merchantable height of tree, SQ- stem quality, CL- crown length, CD- crown diameter, BA- basal area, TSC- tree slenderness coefficient, VOL- tree volume, CPA- crown projection area and CR- crown ratio and Age series.

Source: Field survey 2014

Fig 2: Relationship between TSC and total height of tree for *Pinus caribaea* in the study area

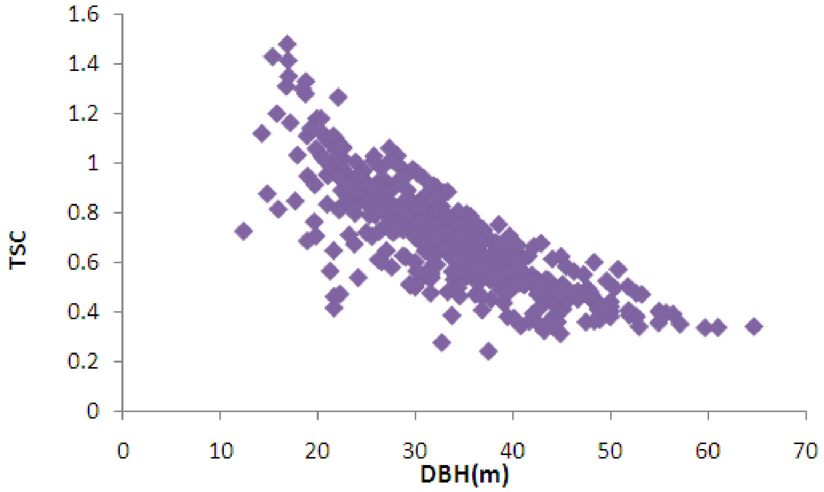

Fig.3: Relationship between TSC and diameter at breast height for *Pinus caribaea* in the study area

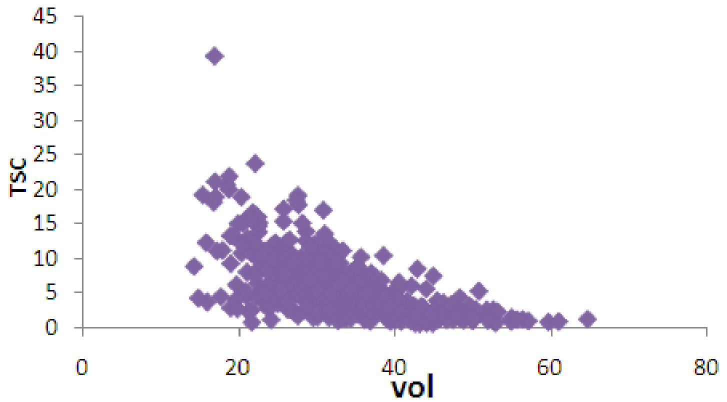

Fig.4: Relationship between TSC and volume *for Pinus caribaea* in the study area

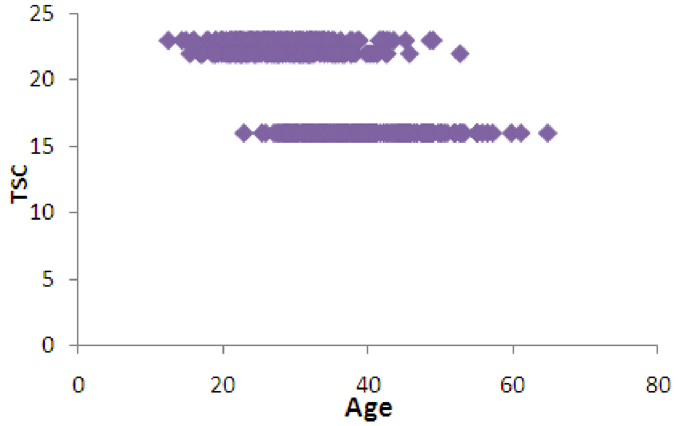

Fig 5: Relationship between TSC and Age for *Pinus caribaea* in the study area

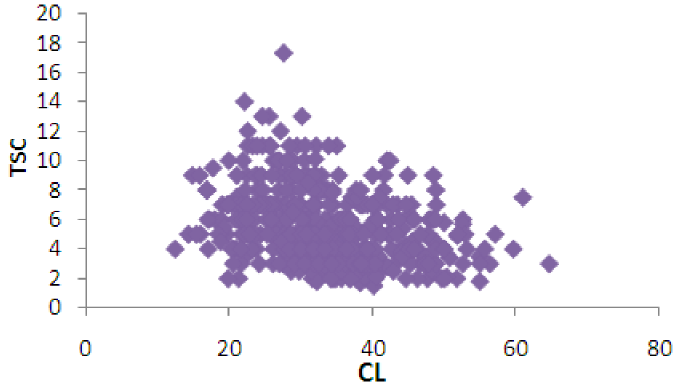

Fig 6: Relationship between TSC and crown lenght for *Pinus caribaea* in the study area

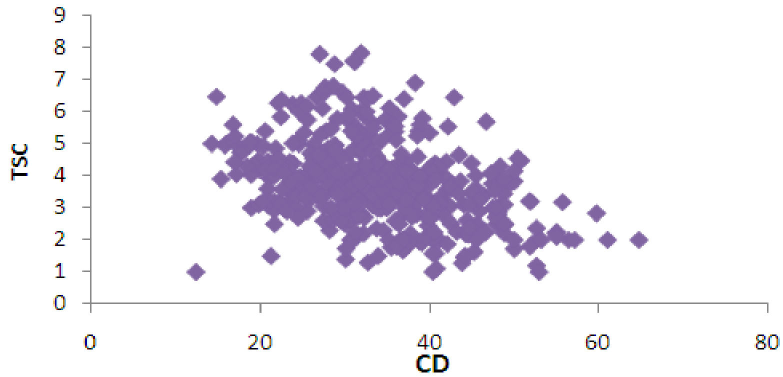

Fig 7: Relationship between TSC and crown diameter *for Pinus caribaea* in the study area

IV. Discussion

Tree Growth characteristics (TGCs)

The results of the major growth attributes for the *Pinus caribaea* indicated that variation exist between the three age series (1990, 1991 and 1997). The mean value of TSC was largest in 1997 pine stand where growth variables such as THT, MHT and SQ were also the highest which relate significantly to the element of the tree height and function of form and tree's taper. This occurrence may prompt incidence of windthrow within this age series since a stand of highest TSC value of a coniferous species of which Pinuscaribaea is a family would always be susceptible to windthow and possible stem damage.

Navratil (1996) reported that certain percentage of TSC reached within a stand can pose a high risk of windthrow. Whereas, the 1990 stand portrayed the inverse of occurrence to 1997 where the height features; THT, MHT and SQ were the least. Conversely, the major tree crown attributes within the 1990 stand had the highest values when compared with other age series. Such tree crown features include crown length, crown diameter, crown projection area and crown ratio. Similarly variations among other tree attributes within and across the age series were in conformity with several studies done on the relationship of TSC and other stand growth attributes (Wang et al., 1998; Vauhkonen, 2008; Persson *et al.*, 2002; Maltamo *et al.*, 2003). Mason (2002) and Ruel (2000) also researched and reported notable variations on tree slenderness coefficient or tree taper as it related to species stand growth characteristics and stability.

Correlation analysis between TSC and TGCs

The results of correlation analysis among growth attributes of Pinuscaribaea and tree slenderness coefficient (TSC) revealed significant variations across the three age series. The low associations or relationship among tree growth attribute of THT, MHT and SQ indicates low impact of these three attribute on the tree slenderness coefficient which implies that there is no significant effect on the tapering up of the Pinuscaribaea across the age series. This trend was in agreement with the reports of several authors on the growth attributes and management scenarios for plantation species in Southwest, Nigeria (Onyekwelu, 2001; Onifade 1998; Onyekwelu *et al.*, 2003). However, the negative coefficients of correlation (r) observed among DBH, BA, VOL and CPA indicated inverse associations or showed that as the individual trees of *Pinus caribaea* taper up (decrease), the DBH, BA and VOL increase.

These occurrences explain the import of tree slenderness coefficient architecturally as an indicator of crown type, crown length, crown class, growth performance and root system size. The results of this study were similar with the report of Wang et al. (1998) where the relationship of tree slenderness coefficients and tree characteristics for major species in boreal mixed forests were evaluated using empirical models. Though, comparison were made here among age series of the monoculture Pinuscaribaea plantation, the relationships showed significant semblance, and many studies have shown that slenderness coefficient (or taper) is the principal factor affecting susceptibility to windbreak (Wang *et al.*, 1998; Mason, 2002; Ruel, 2000).

Faber (2008) reported that relationship of windthrow and slenderness coefficient is indirect and that lower slenderness coefficient can be an indicator of larger crowns with lower centre of gravity and a better developed root system. In general, trees with a higher slenderness coefficient (low taper) are much more susceptible to damage than trees with low slenderness coefficient (high taper). The desirable height and dbh ratio for adequate wind resistance vary according to species and country (Wilson and Baker, 2001). According to Cremer et al., (2009) within Australian *Pinus radiata* plantations, the height and dbh ratio for dominant trees was the most valuable index of risk of damage.

V. Conclusion

This study revealed significant variations among the tree growth characteristics (TGCs) and indicative of relationships between TGCs and tree slenderness coefficient (TSC) within the *Pinus caribaea* plantations in Omo Forest Reserve, Nigeria. The study has projected the possibility of occurrence of wind throw among exotic species such as *Pinus caribaea* in Nigeria and advances the need for enhancing stability among exotic species to reduce susceptibility to wind throw and other environmental degradation within the pine plantations in Nigeria.

References

[1] Oteng-amoako, A. A.and Brink, M. 2008.PinuscaribaeaMorelet. [Internet] Record from PROTA4U. Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa / Ressourcesvégétales de l'Afriquetropicale), Wageningen, Netherlands.

[2] Wang, Y., Titus S. J.,and Lemay V. M. 1998 Relationship Between Tree Slenderness Coefficients and Tree or Stand Characteristics for Major species in Boreal Mixed Forest. Can. J For. Res. 28: Pp. 1171-1183.

[3] Ruel, J. C. 2000 Factors Influencing Windthrow in Balsam Fir Forests: Forest Ecology and Management. 135 (1-3): Pp. 169-178.

[4] Byrne, K. E. 2011 Mechanistic Modelling of windthrow in Spatial Complex Mixed Species Stands. At Vancouver, Canada: University of British Columbia. PhD Thesis.

[5] Nivert J. P. 2001 Factors Affecting Stand Stability, Forest Enterprise 139: Pp. 17-25.

[6] Navratil, S. 1996 Silvicultural systems for managing deciduous and mixed wood 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.

[7] Rudnicki, M., Silinus, U.and Lieffers, V.J. 2004 Crown cover is correlated with relative density, tree slenderness and tree height in lodgepole pine. Forest science 50(3): 356-363.

[8] Liu, X., Silinus, U., Lieffers, V.J. and Man, R., 2003 Stem hydraulic properties and growth in lodgepole pine stands following thinning and sway treatment. Can. J. For. Res. 33(7): 1295-1303.

[9] Becquey, J. andNivert, J.P., 1987 L'existence de "zones de stabilité" des peuplements. Conséquencessur la gestion. RFF XXXIX, 4, 323-334.ESRI Inc., 2009. ArcGis version 9.1.3. New York Street, Redlands, Calif.

[10] Onyekwelu, J. C. 2001 Growth characteristics and management scenarios for plantation-grown *Gmelina arborea* and *Nauclea diderrichii* in South-western in Nigeria. Hieronymus Verlag, Munich, Pp. 196.

[11] Harrison, W., Burk, T. and Beck, D. 2010 Individual tree basal area increment and total height equations for Appalachian mixed hardwoods after thinning. Southern Journal Application for Forestry.10, Pp. 99–104.

[12] Vauhkonen, J. 2008 Estimating crown base height for Scots pine by means of the 3D geometry of airborne laser scanning data. In: Hill, R., Rosette, J. and Suárez, J. (eds.). Proceedings of SilviLaser -2008, 8th international conference on LiDAR applications in forest assessment and inventory. Heriot-Watt University, Edinburgh, UK. Pp. 616–624.

[13] Persson, A, Holmgren, J. and Söderman, U. 2002 Detecting and measuring individual trees using an airborne laser scanner. Photogrametric Engineering & Remote Sensing 68: Pp. 925–932.

[14] Maltamo, M., Malinen, J., Kangas, A., Härkönen, S., Pasanen, A. M. 2003 Most similar neighbour based stand variable estimation for use in inventory by compartments in Finland. Forestry 76: Pp. 449–464.

[15] Mason, W.L. 2002 Are irregular stands more windfirm? Forestry 75(4): Pp. 347–355.

[16] Onifade, O. A. 1998 Growth functions of Nauclea diderrichii in Omo Forest Reserve (Ogun State Forestry Plantation Project Area, J4) Nigeria. An unpublished MSc dissertification, Departnent of Forest Resources Management, University of Ibadan, Nigeria.

[17] Onyekwelu, J. C., Biber, P., and Stimm, B. 2003 Thinning Scenarios for *Gmelina arborea* plantations in South-Western Nigeria using density management diagrams. Journal of Food, Agriculture and Environment. Vol. 1 (2): Pp. 320-325.

[18] Faber, P. J. 2008 Stability of stands to wind: a theoretical approach. Ned. Bosbouwtijdschr. 47: Pp.179–193.

[19] Wilson, J.S. and Baker, P.J., 2001 Flexibility in forest management: managing uncertainty in Douglas-fir forests of the Pacific Northwest. For. Ecol. Manage. 145: 219-227.

[20] Cremer, K. W., Borough, C. J., Mckinnell F. H., and Carter, P. R. 2009 Effects of stocking and thinning on wind damage in plantations. N.2. J. For. Sci. 12(2): Pp.244-68.