DAMAGES INDUCED IN THE WOODS OF SOME TROPICAL TREES DURING FELLING

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ABSTRACT

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Merchantable trees in tropical forests are usually widely scattered and the cost of road construction and logging operations are expensive. This calls for finding ways of minimizing felling-induced mechanical damages on wood. This study was carried out to assess and document the magnitude of the incidental damages during the felling of some Nigerian hardwood species in Shasha Forest Reserve in Osun State Nigeria. With utilization potentials and rate of cropping a criteria data were collected with the aid of a checklist on nine species in five different forest stands within the reserve. These include height, diameter, green moisture contents, and estimate of exploitable logs as well as some wood properties. The Volume of each tree was computed and the damaged volumes were estimated after felling. Analyses of data were carried out using simple percentages and regression models.Results showed that there are wide variations between and within the studied species with respect to both the tree and wood characteristics. The least average tree height of 40.39m was recorded for Mansonia altissima while the highest average tree height of 56.61m was recorded for Khaya ivorensis. Merchantable tree volume ranged from 13.68m^3 for Mansonia to 46.25m^3 for Entandrophragma angolensis while green density ranged from 936.91kg/m^3 to 1845.95kg/m^3 and moisture content ranged and 108.09% and 147.05% respectively. Visual assessment of damage volume shows that the degree of damage expressed as a percentage in the studied species ranged between 6.25% and 13.15%. The average damage volume per species is between 7.39% and 12.66% for the selected species. The regression models revealed that the magnitude of the damage portion has significant relationship with tree height, volume and weight.

Key Words: incidental damages, tropical hardwoods, logging, tree felling.

INTRODUCTION

The long history of tree felling has led to the development of various harvesting techniques aimed at improving productivity (both in quality and quantity), reducing risk of accidents, physical and mental stress {Wackerman (1949), Pearce and Stezel (1972), Conway 1973, FAO (1987), 1998 and 1999, Rudolf (1987)}. In spite of the development of better felling techniques directed at reducing felling induced mechanical damages in tropical forests, the efficiency of felling operation in tropical forest is low and depends on several interrelated variable which could be pooled together as physical and human variables. (Herbauts *et al* (1996), Omole (2000), Omole *et al.* (2005).

Tree felling is a major component in wood exploitation and it substantially contributes to the success or failure of harvesting operations. Felling as the first stage of actual wood processing is an important step as it affects the value of wood recoverable from the logs and the quality of products from them. The magnitude of damages that could result through improper felling technique has been documented (FAO, 1997; Scharpenbery *et al,* 1997). The findings noted that as low as low as 51 percent of log of stem volume of a standing tree may be recovered as products, due majorly to improper felling.

Felling operations in tropical forests occasionally result in serious mechanical damages to the logs. Wood breakages represent a major constraint to the quality and quantity of the final products which will in turn be reflected on the products final price (Omole *et al.* 2005). The incidental damage or breakage in timber resulting from felling and other logging operations in tropical forests pose great challenges to wood harvesting industries. Wood is increasingly being used in Nigeria as load-bearing (structural) material. For wood to perform adequately in structural applications; the quality must be preserved right from felling through bucking and other logging operations. This is by minimizing incidental damage to the logs.

As observed by FAO (1997), in terms of dollar, the value lost ranged well into millions, thus making felling breakage a major problem in wood harvesting operations. The study was carried out to assess and document the magnitude of the incidental damages during the felling of the nine Nigerian hardwood species in Shasha Forest Reserve in Osun State.

MATERIALS AND METHODS

Study area

This study was carried out in the Natural forest of Shasha Forest Reserve (SFR), Osun-State Nigeria where intensive logging operations was being carried out. The forest reserve is located between Latitudes 7^0N and 7^0 3^0N and longitudes 4^0 and 5^0E. It shares boundaries with Omo Forest Reserve in the west. The northern and eastern boundaries are with Ife Native Authority Reserve (No. 2) and Oluwa Forest Reserve Ondo State respectively. The total annual rainfall ranges from 887mm to 2180mm. The mean annual temperature is 26.5^0C with the annual range between 19.5^0C and 32.5^0C (Kio, 1978). Shasha Forest Reserve is generally undulating with occasional flat terrains.

The reserve is drained by three major rivers namely Owena and Oni to the East, and Shasha Ifosho to the West. Bada (1977) and Kio (1978) described the geology and soils of Shasha Forest Reserve as composed of undifferentiated crystalline rocks (basement complex). The rocks are made up of granites, gnesis and schists with occasional rock out - crops on riverbeds. The soil belongs to the Ferruginous tropical group, which varies in depth from a few centimetres near rock out crops and one to two metres in areas occupied by large trees. The vegetation of the forest reserve is of the lowland rainforest type. Kio (1978) described the vegetation structure as three storeys with scattered emergents.

Data collection

Stand and species selection: The data for this study were collected in five (5) forest stands within Shasha Forest reserve during the dry season of 1999. The 5 selected forest stands are: *Idi-ahun, Olomu, Alaagan, Laroka and Onigbin. N*ine (9) different species of high utilization potentials and economic values were selected for the study. The species selected were: *Afzelia africana, Nauclea didderrichii, Terminalia superba, Khaya ivorensis, Triplochiton scleroxylon ,Entandrophragma angolensis, Cordia millenii, Mansonia altissima* and *Meliacia excelsa.* These are export grade logs and also, most of them are in use for structural purpose.

A checklist was designed and information on each tree was documented on this form before felling. The form consists of 2 sections. The first section contains information on tree standard parameter and environmental factors. Information on felling operation and the associated damages were recorded on the second section of the checklist. Before felling, tree standard parameters such as species, merchantable height, total height, crown shape and depth, diameter at 3 levels (stump, middle and top), initial lean position and defects were all recorded on the data form. Also noted on the form were the prevailing environmental conditions like terrain features, ground density, soil characteristics etc.

Felling operation: Although there are different types of tree felling methods, for this study, the conventional tree felling method being practiced in the reserve was adopted. After clearing the bush surrounding the tree to be felled, the operator moved close to the tree to have a critical look at the direction of its initial lean in order to determine the likely direction of falling of the tree direction to decide the escape route. During felling, the manner of fall for individual tree was observed. After landing, the nature of damage and the magnitude of the damages were assessed to be able to qualify and quantify the damages.

Tree volume estimation: In determining the tree volume, the diameter of each tree was measured at three different levels. The butt diameter was measured with diameter tape while the diameters of the middle and the top of the tree were estimated with the aid of Spiegel relaskop.

The merchantable volume of each tree was estimated before felling operation using Newton's formula stated as:

$$V = \frac{\pi \ H}{24} (A_b + 4A_m + A_t)$$

where V = Volume of tree (m3)

H = Height of tree (m)

Ab = cross-sectional area of the base of the tree (m2)

Am = cross-sectional. area of the middle of the tree (m2)

At = cross-sectional area of the top of the tree (m2)

Volume of damaged portions: The volume of damaged portions due to landing impact expressed as a percentage of the whole tree (as a result of landing force) was estimated by subtracting the volume of undamaged wood from the total volume. Physically broken parts of the merchantable logs that are not useful as solid lumber are categorized as wastage.

The formula used is:

$V_d = V_T - V_G$

where

V_d = *volume of damaged portion* (m^3) V_T V_T= *Total volume of tree* (m^3)

V_G = *Volume of good quality wood* ((m^3)

Due to the large sample size, the mean stump diameter for each species was calculated and five trees with stump diameter closest to mean were selected. The volume of the damaged portion of the wood for each of the five trees was estimated. The average values obtained were then employed in computation of the damaged portions.

Data analysis

Data collected were analysed using simple percentages and regression models. For the nine tree species selected for this study, three functional regression models were tried which are simple linear, semi log and double log functions. The specified regression models for damage volume are:

Volume of damaged portion

$V_d = f(H,V,W)$

where V_d = damaged volume (m^3)

H = tree height (m)

V= tree volume (m^3)

W= tree weight (N)

Regression models for Volume of Damaged Portion

Simple linear function

$V_d = a_0 + a_1H + a_2V + a_3W + E_d$

Where a_0 = constant or intercept

a_1 ……. a_3 = regression coefficients

E = residual or error term

Semi-log function

$V_d = \text{Ln } a_o + a_1 \text{LnH} + a_2\text{LnV} + a_3\text{LnW} + \text{LnE}_d$

Double-log function

$\text{LnV}_d\text{=Lna}_0\text{+a}_1\text{LnH+a}_2\text{LnV+a}_3\text{LnW+Ln E}_d$

RESULTS AND DISCUSSIONS

From Table 1, it was observed that a wide variation exists between and within species in terms of total height of tree. Almost all the species (83.8%) have the average total height of about 50 metres indicating that most of the sampled trees are very tall. These heights are not strange for the mature trees in tropical rain forests. For example, Richard (1996) stated that trees in rain forests are extremely numerous in species composition. The tree species range from treelets of one or two metres to giants of over 50m or even up to 80m high. Pires and Prance (1977) reported an average height of taller tree in a rain forest of between 48-58m with individual sometimes above 60m. These observations can then be taken to be in order with the existing figures. The heights of these trees contribute significantly to the magnitude of the damaged portion of the tree and the induced dynamic stresses. This is because the taller trees are expected to travel longer distances thereby gaining higher angular momentum and resulting in higher landing forces which may result in considerable breakages. The mass of a tall tree will definitely be high hence; the tendency is there to destroy more of younger trees around. This is because the taller a tree is the longer the distance it will reach during falling and this couples with the high landing forces, the resulting damages will be considerable.

From Table 2, it is noted that the average volume for the nine species ranged between 13.68m^3 for *Mansonia altissima* and 46.25m^3 for *Entandrophragma angolensis.* Majority of the species (77.78%) recorded an average volume of more than 30m^3. Four species, *Afzelia africana, Nauclea didderrichii, Terminalia superba* and *Meliacia excelsa* have average volume ranged between 30.72m^3 and 37.82m^3 while three species *Khaya ivorensis, Triplochiton scleroxylon* and *Entandrophragma angolensis* have volume over 40m^3. These high values of the estimated volumes are indications of the massiveness of some tropical timbers. The high volumes of the trees will result in higher weights which in turn manifest in heavy landing forces on the wood of the trees at impact; hence the magnitude of the damages will also be dictated by the volume of the tree.

Visually assessed damaged portion

In the course of this study, different kinds of felling induced damages were encountered. These include severe breakages of the thinner branches around the crown of the felled trees, heavy longitudinal splits and cracks on the logs of the felled trees. Also, breakages and/or uprooting of other trees around onto which the tree being felled falls are also some of the common features of tree felling in the study area. Trees with defective heart rot were also encountered. This work is however focused on felling induced impact damages to the trees being felled, rather than taking account of incidental damages to other trees or other defects already existing in the tree.

From table 3 in terms of percentage of visually damaged portion, *Terminalia superba, Afzelia africana, Nauclea didderrichii, Khaya ivorensis* and *Meliacia excelsa* recorded damages range of 11.89-13.15%, 7.89-10.32%, 6.96-9.30%, 9.36-11.43% and 9.17-13.18% respectively. Also, percentage damages ranges of 9.81-11.79%, 8.82-11.87%, 6.25-8.22%and8.75-11.435 were recorded for *Triplochiton scleroxylon, Cordia millenii, Mansonia* *altissima* and *Entandrophrama angolensis* respectively. The wood portion categorized as damages and wastages are the portion of wood that have been rendered unusable for conversion into solid wood member for load bearing materials or rendered useless as solid lumber for most other uses.

In terms of the average percentage damaged portion per species, *Terminalia superba* has the highest percentage of visually assessed damaged portion of 12.66%, this is followed by *Meliacia excelsa,* Triplochiton scleroxylon and *Khaya ivorensis* with average percentage damage portion of 11.86%, 10.79% and 10.22% respectively. The least average volume of damaged portions per tree was recorded in *Mansonia altissima and Nauclea diderichii* with values of 7.39% and 7.68% respectively.

Observed on the logs of all the trees after cross-cutting were surface checks. The majority of these checks occurred mostly in the heartwood region. The length of the surface checks is between 6.2cm and 52.7cm for all the logs of the selected tree species. There were variations in length and depth of the surface checks on the logs. These variations were noticed between and within logs of the same tree and among trees of the same species and of different species. There was no distinct pattern of distribution of the magnitude of these checks from species to species but there were indications that the checks are more pronounced in wood material of logs around the crown region. Previous studies by Maltheck and Walther (1991), and Eronen *et al.* (2000) have confirmed that these checks could have resulted from either growth stresses, bending moment introduced into falling stem by the small uncut hinge or forces created by mass of the logs that result in bending at the point of cross cut and a combination of two or all these factors. Checks resulting from bending moment are expected to be of high magnitude if precipitated by high landing forces.

Checks on logs reduce the volume and quality of timber or veneer obtainable from such logs especially when logs are cut to customers-specified length since this may not allow much margin for further trimming. Excessive splits and checks will considerably reduce veneer and timber yield during conversion. This is in line with the statement of *Eronen et al (2000)* that shorter checks and splits can lead to greater yield or better quantity lumber and veneer while longer checks and splits considerably reduce timber yield from logs because lumber and veneer rejects will be more. The visible checks on the logs are more representative of what will occur in boards and veneer manufactured from the logs. The magnitude of the surface checks observed in the logs will present utilization problems for many solid end uses and veneer production most especially in structural application. Apart from reduction in yield of realizable lumber and veneer, excessive splits and checks will also lead to higher cost of production because adhesives would be required for proper glueing and also more time will be needed for production hence productivity is affected. The checks will expand upon drying and will increase permeability of adhesives thereby resulting in wasting of adhesives for veneer and plywood production. With appropriate improvement of tree felling techniques through reduction of landing forces especially for big trees, the extent of surface checks observed can be minimized considerably.

Tree characteristics such as height, crown, shapes, branches arrangement and angle of suspension of the branchlets also play significant roles in dictating the magnitude of the damages observed in the studied species. For example, species like *Nauclea didderrichii* which recorded very low damages (7.68%) were able to better resist impact damages because of its branching nature. The crown is round and the branches are often horizontal and whorled. The arrangement of these branchlets expectedly will provide a cushioning effect to the tree upon landing, thereby reducing the damaging force. The smaller branchlets which in any case are hardly useable as logs are the portion of the tree that absorb most of the shock for such species.

Table 4 shows that the average moisture content is more than 100% for the nine species with *Nauclea diderrichii* having the highest average moisture content of 147.05%. *Cordia millenii* however has the least average moisture content of 108.09%. It was also observed that the moisture content range for the nine species is between 26% for *Cordia millenii* and 49% for *Afzelia africana.* This high moisture content of the green wood species is responsible for the high value of the green densities of the studied species. Since it is a known fact that high moisture content leads to reduction in the static strength of the wood, the magnitude of the moisture content observed in all the species (above 100%) coupled with the induced higher weights is expected to make the wood more flexible (decreased stiffness).

Volume of damaged portion

Observation on Table 3 shows that the average percentage volume of damaged log portion as seen with the naked eye is between 7.88 and 11. 86. This could be considered low. This estimated volume is low because the terrain of the study area is generally flat with little or no rock outcrop. In spite of the low percentage of the damaged portion, it should however be noted that not all damages can be completely assessed visually because some of the damaged may not be immediately visible to the naked eye.

Although visual grading in by far the most common method of log and lumber grading, visual examination approach of the damaged portion should not be taken as sufficient for total quantification of the damage. Because some damages are microscopic and internal within the fibres and within fibre and middle lamella, using wood

with such internal damage as structural members may pose serious threat to users. There is a tendency for such damages to manifest during the service life of the timber resulting in structural failures.
Regression analysis carried out in order to establish how many factors actually contribute/responsible for the volume of damaged portion per tree species revealed that., out of the 27 fitted models for the nine species and on the basic of coefficient of multiple determination (R^2) standard error (SE) value and significance of the regression model, only 3 models for 3 species were selected. These species are *Afara, Lagos Mahogany* and *Mansonia.* Their equations are: equations as stated below.

Lagos Mahogany

$$V_d = -02.3723 - 25.4460LnH + 25.9753LnW$$
$$R^2 = 99.88\%,\ S.E. = 0.0565,\ F=289.2068$$

Afara

$$V_d = -.4731 - 0.3219LnW_g + 4089LnV$$
$$R^2 = 99.66\%,\ S.E. = 0.0033,\ F=930.52$$

Mansonia

$$V_d = -1.8189 - 0.00225W + 0.1948V + 0.0151H$$
$$R^2 = 99.94\%,\ S.E. = 0.0024,\ F=6556.6$$

CONCLUSIONS

Tree felling in the Shasha Forest Reserve in Osun State, Nigeria is being undertaken using merely the low to middle level technology, with little of those facilities that promote efficiency and minimize damage to the logs of the tree being felled as a result of heavy impact as felled trees strike the ground. The easily visible portions of the tree that suffer mechanical damage as a result of felling of the trees ranged from 7.39% (on volume basis) in *Mansonia altissima* to 12.66% in *Terminialia superba (Afara)* on total volume basis of the tree. These represent portions that are thus rendered unusable as boards. In addition, there are other portions (including both readily visible and those not visible) whose damages are such as to degrade the portions, with these portions yet being of some specific uses. The heavy damage around the crown region is largely as a result of failure of the structure of the wood and this being total failure, makes the portion useable. In addition to the damage frequently suffered by the falling tree at impact, damages are often inflicted on nearby trees as the tree being felled hits these. Those trees which are thus hit are frequently the immature ones not due for felling. Less frequently, injuries are suffered by members of the felling crew.

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Table 1: Average Total Height of the Nine Species Tested

	Height (m)		
Tree Species	Minimum	Maximum	Average
A. africana	33.42	62.30	51.23
N. didemchii	32.70	64.70	49.90
T. superba	41.80	63.10	54.78
K. ivorensis	43.20	62.50	56.61
M. excelsa	39.20	59.25	50.64
C. millenii	30.10	49.90	42.11
T. scleroxylon	42.72	62.70	54.78
M. altissima	33.40	47.80	40.39
E. angolensis	43.70	63.20	56.38
Mean	37.80	59.49	50.76

Table 2: Estimated Average Volume of Trees for the Nine Species

	Tree Volume (m^3)		
Tree Species	Minimum	Maximum	Average
A. africana	8.73	53.80	30.72
N. diderrichii	15.03	52.85	32.29
T. superba	25.31	57.81	37.82
K. ivorensis	25.75	54.26	42.88
M. excelsa	9.46	56.01	35.75
C. millenii	9.16	33.72	21.21
T. scleroxylon	25.79	63.19	40.79
M. altissima	8.73	17.53	13.68
E. angolensis	23.80	64.99	46.25
Mean	16.86	54.12	33.48

Table 3: The average of volume damaged portion of wood (%)

	Visually Assessed Damaged Portion (%)		
Tree Species	Minimum	Maximum	Average
A. africana	7.89	10.32	9.53
N. diderrichii	6.96	8.30	7.68
T. superba	11.89	13.15	12.66
K. ivorensis	9.36	11.43	10.22
M.excelsa	9.17	13.18	11.86
T. scleroxylon	9.81	11.79	10.79
C. millenii	8.82	11.87	9.86
M. altissima	6.25	8.22	7.39
E. angolensis	8.75	11.43	9.64
Mean	8.77	11.08	9.96

Table 4: Averages density of green wood from the nine species

	Moisture Content (M.C%)			Density of green wood samples		
Tree Species	Minimum	Maximum	Average	Minimum	Maximum	Average
A. africana	107	156	133.77	1668	1898	1765.81
N. diderrichii	126	162	147.05	1711	1958	1845.95
T. superba	106	150	126.27	1026	1286	1167.00
K. ivorensis	109	147	129.39	1112	1414	1263.48
M. excelsa	113	147	129.44	1457	1723	936.91
C. millenii	93	119	108.09	856	1003	936.91
T. scleroxylon	103	138	116.39	796	993	882.27
M. altissima	98	127	110.64	1188	1374	1268.57
E. angolensis	123	153	137.62	1527	1714	1612.62