Journal of Environmental Science and Engineering A 5 (2016) 82-89
doi:10.17265/2162-5298/2016.02.004

Dynamics of Lumber Production from Buttressed-Stumps of Logging Residues Using a Fuel Powered Horizontal Mobile Bandsaw Machine

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Abstract: Logging residue can be defined as any form of wood, which under the highest stage of technological development could be used in manufacturing but is left in the forest during logging. Lumber production from logging residues of a previous logging activity by a timber firm was undertaken with the objective of determining the suitability of utilizing buttressed-stumps as raw material for the timber industry. A horizontal mobile bandsaw machine was used to process the buttressed-stumps into lumber. The machine was characterized by a thin-kerf sawing technology (kerf-width 1.6 mm) compared to the conventional bandsaw machines of kerf-widths ranging from 3.0-4.5 mm. Lumber value and volume yields, fuel consumption rate, frequency of tool replacement and lumber production rate were assessed. Results indicated that there is the potential to increase timber production from logging residues by utilizing buttressed-stumps. Lumber value and volume yields of eight timber species investigated in this study ranged from 5%-31% and 34%-54% respectively. Fuel consumption rate which increased with increasing wood density, ranged from 5-14.5 liters/m^3 of lumber produced. Frequency of saw replacement increased with increasing wood density. The number of saws required to produce one cubic meter of lumber, ranged from 1 to 7. Lumber production rate ranged from 0.10-0.38 m^3/hour, increasing with decreasing wood density.

Key words: Buttressed-stumps, downstream processing, logging residues, lumber value and volume yields, mobile bandsaw machine.

1. Introduction

Globally, the area of tropical forest is estimated at 1.756 billion ha and is distributed as: 913 million ha constituting 52% in tropical America, 527 million ha constituting 30% in tropical Africa and 316 million ha constituting 18% in tropical Asia. Human activities have always modified the forest environment, but in recent years, the intensity and scale of forest use has increased significantly. It has been estimated that globally, the loss of tropical forest annually is 15.4 million ha. Environmental problems associated with the depletion of the tropical forest include soil erosion and high sedimentation in river systems that reduce water quality, drought due to poor rainfall pattern, desertification and destruction of properties including buildings due to the absence of trees to act as windbreak [1].

Birikorang, G. et al. [2] reported that the forest resource base in Ghana was under-utilized and that substantial volumes of logging residues were generated annually. Okai, R. et al. [3] also reported that for every tree felled, nearly 50% of the tree volume is left in the forest in the form of branches, crown wood and stumps. Kantola, M. [4] defined logging residue as any form of wood, which under the highest stage of technological development could be used in manufacturing but is left in the forest in the course of logging. Ford-Robertson, F. C. [5] reported that in the process of felling and extraction of timber, residues are generated at all stages and from a variety of sources.

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Traditionally, logging operations were just harvesting the stem and leaving the stumps, branches and crown in the forest. During such operations, damage was caused to the felled tree, residual vegetation and the soil. Usually, the damaged felled and residual trees were not taken out of the forest floor for use but accumulated as waste. With this loss of wood resources during logging in the forest, it was argued that the industry was not contributing its full potential to timber utilization. However, Okai, R. [6] pointed out that although wood residue could not be completely avoided during logging, it could be reduced significantly to minimize the pressure on the dwindling timber resource. Consequently, there have been several calls for the provision of solutions to the problem of wood wastage or residue accumulation [7, 8].

Fegel, A. C. [9] and Manwiller, F. G. [10] studied the comparative anatomy of trunks, branches and root wood among other things in stems and branches of small hardwoods in southern pines. Taylor, G. D. [11], Okai, R. et al. [3, 6, 12, 13] also investigated the relationship between branchwood and stemwood properties. Stuart, W. B., and Walbridge, T. A. [14] showed a new method for recovering branchwood and small diameter treetops as an alternative to whole tree chippings. Lumber from heartwood and sapwood including branchwood of America elm (*Ulmus americana*) have been successfully seasoned to 7% moisture content [15]. Palanius, I. [16] examined the extent to which marginal raw materials like stumps, branches and crowns could be harvested for pulp production as well as the quality of pulps from such materials. Molotkov, L. K. et al. [17] also investigated the suitability of treetops and branchwood for the pulp industry in Russia. Amoah, M. et al. [18] recently conducted studies on the physical and mechanical properties of branch, stem and root wood of iroko and emire tropical trees. The above studies [1-18] have been undertaken with the objective of utilizing the whole tree volume to reduce the pressure on the forest.

Scharai-Rad, M. and Noack, D. [19] conducted studies on better utilization of tropical timber resources in order to improve sustainability and reduce negative ecological impact. They classified the whole tree volume based on the volume of extracted log, stump, buttress, stem offcuts and crown. Results from their studies indicated that buttressed-stump accounted for 9% of the total tree volume. Okai, R. [12] conducted studies on the milling and strength properties of the branchwood of *Terminalia ivorensis* and *Aningeria robusta* and concluded that the branchwood of these species has considerable potential for use in downstream processing. The study never explored the potential of producing lumber from buttressed-stumps, which constitute 9% of the total tree volume. This study aims at investigating the potential of utilizing logging residues from buttressed-stumps. Lumber value and volume yields, frequency of tool replacement, fuel consumption and lumber production rate of a fuel powered horizontal mobile bandsaw machine used for the study are presented in this paper.

2. Material and Methods

2.1 Wood Sample Collection from the Forest

Logging residues in the form of buttressed-stumps of eight timber species from a previous logging activity by a timber firm were extracted from the Pra-Anum Forest Reserve in the moist semi-deciduous forest zone of Ghana. The species were: *Antiaris toxicaria* (Kyenkyen), *Terminalia superba* (Ofram), *Albizia ferrruginea* (Albizia), *Nesogordonia papaverifera* (Danta), *Entandrophragma angolense* (Edinam), *Celtis mildbraedii* (Esa), *Pterygota macrocarpa* (Koto) and *Turraeanthus africanus* (Avodire).

The buttressed-stumps shown in Fig. 1 were of average height of 1 m. For each timber species, flanges were severed from 12 buttressed-stumps using a chainsaw machine. About 60 flanges for each species were obtained. The extraction process was

Fig. 1 Buttressed-stump from a logging activity.

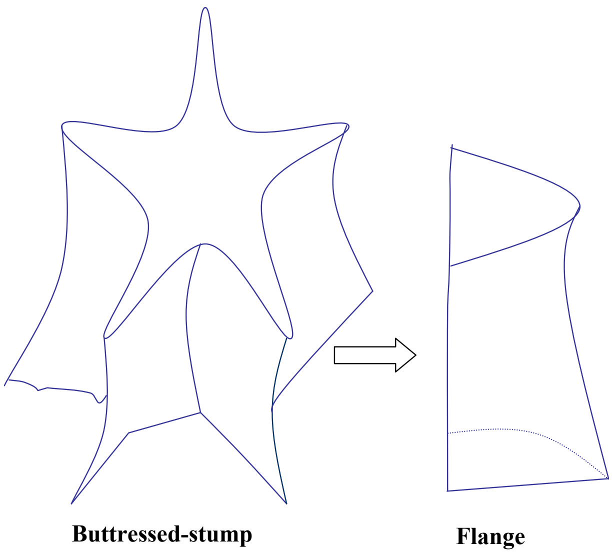

Fig. 2 Flanges severed from buttressed-stumps by chainsaw operation.

cumbersome. In order to sever or saw a flange from a buttressed-stump (Fig. 2), a chain sawing operation was performed by sawing along the vertical and horizontal plane of the stump. The wood samples (flanges) obtained from the post-logging activities were processed into sawn lumber.

2.2 Experimental Design

A Complete Randomized Design (CRD) was used for the experiment. The logs (flanges) were grouped into species, and sawing tests were conducted using a combination of live and cant sawing methods. The machine used for the log breakdown was a horizontal mobile bandsaw machine known as "woodmizer". The saw blade (spring set) had the dimensions: tooth pitch 22 mm, width 30 mm, kerf 1.6 mm and gullet depth of 5 mm.

2.3 Process Flow and Data Collection

The volume V_i of each flange was calculated from Eq. (1) where L_1 and L_2 are thickness of the small end and large end respectively, w is the width of the flange, and h_1 and h_2 are the lengths of the flange. The flanges were sawn into boards with fixed dimensions to prevent any influence of product dimensions on lumber yield and productivity. The flanges were then graded into First and Second (FAS) grade boards. The volumes of the boards were computed by measuring the length, width and thickness at three points along the length of the boards. For each species, the lumber yield was computed by expressing the volume of boards obtained as a percentage of the input volume of the flange. The lumber value and volume yields for the study were calculated from Eqs. (1-3), derived from previous studies by Okai, R. and Okyere, B. [8] and modified in the present study, where Y_{vol} is volume yield (%), Y_{val} is value yield (%), V_i is the input volume of the flange (m^3), V_o is the output volume of the sawn lumber (m^3), C_o is unit price of the standard lumber and C_i is unit price of each lumber produced from the flanges.

$$V_i = \frac{w}{4}\left(h_1 + h_2\right)\left(L_1 + L_2\right) \qquad (1)$$

$$Y_{vol} = \sum \frac{V_o}{V_i} \times 100 \qquad (2)$$

$$Y_{val} = \sum\left(\frac{V_o}{V_i} \times \frac{C_i}{C_o} \times 100\right) \quad (3)$$

2.4 Fuel Consumption, Frequency of Saw Replacement and Lumber Production Rate

The fuel consumption (litres/m^3 of lumber produced) and the lumber production rate (m^3 of lumber/hour) of the horizontal mobile bandsaw machine were assessed. The fuel consumption rate was determined by measuring the total volume of fuel consumed when one cubic meter of lumber was produced. The lumber production rate was determined by measuring the total volume of lumber produced in one hour. The frequency of saw replacement was determined by recording the number of saws required to produce one cubic meter of lumber.

3. Results and Discussion

3.1 Lumber Value and Volume Yields

The relationship between lumber value and volume yields from buttressed-stumps of eight timber species are shown in Fig. 3. It will be observed that the lowest lumber value yield of 5% and the highest lumber value yield of 31% were recorded for *Pterygota macrocarpa* and *Antiaris toxicaria* respectively. The lowest lumber volume yield of 34% and the highest lumber volume yield of 54% were also recorded for *Pterygota macrocarpa* and *Antiaris toxicaria* respectively. The lowest lumber value and volume yields recorded for *Pterygota macrocarpa* may be attributed to the species susceptibility to insects attack when the buttressed-stumps were exposed to the atmosphere. Besides, other species such as *Entandrophragma angolense*, *Turraeanthus africanus*, *Nesogordonia papaverifera* and *Celtis mildbraedii* recorded low lumber value yields, which could also be attributed to the species susceptibility to insects attack and the high proportion of sapwood.

Previous studies by Okai, R. [12] showed that mean lumber value yields of 20% and 25% were recorded when processing branchwood of *Aningeria robusta* and *Terminalia ivorensis* respectively. Results from the present study have confirmed that logging residues in the form of buttressed-stumps have the potential to be used as raw material for the downstream processing sector.

3.2 Fuel Consumption of the Woodmizer

The horizontal mobile bandsaw machine was used to process the logging residues into lumber because of the smaller kerf width of the saw blade and one's ability to move the machine to any desired place or position.

The production efficiency of the horizontal bandsaw machine in terms of fuel consumption was studied and the results presented in Fig. 4. It will be observed that as the density of the timber species increased, the fuel consumption of the bandsaw machine increased. The lowest fuel consumption rate of 5 litres per cubic meter of lumber produced was recorded for *Antiaris toxicaria*, which interestingly also recorded the highest lumber value and volume yields.

Predictably, *Antiaris toxicaria* recorded the lowest wood density among the eight timber species. The highest fuel consumption rate of 14.5 litres per cubic meter of lumber produced was recorded for *Celtis mildbraedii*, which predictably recorded one of the highest wood densities. It will be deduced from Fig. 4 that about three times the volume of fuel used to process *Antiaris toxicaria* into a unit volume of lumber is required to process *Celtis mildbraedii* into the same unit volume of lumber.

A near linear relationship between timber species and fuel consumption rate can also be seen in Fig. 4, which shows increasing fuel consumption rate with increasing wood density.

3.3 Frequency of Saw Wear and Lumber Production Rate

The frequency of saw wear or tool replacement

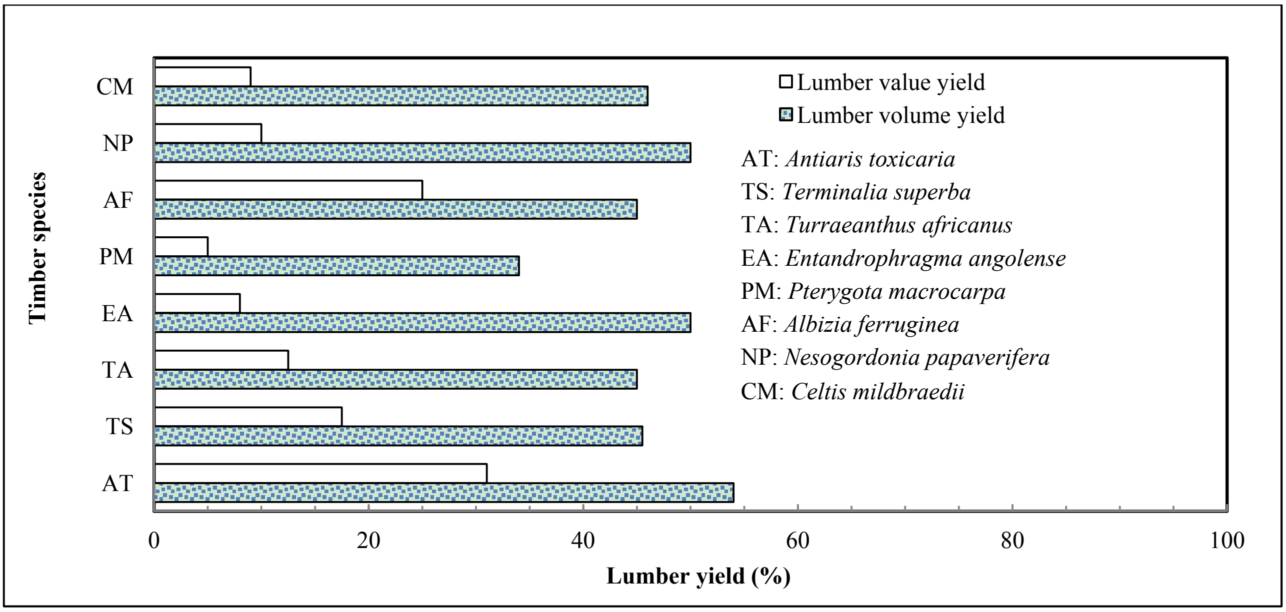

Fig. 3 Lumber value and volume yields from buttressed-stumps of eight timber species.

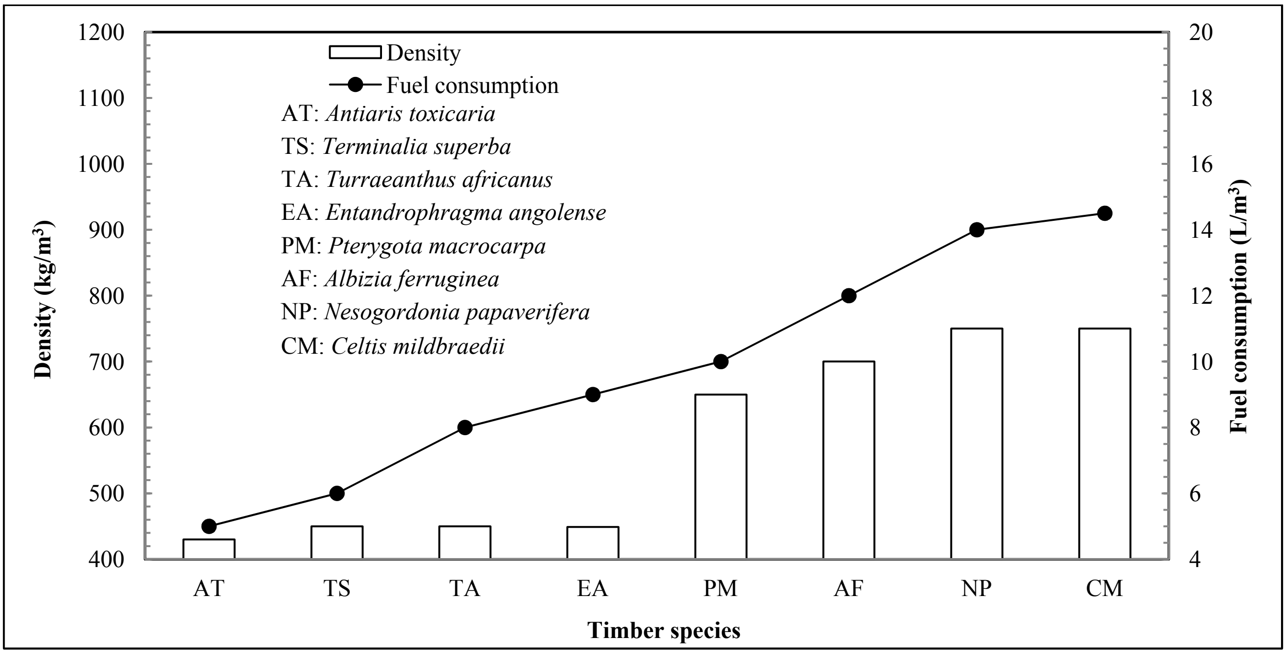

Fig. 4 Fuel consumption rate (litre/m^3 of lumber produced) of the horizontal mobile bandsaw machine.

plays an important role in assessing a mill's operational efficiency. The relationship between timber species and the number of saw blades required to process buttressed-stumps from logging residues of the eight timber species into a unit volume of lumber is shown in Fig. 5. It will be observed that as the density of the wood species increased, the number of saws required to produce a unit volume of lumber also increased. The lowest number of saws required to produce a unit volume of lumber was recorded for *Antiaris toxicaria* (one saw), and the lowest number of saws (seven saws) required to produce a unit volume of lumber were recorded for *Nesogordonia papaverifera* and *Celtis mildbraedii*. The frequency of saw wear has a direct link to the production rate. As the number of saws required in producing a unit volume of lumber

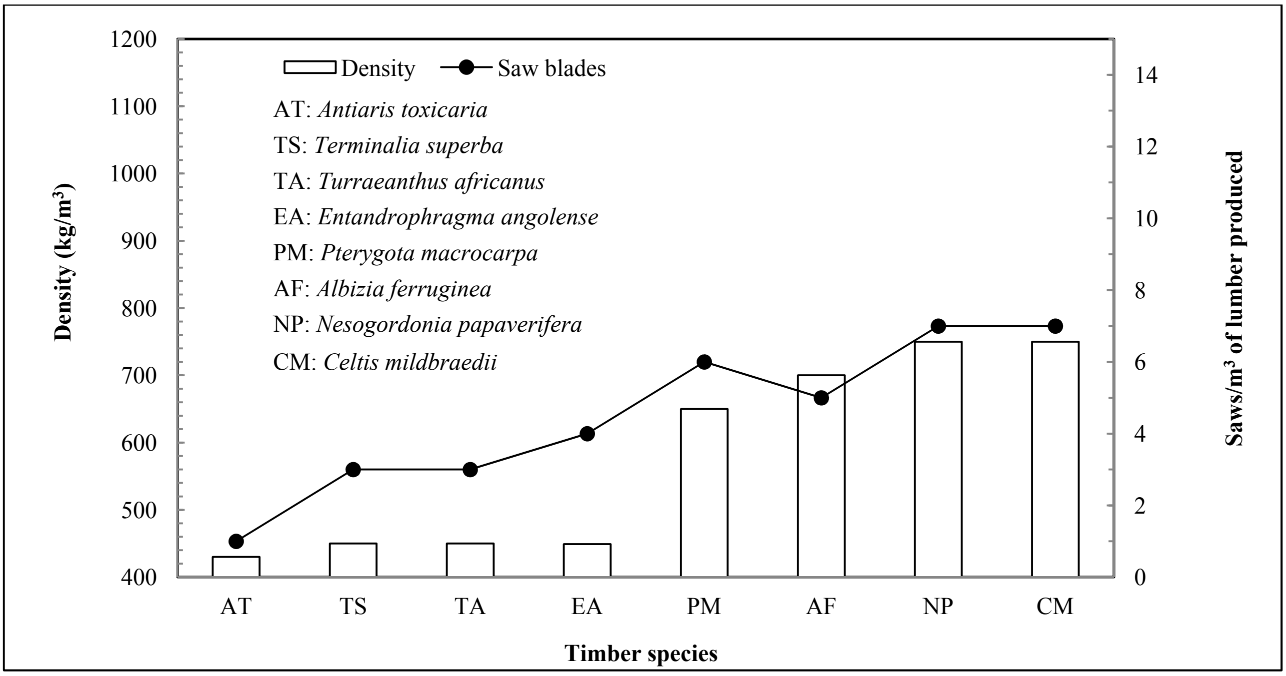

Fig. 5 Relationship between timber species and saws required to produce one cubic meter of lumber.

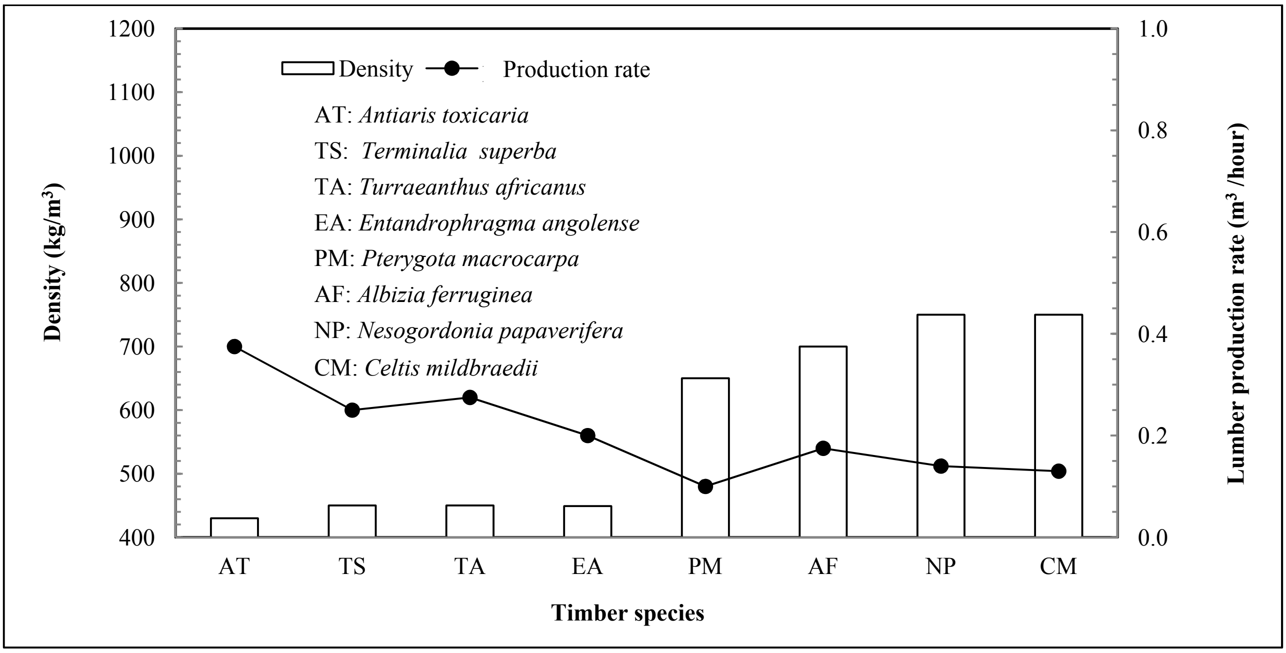

Fig. 6 Relationship between timber species and lumber production rate.

increased, it was expected that the lumber production rate would decrease. Previous studies have associated saw replacement or tool wear with excessive saw blade vibration [20-24].

It will be observed from Fig. 6 that as the density of the timber species increased, the lumber production rate decreased. The lowest lumber production rate of 0.1 m^3/hour to 0.175 m^3/hour were recorded for the high density species within a density range of 600-750 kg/m^3 and the highest production rate of 0.2 m^3/hour to 0.375 m^3/hour was recorded for the low density species within a density range of 400-550 kg/m^3.

4. Conclusion

This study has become necessary because with the rapid reduction in log size coupled with scarcity of raw materials, there is the need to process small diameter logs including stumps into lumber. The horizontal mobile bandsaw machine is suitable for processing small diameter logs because of its thin kerf. The fuel consumption and lumber production rate could serve as a guide to industries involved in the processing of small diameter logs. The results of this study have shown that logging residues in the form of buttressed-stumps have the potential to be used as raw material for the downstream processing sector.

5. Recommendation

Fuel consumption rate of the horizontal mobile bandsaw machine, and lumber value and volume yields of buttressed-stumps from a post-logging activity have been presented in this paper. However, the need to assess the economic feasibility of processing buttressed-stumps into lumber is important since there are other ways of utilizing logging residues, such as for charcoal production.

In future studies, the researchers shall compare and contrast the cost effectiveness of processing buttressed-stumps into lumber and using the buttressed-stumps for charcoal production.

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