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Estimation of Wood Residues from Small Scale Sawmill Operations in Kawetire Forest Plantation in the Southern Highlands, Tanzania

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Abstract

A study on estimation of wood residues from small scale sawmill operations was conducted in Kawetire forest plantation in the Southern Highlands, Tanzania. It involved five (5) low technology (ding-dong) sawmills and one (1) high technology (WM) sawmill operating in the study area during data collection time. Five (5) saw logs were randomly selected from each diameter class (diameter class 1 = ≥ 30 cm, diameter class 2 = ≥ 20 cm, diameter class 3 = < 20 cm) for each sawmill making a total of 90 saw logs. Saw logs were measured for top, mid and bottom diameter and length. Saw logs were marked by assigning numerical numbers before conversion. Sawn timber produced were measured for sizes and length, marked with the same number with that of saw logs. The volume of saw logs and sawn timber, sawn timber recovery rate, percent of sawdust and slabs were computed. It was revealed that sawn timber average recovery rate for low technology (ding-dong) sawmills was 46.1%, average percent of sawdust and slabs were 3.3% and 50.6% respectively. It was revealed that sawn timber average recovery rate for high technology (WM) sawmill was 55.8%, average percent of sawdust and slabs were 2.4% and 41.8% respectively. One sample t-test and paired t-test revealed that no significant difference in conversion efficiency of low technology (ding-dong) sawmills and high technology (WM) sawmill in mean volume of sawn timber produced. However, it was revealed that there was significant difference in individual saw log conversion efficiency. Also, it was revealed that no significant difference in mean volume of sawdust and slabs generated from sawmills.

Keywords: Small Scale Sawmill, Saw Kerf, Sawdust, Slabs, Wood Residues, Wood Conversion Efficiency

1.0 Introduction

A sawmill is a processing industry equipped with various wood processing machines including band and circular saws. Sawmills have been established due to demand of sawn timber [2]. Sawmilling industry in developing countries is dominated by small scale and private establishments with lower sawn timber recovery rate due to non-controllable factors (size, quality and length of saw logs) [15] and controllable factors (kerf of the saw blade, sawing variation, experience of operators, maintenance of sawmill machine, sawing method and product mix) [11, 2]. Sawn timber recovery rate is the ratio of the volume of sawn timber (output) produced to that of saw logs (input) processed in a sawmill [2]. It is measured by recovery of sawn timber milled from a given volume of logs [7]. It is normally expressed as percentage [15]. It measures the efficiency of the sawmill [2] by comparing the quantity of finished product recovered from a log to that resulting into residues [15].

Wood residues from sawmills left as waste after log conversion is one of the sources contributing to the depletion of timber resources posing a challenge in sustainability of forest industries. Minimizing the amount of wood residues from sawmills, reduces the number of trees cut per year for sawn timber production [3, 4, 5]. Minimizing wood residues generated in sawmills is an important component for sustainable use of timber reducing threat to forests by increasing volume of timber (output) [1]. "The amount of wood residues produced from sawmills depends on the type of technology used and its efficiency" [8]. Advanced sawmill technology development improve sawn timber recovery rate per unit timber processed and decrease number of small sawmill operations [21].

A small scale sawmill can be defined as the one with installed capacity of sawing up to 1000 m^3 of logs per year [20]. In this study, low technology sawmill and high technology sawmill refer to ding-dong (Dd) and Wood-Mizer LT40 (WM) respectively (Photo 1 & 2). Ding-dong is a mobile micro-sawmill machine powered by diesel engine. It uses circular saw blade. This sawmill machine has no bench to support saw log when feeding it to the machine for sawing. During feeding of saw log for sawing, workers support it manually through the vertical circular saw blade [17]. According to PFP [17] an average of seven [7] employees work in each ding-dong sawmill. Too large saw logs that do not fit ding-dong saw, the size of saw logs is reduced using a chainsaw to fit pass through ding-dong saw [17]. Wood-Mizer LT40 sawmill is a mobile sawmill machine with horizontal narrow band saws. All size of saw logs fit Wood-Mizer LT40 saw. Band saws are highly mobile and can be set quickly [17]. An average of two (2) operators can work in Wood-Mizer LT40 sawmill.

Photo 1: Ding-dong Sawmill

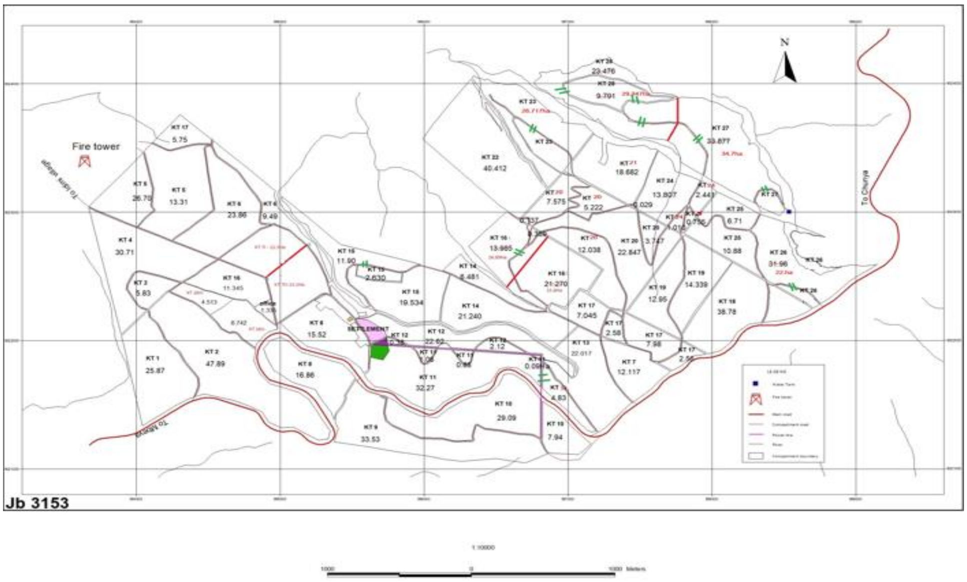
Photo 2: WM Sawmill

2.0 Materials and Methods

2.1 Study area

Kawetire forest plantation is a government forest plantation managed by Tanzania Forest Services Agency (TFS) under the Ministry of Natural Resources and Tourism. It is in Mbeya district in Mbeya region in the Northern Usafwa and part of Mbeya forest reserve [19]. Geographically, Kawetire forest plantation lies at latitude 8049′ South and longitude 33029′ East [18]. It receives average rainfall of 1,099 mm annually and temperature ranges from -5 ˚C to 35 ˚C. The humidity of the area is very low during dry season and near to saturation point during rainy season [19]. Kawetire forest plantation has a total area of 5,181.4 ha. This forest plantation is divided into six (6) ranges namely Kawetire (name of the mother forest plantation), Ipinda, Lwanjiro, Mbeya Peak, Mbeya fuel and Karuwe [18]. Small scale sawmills were operating in Kawetire forest range with 836.3 ha (Fig. 1).

Figure 1: A map of Kawetire Forest Range



2.2 Sampling method and sample size

This study focused only on the wood residues (sawdust and slabs) generated from low technology and high technology sawmills. It has not considered forest residues from logging or land clearing. A list of sawmills operating within Kawetire forest plantation was obtained from Kawetire forest plantation Manager's office. Five (5) ding-dong and one (1) WM sawmills which were in operation during data collection time were taken as a population. All six (6) sawmills (100%) were taken as a sample size (total sampling). In each sawmill sampled, saw logs were classified basing on diameter class to ensure that saw logs represent all saw log diameter classes. Three (3) diameter classes were used (diameter class 1 = ≥ 30 cm, diameter class 2 = ≥ 20 cm, diameter class 3 = < 20 cm). For each diameter class, five (5) saw logs were selected randomly making a total of 15 saw logs per sawmill and 90 saw logs for six (6) sawmills.

2.3 Data collection

Top, mid and bottom diameter, and length for each saw log were measured and saw log diameter class was determined using mid diameter. Saw logs were marked with numerical numbers using a marker pen before conversion. Sawn timber produced from each saw log were marked with the number of saw log produced such sawn timber, measured for length (m), thickness (mm) and width (mm), and counted with respective to size (thickness and width). The observed saw kerf in each sawmill included in the sample was determined using saw blade thickness and saw teeth setting. Five (5) saw teeth from each side of the saw blade making 10 teeth were selected randomly and measured for average teeth setting.

2.4 Computations

2.4.1 Volume of saw logs

The volume of each saw log was computed using Newton's formula [3, 4, 2].

$$\mathrm{Vlog} = \frac{\pi L}{24}\left(d_1{}^2 + 4d_m{}^2 + d_2{}^2\right) \qquad (1)$$

Where:

Vlog = Volume of saw log (m^3)

d_1 = diameter of saw log at the small end (m)

d_m = diameter of saw log at the middle part (m)

d_2 = diameter of saw log at the large end (m)

L = Length of saw log (m)

$\pi = 3.14$

2.4.2 Volume of sawn timber

The volume of sawn timber for a single piece was computed using equation 2 [2].

$$\mathrm{Vst} = T \times W \times L \qquad (2)$$

Equation 3 was used to compute volume for n pieces of sawn timber with the same length [3, 14].

$$\mathrm{Vst} = n(T \times W \times L) \qquad (3)$$

Equation 3 was modified to accommodate volume computation for n pieces of sawn timber with different length using equation 4.

$$\mathrm{Vst} = T \times W \times \mathrm{Rm} \qquad (4)$$

$$\mathrm{Rm} = \Sigma(n \times L)$$

Where:

Vst = Volume of sawn timber recovered (m^3)

W = Width of sawn timber (m)

T = Thickness of sawn timber (m)

L = Length of sawn timber (m)

n = Number of pieces of sawn timber from each saw log

Rm = Running metres (m)

2.4.3 Sawn timber Recovery Rate

Sawn timber recovery rate as a ratio of output to input [14] was computed using equation 5 [2].

$$\mathrm{RR}\ (\%) = \frac{\mathrm{Vst}}{\mathrm{Vlog}} \times 100 \quad (5)$$

Where:
RR = Sawn timber Recovery Rate (%)
Vst = Volume of sawn timber recovered (output) (m^3)
Vlog = Volume of saw log (input) (m^3)

2.4.4 Saw kerf

The observed saw kerf was determined using equation 6 [12].

$$K = 2S + B \quad (6)$$

Where:
K = Saw kerf (mm)
S = Saw set (mm)
B = Saw blade thickness (mm)

2.4.5 Volume of sawdust and slabs

The volume of sawdust (Vsd) and volume of slabs (Vsb) from each saw log were estimated using equations 7 and 8 respectively [15].

$$\mathrm{Vsd} = b.l \int_1^n w \quad (7)$$

Where:
Vsd = Volume of sawdust (m^3)
b = Kerf of the saw blade (m)
l = Length of saw log (m)
w = Width of each sawn timber (m)
n = Number of pieces of sawn timber from each saw log

$$\mathrm{Vsb} = \mathrm{Vlog} - (\mathrm{Vsd} + \mathrm{Vst}) \quad (8)$$

Where:
Vsd = Volume of sawdust (m^3)
Vlog = Volume of saw log (m^3)
Vsb = Volume of slab (m^3)
Vst = Volume of sawn timber (m^3)

2.4.6 Percentage of wood residues (sawdust and slabs)

The percentage (%) of sawdust and slabs were computed using equation 9 and 10 respectively. These equations were modified from Aina [3], Adu et al. [1].

$$\%\ \mathrm{Sawdust} = \frac{\mathrm{Vsd}}{\mathrm{Vlog}} \times 100 \quad (9)$$

$$\%\ \mathrm{Slabs} = \frac{\mathrm{Vslab}}{\mathrm{Vlog}} \times 100 \quad (10)$$

Where:
$\text{Vsd} = \text{Volume of sawdust } (\text{m}^3)$
$\text{Vlog} = \text{Volume of saw log } (\text{m}^3)$
$\text{Vslab} = \text{Volume of slab } (\text{m}^3)$

2.5 Data analysis

Microsoft Excel and Statistical Package for Social Sciences (SPSS) software were used for analysis. One sample t-test was used to test sawmills and individual saw log conversion efficiencies between low technology (ding-dong) sawmills and high technology (WM) sawmill. Furthermore, one sample t-test was used to test if there was significant difference in mean volume of wood residues (sawdust and slabs) generated from low technology (ding-dong) sawmills and high technology (WM) sawmill. It was also used to test if there was significant difference in mean volume of sawdust and slabs generated from individual saw log between low technology (ding-dong) sawmills and high technology (WM) sawmill. For one sample t-test, the mean volume of high technology (WM) sawmill was used as the hypothesized mean of the population. Paired t-test was used to test individual saw log conversion efficiency between low technology (ding-dong) sawmills and high technology (WM) sawmill. It was also used to test if there was significant difference in volume of sawdust and slabs generated from individual saw log between low technology (ding-dong) sawmills and high technology (WM) sawmill. All statistical tests were tested at a significance level of 5%. In these tests, a *p-value* ≤ 0.05 the difference was significant and verse versa.

3.0 Results

3.1 Wood conversion efficiency in small scale sawmills

The results of this study from five (5) low technology (ding-dong) sawmills and one (1) high technology (WM) sawmill sampled in the study area revealed that the mean volume of sawn timber at 95% confidence level, high technology (WM) sawmill had the highest mean volume of sawn timber compared to all low technology (ding-dong) sawmills. Furthermore, low technology (ding-dong) sawmills varied in mean volume of sawn timber at 95% confidence level. Low technology (ding-dong) sawmill 4 was leading followed low technology (ding-dong) sawmill 2 (Fig. 2).

The average sawn timber recovery rate for low technology (ding-dong) sawmills was 46.1% and that of high technology (WM) sawmill was 55.8%. Low technology (ding-dong) sawmills 2 and 5 were efficient almost as high technology (WM) sawmill while low technology (ding-dong) sawmills 1, 3 and 4 were less efficient compared to high technology (WM) sawmill (Fig. 3). The difference in average sawn timber recovery rate between low technology (ding-dong) sawmills and high technology (WM) sawmill was 9.7%. The slope of the trend line for high technology (WM) sawmill was steep compared to trend lines for all low technology (ding-dong) sawmills. The high technology (WM) sawmill converted large diameter saw logs compared to low technology (ding-dong) sawmills (Fig. 4).

One sample t-test revealed that there was no significant difference in conversion efficiency between low technology (ding-dong) sawmills and high technology (WM) sawmill at *p-value* = 0.163 when the mean volume of sawn timber produced from high technology (WM) sawmill was used as the hypothesized mean of the population. However, the same statistical test revealed that there was significant difference in individual saw log conversion efficiency between low technology (ding-dong) sawmills and high technology (WM) sawmill at *p-value* = 0.000 when the mean volume of sawn timber produced from high technology (WM) sawmill was used as the hypothesized mean of the population.

Paired t-test revealed that there was no significant difference in individual saw log conversion efficiency between low technology (ding-dong) sawmills 2, 5 and high technology (WM) sawmill at *p-values* = 0.165 and 0.137 respectively. The same statistical test revealed that there was slight significant difference in individual saw log conversion efficiency between low technology (ding-dong) sawmills 1, 3, 4 and high technology (WM) sawmill at *p-values* = 0.057, 0.054 and 0.067 respectively.

Figure 2: Mean of Sawn Timber Produced from Small Scale Sawmills

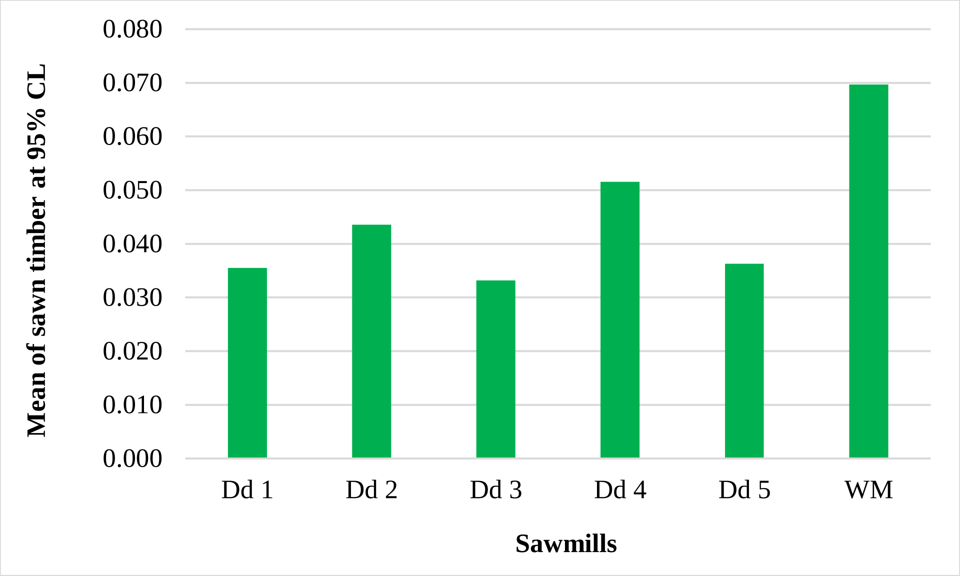


Figure 3: Sawn Timber Recovered from Small Scale Sawmills

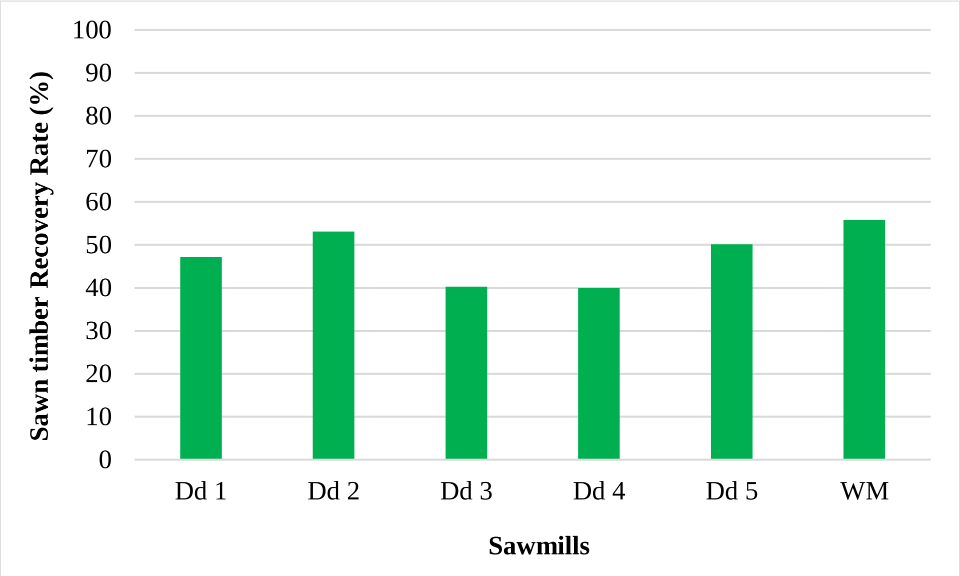
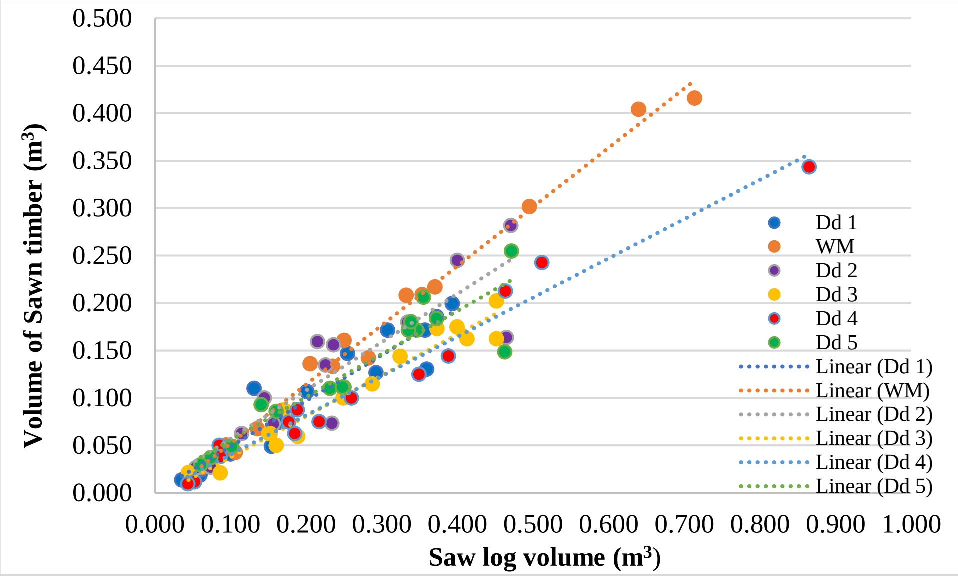


Figure 4: Saw Log Volume Vs Volume of Sawn Timber Produced from Small Scale Sawmills



3.2 Wood residues (sawdust and slabs) generated from small scale sawmills

The results of this study from five (5) low technology (ding-dong) sawmills and one (1) high technology (WM) sawmill sampled in the study area revealed that the average percent of sawdust and slabs generated from low technology (ding-dong) sawmills were 3.3% and 50.6% respectively while the average percent of sawdust and slabs generated from high technology (WM) sawmill were 2.4% and 41.8% respectively (Table 1). The differences in percent of sawdust and slabs generated from low technology (ding-dong) sawmills compared to that from high technology (WM) sawmill were 0.9% and 8.8% respectively (Table 1). High technology (WM) sawmill used narrow band saws with 2.0 mm saw blade thickness and saw teeth setting 0.30 mm generated less volume of sawdust compared to all low technology (ding-dong) sawmills used circular saws with saw blade thickness ranging from 4.0 mm – 5.5 mm. However, low technology (ding-dong) sawmills differ in volume of sawdust generated in relation to saw blade thickness. Low technology (ding-dong) sawmill 2 with saw blade thickness 4.0 mm and saw teeth setting 0.35 mm generated less volume of sawdust compared to other low technology (ding-dong) sawmills with saw blade thickness greater than 4.0 mm but the same saw teeth setting 0.35 mm.

The slope of the trend line for high technology (WM) sawmill was less steep compared to the trend lines for all low technology (ding-dong) sawmills. High technology (WM) sawmill generated less volume of sawdust and slabs compared to low technology (ding-dong) sawmills (Fig. 5 & 6).

Table 1: Volume of Wood Residues (Sawdust and Slabs) Generated from Small Scale Sawmills

Sawmill	Vlog (m^3)	Vsd (m^3)	Vsb (m^3)	% Av. Sawdust	% Av. Slab
Dd 1	3.241	0.129	1.543	3.2	49.7
Dd 2	3.514	0.118	1.515	3.3	43.6
Dd 3	3.858	0.125	2.176	2.9	56.8
Dd 4	3.969	0.126	2.223	2.7	57.4
Dd 5	3.946	0.172	1.831	4.3	45.6
Average	3.706	0.134	1.857	3.3	50.6
WM	4.336	0.114	1.676	2.4	41.8

Difference	0.630	0.020	0.181	0.9	8.8

One sample t-test revealed that there was no significant difference in mean volume of sawdust and slabs generated from low technology (ding-dong) sawmills and high technology (WM) sawmill at *p-values* = 0.705 and 0.765 respectively when the mean volume of sawdust and slabs generated from high technology (WM) sawmill was used as the hypothesized mean of the population. The same statistical test revealed that there was no significant difference in mean volume of sawdust and slabs generated from individual saw log between low technology (ding-dong) sawmills and high technology (WM) sawmill at *p-values* = 0.119 and 0.220 respectively when the mean volume of sawdust and slabs generated from high technology (WM) sawmill was used as the hypothesized mean of the population.

Paired t-test revealed that there was no significant difference in mean volume of sawdust generated from individual saw log between low technology (ding-dong) sawmills 1, 2, 3, 4 and high technology (WM) sawmill at *p-values* = 0.639, 0.882, 0.694 and 0.712 respectively. However, there was significant difference in mean volume of sawdust generated from individual saw log between low technology (ding-dong) sawmill 5 and high technology (WM) sawmill at *p-value* = 0.028. The same statistical test revealed that there was no significant difference mean volume of slabs generated from individual saw log between low technology (ding-dong) sawmills 1, 2, 3, 4, 5 and high technology (WM) sawmill at *p-values* = 0.674, 0.474, 0.104, 0.247 and 0.613 respectively.

Figure 5: Saw Log Volume Vs Volume of Sawdust Generated from Small Scale Sawmills

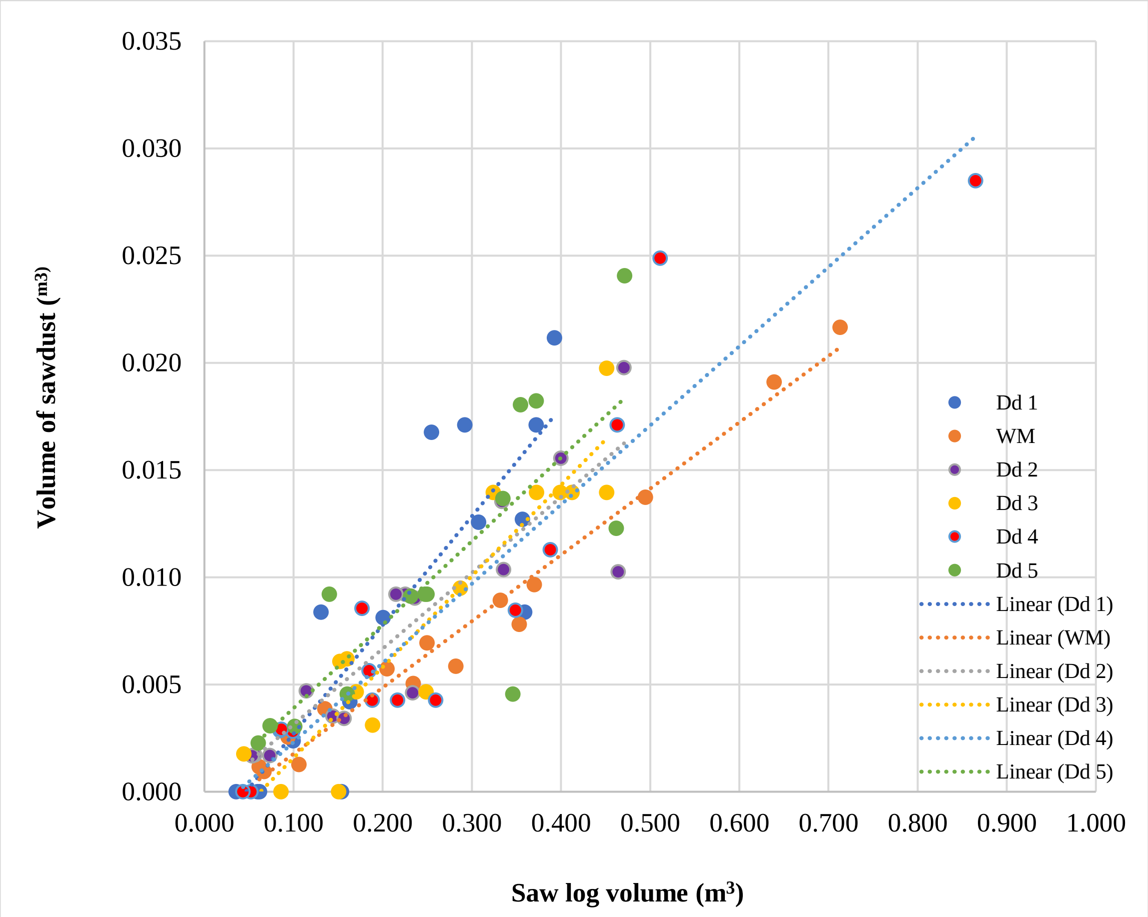
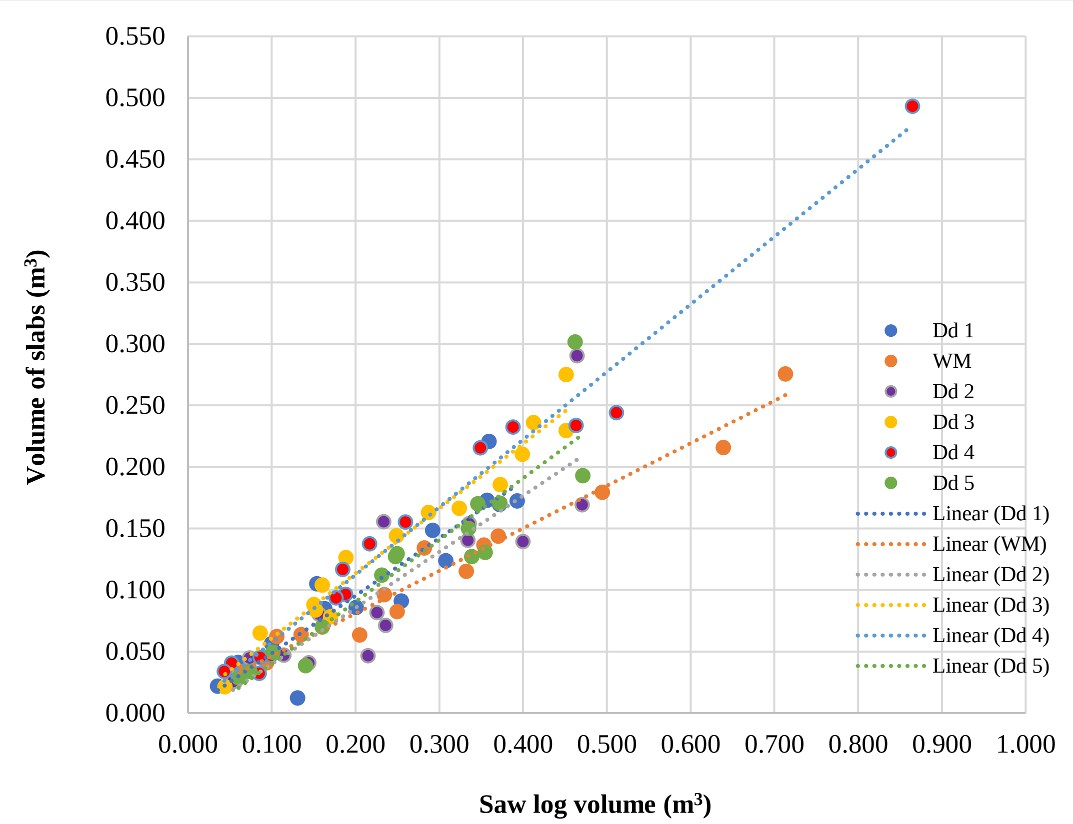


Figure 6: Saw Log Volume Vs Volume of Slabs Generated from Small Scale Sawmills



4.0 Discussion

4.1 Wood conversion efficiency in small scale sawmills

The conversion efficiency of sawmills was measured by the volume of sawn timber produced. The conversion efficiency of sawmills was not significantly difference between low technology (ding-dong) sawmills and high technology (WM) sawmill. One sample t-test revealed that the conversion efficiency of individual saw log differed significantly between low technology (ding-dong) sawmills and high technology (WM) sawmill in the study area due to saw log's size and form, saw kerf and sawmill operator's skills and experience in sawing operations. Saw logs with large diameter and good form have high sawn timber recovery rate compared to those with small diameter and poor form. This agrees with the finding reported by Egbewole et al. [6] that large diameter logs have high sawn timber recovery rate compared to small diameter. Also, Aghimien et al. [2] reported that large girth and straightness of logs increase sawn timber recovery rate while small girth and poor form reduce sawn timber recovery rate. Paired t-test revealed that there was no significant difference in individual saw log conversion efficiency in some low technology (ding-dong) sawmills compared to high technology (WM) sawmill while there was slight significant difference in some low technology (ding-dong) sawmills compared to high technology (WM) sawmill. This was contributed by saw kerf, sawmill operator's skills and experience, and saw log's size and form. A study conducted in Ghana by Owusu et al. [16] reported that sawmill machines technology differ in log conversion efficiency. Low technology (ding-dong) sawmills' saws were maintained when needed while for high technology (WM) sawmill's saws were maintained daily. Olufemi et al. [15] reported that log conversion efficiency can be improved by adequate maintenance of sawmill equipment.

The average sawn timber recovery rate of low technology (ding-dong) sawmills was low compared to that of high technology (WM) sawmill. This finding agrees with the finding reported by Owusu et al. [16] in Ghana that high technology sawmills have high percentage mean recovery rate compared to low technology sawmills. Furthermore, it agrees with the finding reported by Kambugu et al. [10] in Uganda that the average log conversion efficiency of band sawmills was high compared to that of locally manufactured sawmills. PFP [17] reported that most sawmills using band saws have high sawn timber recovery rate. High technology (WM) sawmill was able to convert saw logs with large diameter while the same saw logs were not possible to convert using low technology (ding-dong) sawmills without reducing the size by using a chainsaw which contributed to reduce sawn timber recovery rate. It was observed that sawn timber produced from low technology (ding-dong) sawmills have rough surface compared to sawn timber produced from high technology (WM) sawmill. This agrees with the finding reported by Ngaga [13] and PFP [17] that ding-dong sawmills produced poor quality and rough surface sawn timber.

The average sawn timber recovery rate of low technology (ding-dong) sawmills revealed in this study was higher than the values revealed by other studies conducted in ding-dong sawmills in the country. A study conducted by Naburi [12] in ding-dong sawmills operated around Sao Hill Forest Plantation in the Southern Highlands, Tanzania reported that the average sawn timber recovery rate was 27%. A study conducted by Ngaga [13] at Sao Hill Forest Plantation in the Southern Highlands, Tanzania revealed that the sawn timber recovery rate in ding-dong sawmills was 33%. Furthermore, the study conducted by PFP [17] in the Southern Highlands, Tanzania revealed that ding-dong sawmills have sawn timber recovery rate of 25 – 35%. The study conducted in ding-dong sawmills in Njombe in the Southern Highlands, Tanzania by Hingi [9] reported that the sawn timber recovery rate was 20 – 35%. The reason for the difference in values reported by studies above and the finding of this study could be due to saw log diameter, saw log form, saw kerf, skills and experience of sawmill operators in sawing operations among other factors that can affect sawn timber recovery rate. Eguakun and Nwankwo [7] reported that low sawn timber recovery rate for circular sawmills was the result of saw kerf, age of machines and the experience of the sawmill operators. It was observed that there were sawing variations of sawn timber within low technology (ding-dong) sawmills and within a single board of sawn timber produced. This could have been contributed by handling of saw logs by two (2) operator's helpers at each end of the saw log during sawing. Olufemi et al. [15] reported that log conversion efficiency can be improved by ensuring level of accuracy of sawyers.

4.2 Wood residues (sawdust and slabs) generated from small scale sawmills

The inefficiency conversion of sawmills was measured by the volume of wood residues (sawdust and slabs) generated. One sample t-test revealed that there were no significant differences in mean volume of wood residues (sawdust and slabs) generated from sawmills and individual saw log between low technology (ding-dong) sawmills and high technology (WM) sawmill. Paired t-test revealed that there was no significant difference in mean volume of sawdust and slabs generated from individual saw log between low technology (ding-dong) sawmills and high technology (WM) sawmill. However, there was significant difference in mean volume of sawdust generated from individual saw log in low technology (ding-dong) sawmill 5 and high technology (WM) sawmill. This was contributed by large saw kerf of the low technology (ding-dong) sawmill 5.

The average percent of wood residues (sawdust and slabs) generated from low technology (ding-dong) sawmills indicated that high percent of saw logs was converted to wood residues (sawdust and slabs) compared to sawn timber recovered. Aghimien et al. [2] reported that sawmills with high volume of wood residues have low volume of sawn timber recovered. Also, the findings of this study are within the range of the findings reported by Asamoah et al. [5] in Ghana that 45% to 55% of saw log input to a sawmill become waste and the findings reported by Olufemi et al. [15] in Nigeria that wood residues were 43.92% of saw logs input. PFP [17] reported in the Southern Highlands, Tanzania that ding-dong sawmills produce large volume of wood residues, however the percent of wood residues was not revealed.

The average percent of wood residues (sawdust and slabs) generated from low technology (ding-dong) sawmills was high compared to that from high technology (WM) sawmill. This was contributed by sawmill operator's skills and experience, saw kerf and saw log form. The circular saw blade thickness for ding-dong sawmills ranged from 4.0 mm – 5.5 mm with the uniform saw teeth setting 0.35 mm making the saw kerf of 4.7 mm – 6.2 mm. This contributed to the volume of sawdust generated from low technology (ding-dong) sawmills while the narrow band saw blade thickness for high technology (WM) sawmill was 2.0 mm with the saw teeth setting 0.30 mm making the saw kerf of 2.6 mm. The finding of this study on maximum saw kerf for low technology (ding-dong) sawmills was the same as the finding reported by Naburi [12] that the average saw kerf of low technology (ding-dong) sawmills was 6.2 mm. Furthermore, this finding relates to the finding reported by Kambugu et al. [10] in Uganda that locally manufactured sawmills operating in softwood plantations using circular saws with average kerf width of 8.2 mm generated more sawdust compared to band saws with average kerf width of 2.75 mm. Large percent of slabs generated from ding-dong sawmills was contributed by large diameter saw logs with poor form making difficult to saw since sawmill operator's helpers used hands as a bench to fit saw logs into the machine. It was observed that no re-sawing of slabs in low technology (ding-dong) sawmills. However, low technology (ding-dong) sawmills 1 and 2 generated a bit less volume of slabs compared to high technology (WM) sawmill. This could have been contributed by small diameter saw logs with poor form sawn using high technology (WM) sawmill. Olufemi et al. [15] reported that greater volume of slabs generated can be contributed by greater variations in log forms.

It was observed that in all low technology (ding-dong) sawmills' operators used "Through and Through" sawing method ending producing large slabs. High technology (WM) sawmill's operator used "Cant" sawing method to maximize sawn timber produced. Olufemi et al. [15] reported that log conversion efficiency can be improved by positioning saw log properly and turning frequently due to variation in shape and form of saw logs to minimize wood residues generated. Sawmill operators had experience between 3 to 5 years in sawing operations. This could have contributed to the amount of wood residues generated. Eguakun and Nwankwo [7] reported that sawmills operated by circular saw operators with little experience (0 – 5 years) have less lumber recovery rate and therefore generate more wood residues.

5.0 Conclusions

The sawn timber average recovery rate for low technology (ding-dong) sawmills was 46.1% and that of high technology (WM) sawmill was 55.8%. There was no significant difference in sawmills conversion efficiency between low technology (ding-dong) sawmills and high technology (WM) sawmill. However, there was slight significant difference in individual saw log conversion efficiency except for low technology (ding-dong) sawmills 2, 5 and high technology (WM) sawmill.

The average percent of sawdust and slabs generated from low technology (ding-dong) sawmills were 3.3% and 50.6% respectively and that from high technology (WM) sawmill were 2.4% and 41.8% respectively. There was no significant difference in mean volume of sawdust and slabs generated from low technology (ding-dong) sawmills and high technology (WM) sawmill. However, low technology (ding-dong) sawmill 5 and high technology (WM) sawmill differed significantly in mean volume of sawdust generated from individual saw log.

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Abbreviations and Acronyms

Dd	-	Ding-dong
FAO	-	Food and Agriculture Organization
PFP	-	Private Forestry Programme
TFS	-	Tanzania Forest Services Agency
URT	-	United Republic of Tanzania
WM	-	Wood-Mizer LT40