

Productivity and Energy Expenditure by Sawyers When Using Pitsawing and Portable Steel Log Sawing Platforms in Agroforestry Farms

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Abstract

Although the future increase in timber supply in many countries is expected to come from agroforestry farms, the problem of on farm timber sawing, physical strain on sawyers caused by "Pitsawing" have to be addressed in order to increase the timber sawing productivity. This study was designed to analyze the productivity and energy expenditure by sawyers when using Pitsawing platforms (PSP) and Portable Steel Log Sawing Platforms (PLSP) in agroforestry farms. The study was conducted in South Kilimanjaro in Kiruweni and Nduweni villages. Data on energy expenditure were obtained through heart rate measurement by using heart rate monitor. Productivity data of both Pitsawing and Portable log sawing platforms were obtained through time studies by using stop watch. Microsoft Excel spread sheet was used for data analysis. Results indicated that when using PLSP site preparation production rates increased from 0.1 m³ per hour observed under PSP to 2.9 m³/h. The skidding production rate when using PSP technique was 3.5 m³/h while when using PLSP, the production rate was 11.9 m³/h. Loading productivity improved from 4.97 m³/h when using PSP to 7.27 m³/h when using PLSP. Sawing productivity improved from 0.055 m³/h when using PSP to 0.057 m³/h and the Energy Expenditure (EE) for the same work element was 12.69 kJ/min and 12.4 kJ/min respectively. During pit/structure assembling, PLSP reduced the energy expenditure from 14.05 kJ/min to 2.61 kJ/min and the physical workload were classified as unduly heavy and light respectively. For the skidding work element PLSP minimized the energy expenditure from 5.88 kJ/min to 4.48 kJ/min, the same to loading work element, the EE decreased from 5.20 kJ/min to 3.55 kJ/min. Therefore, based on overall results it is concluded that, the PLSP is technically more appropriate technology or method for reducing energy expenditure and for increasing productivity during timber harvesting in agroforestry farms.

Key words: *Productivity, Energy expenditure, Pitsawing and Portable log sawing*

1. Introduction

In recent years, demand for timber and other forest products has been increasing at local, national and international levels (Nilsson, 2005). Timber supply from natural forests is dwindling because of conservation, environmental and social concerns while expansion of industrial plantations is limited by competition from alternative land uses. This implies that future increase in timber supply in many countries will come from other sources such as agroforestry farms (Enters and Durst, 2004). However most of agroforestry farms are often established with the thought of improving agricultural yield but with little consideration about how tree harvesting operations will be carried out when trees mature. Apart from that, these farms are small in size compared to other forest plantations, thus tree harvesting must be done selectively which lead to higher cost of timber extraction for every tone of logs. The common method used for on farm timber processing in many developing countries is ‘pitsawing’.

According to Kweka and Mganilwa (2004) digging causes a lot of soil disturbances and damage to the environment. Pitsawing has also been reported to cause heavy physical workload and stress to pit sawyers (Ole Meiludie *et al.* 1988; Strehlke, 2003) To minimize these negative consequences of using ‘pitsawing’ technique, Kweka (2007) designed a Portable Steel Log Sawing Platform (PLSP). Studies done on PLSP showed that, the platform reduces most of environmental damages, occupational accidents and increases workers productivity. However, the question remains whether the reported increased production rate when using PLSP goes hand in hand with reduction in Energy expenditure or physical workload. This study was therefore conducted to determine the productivity and energy expenditure of sawyers when using pitsawing and portable steel logsawing platform in Agroforestry farms.

2. Materials and methods

Study area

The study was done within the agroforestry zone on the Southern slopes of Mountain Kilimanjaro ($3^{\circ}00' - 3^{\circ}20'S$ and $37^{\circ}00' - 37^{\circ}40'E$), in Northern Tanzania. Two villages namely Kiruweni and Nduweni were selected for the study due to their participation in a study to test

the designed Portable Steel Log Sawing Platforms (PSLSP) (Kweka et al, 2007). Rainfall pattern is bimodal with short rains and long rains with an annual average of between 1,000 to 1,700 mm. In general, the soils are fertile volcanic ash with a high base saturation and high cation exchange capacity.

Methods

Energy expenditure

Four males performing manual timber sawing activity regularly were selected for the study. Physical characteristics (height and weight) were measured using tape measure and weighing balance (scale) respectively. Heart rate monitor was attached (tied) to every subject under study and switched on, to record the heart rate at every minute during the sawing operation. Before starting working, subjects were requested to sit on a chair for approximately 15 minutes and their resting heart rate was recorded. Heart rate per minute was recorded on each work element as it proceeded. At the end of work for the day, the subjects were requested to seat on a chair again and rest for 15 minutes and the recovery heart rate per minute was recorded. At the end of the session, the heart rate monitor was detached from the subjects and data from the monitor was manually transferred to the computer and analyzed.

Time study and productivity

Time studies to assess the efficiency of log sawing operations in small scale timber production in agroforestry farms when using both pitsawing and portable steel log sawing platforms were conducted in accordance with generally accepted work study procedures described in IUFRO (1995) using time study data sheet. Cumulative timing methods by the Snap back or Zero reset timing method was used to collect production data for each work element. Log sawing was comprised of a set of activities used to saw the tree log into planks. Depending on the method, the activities time study elements were segregated into: pit excavation and platform assembling; skidding the log to the pit; loading and sawing. In this study, the PLSP work elements were: platform assembling; skidding; loading and sawing, apart from productive times, delay times were also recorded. The work elements mentioned above were studied to establish time

consumed on each work element and to estimate the production rate of each work element.

Data analysis

Data were summarized by descriptive statistics using Microsoft Excel spread sheet. Based on the collected data, valid statistical models for estimating energy expenditure on sawyers and physical workload classification were used.

Based on the heart rate records the following parameters were calculated.

- i. Average heart rate during rest, work and recovery period.
The energy expenditure per minute (kJ/min) was estimated from average heart rate (Av HR in beats/minute) using the following formula and the classification of work load was as per (McArdle *et al.*(2001)

$$\text{Energy Expenditure} = 0.159 \times \text{Av HR} - 8.72$$

Productivity

Mathematical models based on time study data were used to calculate the average production rates and generate productivity model for each work element of both pitsawing and portable steel log sawing platforms.

Log volume was computed using Huber's formula as shown in the following equation which was then used to determine the sawing production rates of both pitsawing and portable steel log sawing platforms.

$$Lvol = \frac{\pi md^2 L}{4}$$

Where:

- $Lvol$ = Log volume (m³)
 π = pi = $\frac{22}{7}$
 md = log mid-diameter (m)
 L = log length (m)

Production rate equation

$$P = \frac{(Tvol)(F)(60)}{T}$$

Where:

P = productivity in (m³) for a given sawing operation, m³/h

$Tvol$ = total volume of all sawn logs for a given sawing operation, m³.

60 = number of minutes per workplace hour,

F = proportion of productive time to workplace hour,

T = the average productive time (minutes) (can also be estimated using a regression model developed for the productive times)

$$F = \frac{100 - D}{100}$$

Where: F = a fraction measuring the proportion of productive time.

D = delay time expressed as percentage of workplace time

This formula was used to determine the sawing production rates of both traditional pitsawing and portable steel log sawing methods.

3. Results and discussion

Energy expenditure when using Pitsawing Platform (PSP)

Sawing was performed with a two man ripping saw weighing about 5kg. The average heart rate recorded while performing the pit excavation was 143.21 beats/min (Table 1) while energy expended was 14.05kJ/min and the workload was classified as unduly heavy workload. For skidding when using PSP method the average heart rate was 91.86 beats/min which consumed about 5.88kJ/min, thus skidding work element was classified as moderately heavy. Slightly less energy was required for loading (5.2kJ/min) at the heart rate of 87.55 beats/min and hence classified as moderately heavy. Energy demanded to perform the core activity of sawing was high (12.69kJ/min) at the heart rate of 134.68 beats per minute. The sawing work element was classified as very heavy workload. These results show that sawing was the second activity to pit excavation with respect to energy expenditure on sawyers. After the sawing

activities, workers were given 15 minutes for recovery heart rate recording which was 2.95kJ/min and classified as a light workload.

Table 1: Peak heart rate and energy expenditure of the sawyers while using pitsawing platform (PSP)

Activity	Working heart Rate (beats/min)		Energy Expenditure (kJ/min)		Classification of work load	
	Average	Peak	Average	Peak	Average	Peak
Pit/platform	143.21	159	14.05	16.56	Unduly heavy	Unduly heavy
Skidding	91.86	120	5.88	10.36	moderate	heavy
Loading	87.55	127	5.20	11.47	moderate	heavy
Sawing	134.68	150	12.69	15.13	Very Heavy	Unduly Heavy
Recovery	73.4	98	2.95	6.86	Light	moderate

Energy expenditure when using Portable Log Sawing Platform (PLSP)

The results in Table 2 show the energy expenditure on each work elements when using the portable log sawing platform. Comparing to the traditional pitsawing method (PSP), this method is less energy demanding. Therefore, the results revealed that 2.61kJ/min was spent for the structure assembling activity and the workload was classified as the light workload, on skidding work element, workers spent 4.48kJ/min which is the light workload, loading and sawing consumed 3.55 and 12.4kJ/min and were classified as light and very heavy workload respectively. After performing the work, the same as in traditional pitsawing method, the workers were also given 15 minutes for heart rate recovery and therefore the results show that the energy expenditure of resting for recovery heart rate was 2.43kJ/min. In this method, sawing is the only energy demanding activity since the sawyers spent 133.74 beats/min which is higher than the allowable HR for eight hours (108.15beats/min).The decrease of energy expenditure when using PLSP is due to the use of pulley block when loading and the fact that this structure can be erected near the log to be sawn since it is portable, so all of these parameters

reduces the workload on sawyers and it cuts down the time needed for the whole operation which increases the productivity.

Table 2: Average and peak heart rate and energy expenditure of the sawyers while using Portable Steel Log Sawing Platform (PLSP).

Activity	Working heart Rate (beats/min)			Energy Expenditure (kJ/min)		Classification of work load	
	Average	Peak	Number of observations	Average	Peak	Average	Peak
Structure assembling	71.26	99	80	2.61	3.78	Light	light
skidding	83.08	99	78	4.48	5.98	Light	moderate
loading	77.23	97	67	3.55	5.39	Light	moderate
Sawing	133.74	174	105	12.4	18.94	Very Heavy	Unduly Heavy
Recovery	70.16	92	73	2.43	5.90	Light	moderate

Productivity

Work and time studies were carried out when log sawing on the two types of platforms. Main work elements studied included pit excavation (for PSP only), skidding/rolling the log to the ‘pit’ or platform, loading the log on the sawing pit or platform and finally sawing the log. These work elements were studied to establish time consumed for each work element and to estimate the production rate of each element.

Productivity of Pitsawing Platforms (PSP)

The productivity for PSP method was 0.055 m³ per hour. These results are similar to those reported by Kijoti and White (1981), Migunga (1985) and Kweka (2007), whose pitsawing productivity were 0.054, 0.088 and 0.06 m³/h, respectively. Pit excavation work element productivity was 0.1 m³ per hour (Figure 1).

Skidding and loading work elements productivities were much higher than those of pit preparation and sawing. In PSP method, the skidding and loading productivities were 3.5 and 4.97 m³/h respectively.

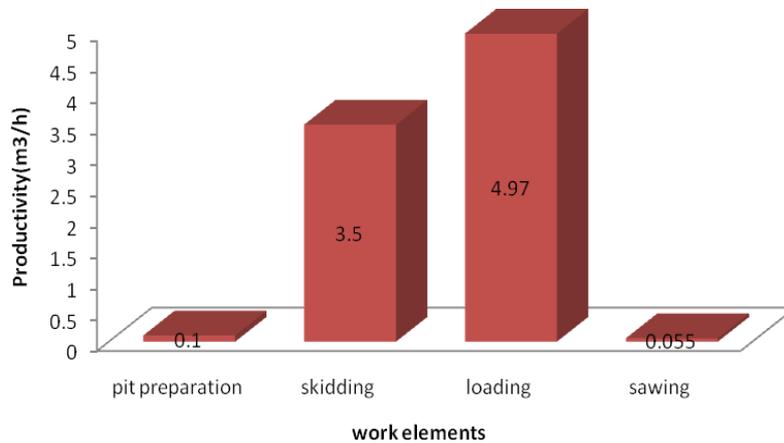


Figure 2: Productivity of each work element when using pitsawing platform (PSP)

Productivity of Portable Steel Log Sawing Platform (PLSP)

The sawing productivity for portable log was 0.057 m³/h. Structure assembling work element productivity was 2.9 m³/h (Figure 2). Skidding and loading work elements productivities were much higher than those of Structure assembling and sawing. In portable log sawing platforms, the skidding and loading productivities were 11.9 and 7.27 m³/h respectively.

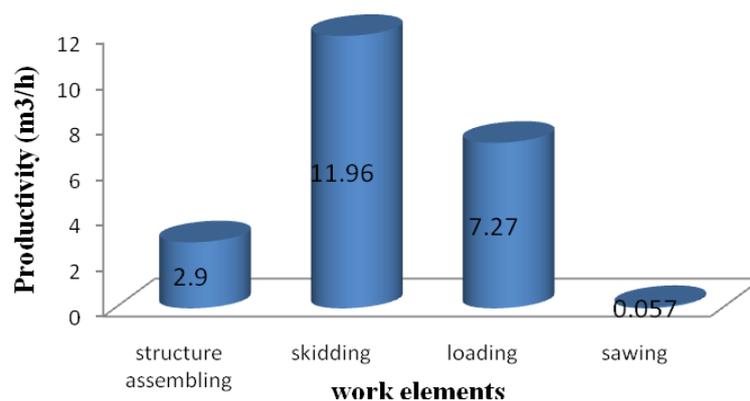


Figure 3: Productivity of each work element when using PLSP)

4. Conclusion

Despite the fact that currently tree harvesting for timber production in agroforestry farms is a profitable venture, minimization of energy expenditure or physical workload on sawyers could increase sawing productivity and minimize the sawing cost. As the aim of this study was to compare productivity and energy expenditure of sawyers when using Pitsawing Platforms (PSP) and the Portable Log Sawing Platforms (PLSP), it can be therefore concluded that Portable Logsawing Platforms (PLSP), is more productive, economic and reduces the physical workload on sawyers than Pitsawing according to the results of this study. Therefore, it could be concluded that the Portable Log Sawing Platform (PLSP) could be the most appropriate technology to be adopted for increasing productivity and reducing physical workload on sawyers during timber sawing operations in agroforestry farms.

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