TIMBER FOREST PRODUCT RECOVERY EFFICIENCY OF HORIZONTAL BAND SAW, CIRCULAR SAW AND CHAIN SAW MACHINES IN SAWMILL INDUSTRIES IN NIGER STATE, NIGERIA

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Abstract
This study was carried out in Zone-B comprising Bosso, Gawu-Babangida, Kagara, Kusherki, Minna, Shiroro and Tafa Local Government Areas of Niger State to determine the efficiency in the rate of timber recovery of horizontal Band saw, circular saw and Chain saw machines. The production levels were investigated in percentages and compared to machine output rating of 17m³ or 600ft³ of timber per eight hour work period for non automated machine plant. Result shows recovery rates of 27.11%, 75% and 14.15% for horizontal Band saw, circular saw and Chain saw machines respectively. Result also shows very low performance of horizontal Band saw, circular saw and Chain saw. It was recommended that the industry should invest in advanced modern technology of timber processing to achieve higher recovery rates and reduce wastages of forest products; make the work safer, more attractive, train employees on maintenance and safety practices to improve efficiency of machine and labour.

Keywords: Sawmill Efficiency, Timber Forest Products (TFP), Timber Conversion, Timber Recovery.

Introduction

Sawmilling is primarily an industrial process that consists of a system of converting logs into usable marketable products. Conversion of timber involves primarily sawing logs into marketable sizes (primary conversion) or forms that will require further conversion or processing (re-sawing or secondary conversion). According to the Forest Product Economic Research ((FOPER), 2015), the major Timber Forest Products (TFP) categories produced by sawmills industry are sawn timber, wood-based panels, wood chips, pulpwood and miscellaneous others including poles and railway sleepers. Flakes, strips, bark, sawdust and slabs that are less than 3.6 metres in length where discarded as wastes (Saba & Mohammed (2004). The recovery of Timber Forest Products (TFP) other than solid timber may require different conversion or processing using automated machines.

Current trend in timber conversion involves the use of automated machines and labour. Caswell (2015) observed that computers, conveyors, scanners, lasers, digital cameras, and bar coding systems do most of the work. The saws are flexible band saws. Employees are mainly to double check the computers and intervene if there's a problem. Machines are used for debarking, transporting, scanning and processing timber for various uses including building larger stock from smaller strips providing a stronger and stable construction timber. According to Caswell (2015) all this technology is directed at plant efficiency and that efficiency is all about having less sawdust and chips out the door and more timber go out the door,"

The trend in Northern States of Nigeria of transporting primary converted timber rather than logs, from the forest to mill sites suggest an unprecedented rise in the number of sawyers that fell trees and carry out primary conversion at felling sites. The researcher observed that major machines used by sawmill industries in Niger State include horizontal band saw, Circular saw and chain saw. Saastamoinen & Matero (2014) posited that there exist a high number of outdated sawmills operating with a lower than 40% recovery rates. This clearly suggests lack of efficiency of timber processing by such sawmill industries. Conversion at felling site is often carried out using chain saw or horizontal band saw. It is easier to convey primary converted timber to re-sawing mills for final conversion. This study investigates the timber recovery rates of horizontal band saw, circular saw and chain saw machines in order to estimate wastages resulting from inefficient timber processing by sawmill industries in Niger state.

Efficiency in Timber Recovery

Timber processing technologies have in recent time undergone extraordinary advances especially in terms of timber recovery efficiency, higher qualities in terms of durability and protection, higher utilization of TFPs as well as the development of new products such as reconstituted wood-panels that include plywood, hardboard, fiberboard, and flake board. Sawmill industry can also process smaller log diameters today (FOPER, 2015). One way to determine a mill's efficiency is to measure its ability to cut timber consistently within specified thickness standards. Lunstrum (1993) identified two basic factors that may affect lumber sizing accuracy: first, the mechanical capability of sawing within given tolerances and second, the human capability of determining the correct setting.

> Meil, Wilson, O'connor & Dangerfield (2007) reported that in 1968, the Committee on Renewable Resources for Industrial Materials (CORRIM) found that log volume of 17,920 cubic feet (507 m3) of wood produced only 3,640 ft3 (103 m3), 20.31% of timber product in 1948, while 14,280 ft3 (404 m3), 79.69% was burned or used for fuel. The same harvest volume produced 4,617 ft3 (131m3), 25.76% of timber as the result of gradually improving mill utilization in 1968. Also in 1970 it was determined that one metric ton (t)(2,205 lbs) of logs (including bark) yielded 0.35 t (35%) of timber, 0.29 t of pulp chips, 0.11 t of sawdust, 0.15 t of planer shavings and 0.10 t of bark".

The sawmill industry currently utilizes the whole tree from previously under used hardwood and softwood species living little on the forest floor. The results of a detailed mill survey carried out in 1999/2000 by CORRIM II and reported by Meil, Wilson, O'connor & Dangerfield (2007) indicated that one metric ton of logs (including bark) yielded 0.45 t of lumber, 0.31 t of pulp chips, 0.08 t of sawdust, 0.06 t of planer shavings and 0.11 t of bark. Logs are sawn into timber using variety of techniques. Sometimes logs are selected for special purposes and are cut (converted) accordingly; otherwise the method which will produce the highest timber output is used. Thomas (2009) categorized the sawing patterns into three, namely, Live Sawing, Quadrant sawing and Cant sawing.

Factors Determining Timber Recovery in Sawmill.

There are several methods of determining the efficiency of timber recovery. Two basic methods that lend to this study are: 1) cubic volume of timber as a percentage of total log volume, and 2) board feet of timber from a given cubic volume of logs commonly known as Timber Recovery Factor (TRF). This study adopted the TRF method. Charles, Keegan, Todd Morgan, Blatner, and Daniels (2010) used TRF to compute the recovery rates of some selected timber. Factors determining timber recovery include characteristics of the Log (diameter, length, taper, and quality), Kerf width, Sawing variation, rough green-lumber size, and size of dry-dressed lumber, Product mix, decision making by sawmill personnel, and condition and maintenance of *mill* equipment and Sawing method (Steele, 1984).

Naturally large diameter logs yield more TFP than small diameter logs. However, this may depend upon, i) the length of the log. Longer logs will produce more yield than shorter ones; ii) the amount of taper, that is, differences between the diameter of the two ends; and iii) the soundness of the log; a crocked log will yield less timber compared to straight log. The width of cut otherwise referred to as kerf width can affect yield. Narrow kerfs will produce higher recovery. The variation in sawing method can also affect yield. Radial method will yield less timber than live sawing and boxed sawing. The sizes of timber and the allowances that may be required for planning must be determined during sawing which also affects recovery rates, smaller size timber will produce fewer yields than larger sectioned timber; recovering the same sizes of wider boards and heavier timber from a particular log can lower timber yield. Also, differences in the shape and sizes of logs demands that machine operators make thousands of decisions every day. Fatigue, lack of knowledge or ability, or carelessness can mean poor decisions and recovery of product. In an advanced sawmill the log is scanned and the sizes that will produce more yields is determined.

Machine/Labour Efficiency

Efficiency is the state of being competent, effective in performance or the ability to produce a desired effect or product with minimum effort, cost expenditure of time and waste. For example, efficiency of a machine is determined by the ratio of work done (output) to the energy that supplied (input) the work. Bryan (1996) observed that sawmill efficiency is dictated by the total production cost and production value (timber) of a given mill. In order to achieve maximum efficiency, the later must exceed the former.

Advanced sawmill industry use computers, conveyors, scanners, lasers, digital cameras, and bar coding systems to improve sawmill efficiency. The saws are flexible band saws. In a typical sawmill, the amount of seful timber produced per day by an installed machine and the capacity of the operator to handle different sizes and species of logs supplied is termed efficiency. Alan & Bayard (2012) identified technological innovation, rate of utilization of capacity, change in scale of output, capital investment per worker and entrepreneurial skills as contributors to changes in efficiency.

Technological innovations are major contributors to efficiency in TFP recovery. Meil, Wilson, O'connor & Dangerfield (2007) found that process improvements in chipping technology, thinner kerf saws, curve sawing, and computerized scanning and optimization" technology have led to better recovery of higher value products such as timber and pulp chips in favor of sawdust and planer shavings. Steady improvement in processing technology as well as new product development has herald the utilization of TFPs and kept waste down from about 79.69% in 1948 to almost zero percent by the year 2000. Below is a summary of findings on the recovery rates for five TFPs for periods between 1970 and 2000.

Table 1:
Material balance for conversion of 1 ton of logs with bark into softwood lumber (based on oven dry weight)

CORRIM I	1970	1985a	CORRIM II 2000a	1999/2000
Lumber	0.35	0.40	0.45	0.45
Pulp chips	0.29	0.29	0.29	0.31
Sawdust	0.11	0.08	0.08	0.07
Bark	0.10	0.10	0.10	0.11
Planer shavings	0.15	0.13	0.08	0.06
Total	1.00	1.00	1.00	1.00

Source: Meil, Wilson, O'connor & Dangerfield (2007).

Machine and labour efficiency are inter-related given the considerable level of manual operations involved in log conversion operations in Nigeria's sawmill industry. A horizontal band saw (commonly used by sawmills studied) is rated at 17m^3 (600 linear ft) of timber per eight hour shift by the manufacturers.

Aim and Objectives of the Study

The study was carried out to determine the efficiencies of horizontal band saw, circular saw and chain saw machines on timber forest product recovery. Specifically, the study identified:

1 Method of sawing adopted in timber conversion
2 Determine the efficiencies of horizontal band saw, Circular saw and Chain saw machine.

Significance

The result of the study provides performance indices of machine and labour in the sawmill industry that could help the management and labour of the sawmill industry. The managers are provided with the machine and labour improvement needs in sawmill industries. It also identified processes that generate waste and provide information on areas that machinists may require up skilling. Machinists of horizontal band saw, Circular saw and Chain saw machines now know areas where efforts applied are efficient or wasted and make appropriate adjustment.

Research Questions

1. What methods of sawing are adopted for timber conversion?
2. What are the averages of timber forest product recovered by horizontal band saw, circular saw and chain saw machines per eight hour work day?

Methodology

The study adopted an experimental research design to determine the efficiencies in timber recovery of chain saw, horizontal band saw and circular saw machines. 12 subjects that include three chain saw, three horizontal band saw and six circular saw machinists were selected using stratified and simple random sampling from nine sawmill plants from Minna and Suleja Local Government Areas (LGA) for the study. Data collected were computed using Rank, mean ($\bar{x}$), Standard Deviation (SD) and Timer Recovery Factor (TRF).

To answer research question one, mean and SD were used to determine the method of sawing timber adopted. To determine TRF and answer research question two, the ratio of timber volume recovered was compared to that of log or timber/bulk volume expressed in percentage. Thus:

$$= \frac{t(\sum w)l}{\pi(d^2)l} x \frac{100}{1}$$ (For logs), and

$$= \frac{t(\sum w)l}{TWL} x \frac{100}{1}$$ (For primary converted timber)

Where:
☐ = Level of efficiency for timber recovered in percentage
Σ = Summation of the width of timber (if constant)
= 3.142 or 22/7
d = diameter of log (smallest diameter)
T = thickness of timber
W = width of timber
L = length of the log/timber in meter (m)

Data Analysis
The data for answering research question 1 is presented in Table 1.
Research Question One:
What methods of sawing are adopted for timber conversion?

Table 2.
Mean and Standard Deviations of Horizontal Band Saw, Circular Saw and Chain saw Machinists on Methods used in sawing timber. N=12

Sawing method	X_1	X_2	X_3	X_t	SD_1	SD_2	SD_3
Live Sawing	4.50	4.90	5.0	4.77	0.39	0.73	0.0
Quadrant Sawing	1.22	1.01	0.0	0.74	0.29	0.24	0.0
Cant Sawing	3.50	2.51	1.14	2.38	0.49	1.06	2.93

X_1= Horizontal Band Saw Machinists; X_2= Circular Saw Machinists; X_3= Chain saw Machinists; X_t= Mean Total

Data in Table 2 show that horizontal band saw, circular saw and chain saw machinists produced mean above the cut off point of 2.00 on live sawing. This means that all the three groups of machinists use live sawing. The three groups of machinists also produced mean below 2.00 on quadrant sawing. This means that all the three groups of machinists do not use quadrant sawing. On cant sawing, only horizontal band saw and circular saw machinists produced mean above 2.00 while chain saw machinists returned a mean of 1.14 which is lower than the cut off point of 2.00. Consequently, horizontal band saw and circular saw machinists use cant sawing method while chain saw machinists do not.

Research Question Two:
What are the averages of timber forest product recovered by horizontal band saw, circular saw and chain saw machines per eight hour work day?

Table 3:
Rank and percentage Average of machine Timber forest product Recovery Rates.

S/No	Machine	N	% Average	Rank
1	Horizontal Band Saw	3	27.11	2
2	Circular Saw	3	75.0	1
3	Chain saw	6	14.15	3
	Total	**12**		

Field Study, 2016

Results and Discussions

Sawmills in zone B predominantly used live sawing method in sawing both round timber and cants. Live and cant sawing methods produces the highest TFP recovery rate. Timbers sawn are ungraded and largely for construction and furniture use. The method also affects rate of utilization of capacity, change in scale of output and entrepreneurial skills needed to optimize sawmilling efficiency. While the horizontal band saw and the chain saw machines were both used for primary conversions, the circular saw was used for secondary conversion of small size cants of not more than 300mm wide and 150mm thick.

The recovery rates for all the machines studied except circular saw machine were below 30% of the TFPs outputs ratings. The rates produced were: horizontal Band Saw Machine, 27.11%; Circular Saw Machine, 75% and chain Saw Machine, 14.15%. It was however noted that saw blades used for processing timber were of olden design that often requires grinding, horning and setting of the teeth and there were no modern equipment that can accurately perform the operation of reconditioning the blades. Lack of standard equipment for setting the teeth of circular and horizontal band saw blades result in larger saw kerfs resulting in larger amount of sawdust. This might have contributed to the reduced efficiencies in TFP recovery of circular and horizontal band saws. Wilson, O'connor & Dangerfield (2007) found that process improvements in chipping technology, thinner kerf saws, curve sawing, and computerized scanning and optimization" technology have led to better recovery of higher value products. Modern equipment that are characteristics of efficient sawmill are lacking by the industry.

There is a dearth of modern technology required by a 21st century mill for reasonable efficiency in recovery of TFPs. According to FOPER (2015) the major TFP categories produced by sawmills industry are sawn timber, wood-based panels, wood chips, and pulpwood. Others include poles and railway sleepers. The results of this study revealed that only the log is converted and only construction timber are utilized. The rest tree products (branches, leaves and roots are left on the forest floor while Flakes, strips, bark sawdust and slabs that are less than 2 metres in length are discarded as wastes. This agrees with Saba & Mohammed (2004) who found that Flakes, strips, bark sawdust and slabs that are less than 3.5 metres in length are discarded as wastes.

Differences in recovery rates may be due to two reasons: Firstly, the crooked nature of the log or cant; and secondly, the saw kerfs. The secondary sawing produced the highest timber recovery because only cants are converted with sawdust and in some cases, strips as waste; while the horizontal band saw converts logs to timber thereby generating more waste in the form of slabs and sawdust. Large diameter log is first reduced to cants of approximately one mitre by 0.6m then sawn to plank sizes of 25 to 50mm x 0.6m.

The chain saw produced the lowest TFP recovery rate. This might have resulted from the size of the saw kerf when compared to that of the horizontal and circular saws. The size of the saw kerf is responsible for the sawdust produced by sawing machines. A simple comparison between Nigeria's 27% TFP recovery rate in 2016 and US 35% TFP recovery rate in 1968 suggest that Nigeria is wasteful of its scarce economic resources and lag 48 years behind the US in TFP technology development. No effort is targeted towards all-around resource utilization. Current sawmill processes in the US yields 45% timber recovery rate (Meil, Wilson, O'connor & Dangerfield; 2007).

The factors contributing to these low values include rate of supply of logs; quality of logs – (the shape or profile of the logs); quality of labour; quality of time management; frequent breakdowns of machines; lack of constant supply of electricity and lack of standby generator. All these factors were identified as hindrances to timber production.

Conclusion

From a six day study of the operations of sawmills it was concluded that sawmill activities at present are erratic hence both output and efficiency levels are low. The chain saw yields fewer products than horizontal band saw, and circular saw machines. All the machines and equipment are very old. Most machines are locally fabricated and are poorly maintained. It was noted that poor decisions by machinists, which may be due to fatigue, inadequate skills and lack of machine efficiency all contribute to poor speed and product quality.

Recommendation

The following are some recommendations that will improve on the current state of technology used for TFP in the sawmill industry.

1. The industry needs to invest in advanced modern technology of timber production to achieve higher TFP recovery rates and reduce the waste to make the work safer and more attractive.
2. Employees should be trained on maintenance and safety practices to improve efficiency for machine and labour.
3. There is need for sawmills to procure and install a power plant.

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