DETERMINANTS OF ENERGY AND TIME EFFICIENCIES OF LUMBER PRODUCTION IN SAWMILLS IN ONDO AND EKITI STATES, NIGERIA

BY

Samuel Olorunyomi OLANREWAJU
MATRIC NO: 12921

B.Sc. (FORESTRY) U.I., M. Tech (FOREST ECONOMICS) FUTA

A Dissertation Submitted in the Department of Forest Production and Products, Faculty of Renewable Natural Resources in partial fulfillment of the requirements for the degree of

MASTER OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

Supervisor: Prof. O.Y. Ogunsanwo

JULY, 2018

ABSTRACT

Energy and Time efficiencies are important factors to lumber production in sawmills. General inefficiencies, such as energy waste and idle time jeopardise sustainability of the sawmill industry. For effective evaluation of energy and time in lumber production, there is need to identify critical factors determining Energy Efficiency (EE) and Time Efficiency (TE). However, there is limited information on the roles of time and energy efficiencies in lumber production in Nigeria. Therefore, this study was conducted to investigate critical factors determining EE and TE during lumber production in Ondo and Ekiti States.

Ondo and Ekiti States were randomly selected among timber producing states in Southwestern Nigeria. Seventeen functional sawmills were purposively selected in Ondo (n = 10) and Ekiti (n=7) States, and 12 logs were randomly selected in each sawmill. Characteristics of sampled logs were determined to provide information onLog Diameter Classes (LDC: small≤40; medium- 40.1-65; large≥65.1 cm), Log Forms (FL: straight, tapered, crooked) and Frequency Distribution of the Species (FDS). Data on the log parameters: Log Diameter (LD, m), Log Volume (LV, m^3), Lumber Recovery (LR, %) were obtained from the processed logs. Idle Energy (IE, kwh), Wood Conversion Rate (WCR, min./m^3), Idle Time (IT, min.) Total Time (TT, min.), Sawing Pattern (SP), Product Mix (PM) and Energy Consumption Rate (ECR, kwh/m^3) were also determined using standard methods. Structured questionnaire was administered on five respondents: Manager (1), Headrig operator (2), Saw Technician (1) and Timber contractor (1) in each sawmill for information on Age of Machine (AM, yr.),Experience of Headrig Operator (EHO, yr.) and Labour Force (LF). Data were analysed using descriptive statistics, regression and ANOVA at $\propto_{0.05}$

The small, medium and large LDC were 11% , 45%and 44% respectively while 29% of the logs were straight, 61% tapered and 10% crooked. A total of 196 logs comprising 24 species were sawn. *Ceibapentandra*was the most sawn species, (FDS 24) while *Funtumiaelastica*had the least (1). The mean LD: 0.69±0.3, 0.64 ±0.01; LV: 0.73 ±0.12m 0.70±0.06; LR: 50.6± 1.2, 51.5±0.2; AM: 10.01±1.3, 8.22±1.5; EH0:8.78±0.03, 8.1±0.13; and LF: 3.87±0.32, 3.53± 0.33 were obtained for Ondo and Ekiti States, respectively. There were no significant differences in WCR and ECR within and between sawmills in Ondo and Ekiti States. The LV, SDV, EHO and IE had significant positive effect while AM had significant negative effect on EE (R^2=0.83) in sawmills in the study area. Also, TT and SP had significant positive effect while IT, AM and PM had significant negative effect on TE (R^2=0.54) in sawmills in the study area.

Age of Machine had a negative influence on Energy and Time efficiency; hence old machines should be replaced with newer ones to enhance Energy and Time efficiency. Also effective supervision of workers during log conversion will reduce Idle Time and in effect lead to higher Time Efficiency.

Keywords: Effective energy, Idle energy, Idle time, Sawing pattern, Headrig operator.

Word Count: 495

ACKNOWLEDGEMENTS

I give my greatest appreciation to God Almighty who has granted me the good health, protection, financial capability and encouragement to carry out this research work, I return all the glory to Him.

First, this study was accomplished under the able and motivating supervision of Prof. O.Y. Ogunsanwo who has always been ready and, not minding the inconveniences that he might be experiencing, to guide me like a child from the beginning to the successful completion of this study. It is my belief that he is God sent and I pray that God Almighty will always abide by him in all his undertakings. I will like to express my sincere appreciation to all the members of the Departmental and Faculty Post Graduate Committee. I thank all my lecturers in both the Department of Forest Production and Products and the Department of Social and Environmental Forestry. I will not be doing enough justice if I fail to mention the names of Prof. J.S.A. Osho, Prof. B.O. Agbeja, Prof. A.O. Oluwadare, Prof. A.O. Adegeye and the Emeritus Professor who was also my Head of Department during my undergraduate days and who still made available his valuable advice to me in the course of this study, Prof. S.K. Adeyoju. Thank you all.

I also appreciate my other able lecturers in persons of Dr. A.O. Akinyele (my able PG Coordinator) Dr. O.I. Ajewole, Dr. I.O. Azeez, Dr. L.A. Adebisi, Dr. S.O. Olajuyigbe, Dr. A.O. Omole., Dr. O.F. Falade, Dr. A.A. Alo (my own "son") Dr. P.O. Adesoye, Mr. O.A. Onefeli and Mr. F.N. Ogana. Let me also appreciate all the administrative and technical staff of both the Departments of Forest Production and Products, and Social and Environmental Forestry including Mrs. T.O. Odofin, Mrs. A.E. Adegoke, Mr. K.A. Adeyemi, Mrs. V.A. Olatubosun, Mr. M.O. Famoroti, Mrs. B.F. Oyetunji, Miss M.T. Balogun, Mrs. M.K. Ogunmefun, Mr. A.O. Fagbemi, Mr. H.T. Fatoba and Mr. KayodeAfolayan. I wish to give my profound gratitude to my friends, Mr. TubosunAnimasaun, Mr. S.O. Ojo, Mrs. T.A. Adekunle, Mr. GboyegaOmotola, Mr. G.A. Ajayi, Mr. BayoAjishe, Dr. KayodeFakolade, Mr. Fasasi Bello and Late Alhaji A.O. Ogundana.

I appreciate my late father, Pa ShiabaOlanrewaju and my aged mother Mrs. OmoleyeOlanrewaju for their efforts in exposing me to Western Education and for the moral lessons they impacted in me. I sincerely appreciate my immediate senior brother Prof. D.O. Olanrewaju for his fatherly roles and his financial and moral support. I

appreciate my siblings RotimiOlanrewaju, Mrs. OlufunkeAjayi, Mrs. AderemiAlabi, Mr. MeyeOlanrewaju and Dr. OlawaleOlanrewaju. Mr. AyodeleOlanrewaju played a great role in supporting me financially. May God continue to bless them all.

The last but not the least of my sincere appreciation goes to my immediate family. I thank my darling wife, OlufunmilayoOlanrewaju for her support and for holding firmly the home front. My sincere appreciation goes to my invaluable children, OlaniyiOlanrewaju, OlayinkaOlanrewaju, OlalekanOlanrewaju, OlusolaOlanrewaju, AbiolaOlanrewaju and TemitopeOlanrewaju, I remember with heavy heart my only and late daughter OmodolapoOlanrewaju who passed on some eighteen years ago. May her gentle soul continue to rest in perfect peace.

Finally, I once again thank God Almighty for seeing me through this research project. Glory be to Him.

OlorunyomiOlanrewaju

DEDICATION

This knowledge search is dedicated to God Almighty

CERTIFICATION

I certify that this work was carried out by **Samuel Olorunyomi, OLANREWAJU** under my supervision in the Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria.

______________________ ______________

Supervisor **Date**

O.Y. OgunsanwoPh.D (Ibadan)
Professor of Wood Utilisation
Department of Forest Production and Products
University of Ibadan, Ibadan,
Nigeria.

TABLE OF CONTENTS

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Nigerianforests support a wide range of forest industries. Forest based industries constitute one of the largest in the economy, (Ogunsanwo*et al*., 2011). The industry can be classified into formal and informal sectors. The informal sector comprises of small forest based industries which include charcoal making, chewing sticks, firewood and sculptures among others (Ogunsanwo, 2014). The sawmill industry belongs to the formal sector (GWVC, 1994).

It also includes plymills, furniture industries, pulp and paper mills and particle board mills (Mijinyawa*et al.,* 2010).

The sawmill industry remains the most dominant and active wood based industry in Nigeria accounting for about 95% of the total wood input into the industry Fuwape, (1998) , (Owonubi and Badejo, 2000 andOgunsanwo, 2014).

A sawmill is a facility where logs are sawn into lumbers. The basic operation of a sawmill is that a log enters at one end and dimensional lumber exists from the other end.Technically,a sawmill includes any equipment, usually power driven, employed in the breakdown or sawing of timber. It has also been described as a process (Lucas, 1982) as well as an industry (Bennett, 1974). As a process it involves converting logs into dimensional lumbers through different methods of sawing.

Sawmilling started as a business in Nigeria with the first sawmill established near the lagoon shore in 1940 in the Lagos colony which is the present Lagos State (Ogunyinka, 1976). Since then the number of sawmills, especially in western Nigeria continued to increase. By the year 2000 the number of sawmills in Nigeria had increased or risen to 1259 (RMRDC, 2008). The total number of sawmills in Ondo and Ekiti states by the end of year 2014 stood at 437 for Ondo state and 250 for Ekiti, making a total of 687 sawmills for both states,(Forestry Department Ondo State and Forestry Department Ekiti State).

Nigerian sawmill is dominated by small scale operators who constitute more than 90% of the entrepreneurs in the sector (Ogunsanwo 2010). However, in the last few years there have been a downward trend in their activities. (FAO, 2003, Ogunsanwo*et al.,* 2005). The Major problems facing sawmill industry in Nigeria include among others, old and obsolete equipment, shortage of power supply, declining sizes,quality and quantity of timber as well as inefficient log conversion methods (Dele,*et al*.,2014).

1.2 Statement of Problems

The ever increasing demand for sawn wood by the furniture, building and construction industries has continued to exert pressure on the dwindling resources, especially timbers. A part from demand factor which continually drive deforestation, general inefficiency in the industry such as idle time, energy waste and some anthropogenic factors are also potential factors that may jeopardise the sustainability of the industry. Also the low level of timber conversion constitutes a threat to wood industries for their continued survival. A lot of factors singly and collectively affect sawmill efficiency and lumber recovery. It is therefore imperative that these factors should be examined to determine their impacts. The earlier attempts by some studies to examine only some and not all of these factors would not suffice. Sawmill efficiency and lumber recovery is dictated by an interaction of several factors. The sawmilling industry in Nigeria is dominated by small scale and mostly privately owned establishments (Olufemi*et al.,* 2012). These sawmills are concentrated more in cities and sub – urban communities because of readily available market and probably as an expectation of regular power supply. Alviar, (1993), reported that these small scale sawmills had individual production capacity of 500 cubic meters per year and they numbered about 1,500 across the country. Badejo,(1990), discovered that the volume of wastes generated in the sawmills by 1988 was 2.32 million m^3 and by 1993 the volume had risen to 3.87 million m^3 (Owonubi and Badejo, 2000). The number of sawmills in Ondo and Ekiti states had risen to 687 in 2014. In the past most studies hadconcentrated their efforts on volumes of lumber yield or lumber recovery without actually quantifying the energy and time efficiency in relation to lumber recovery. As part of the studies on yield improvement in log conversion process in Nigeria, (Badejo and Onilude, 1987) discovered, while appraising small size sawmilling operations in Nigeria that, variations in the years of experience of headrig operator, kinds of headrig, saw kerf, log sizes and log form lead to variations in lumber recovery (LR). They however did not quantify the effects of these variables on technical efficiency of the sawmills, neither did they pay attention to the energy and time efficiency of the sawmills.

Also, Fuwape, (1985), while working on time efficiency reported idle working time of between 12.79-76.43%, effective working time of between 23.6-87.21% and lumber recovery of 56% separately without quantifying the total effect of all these factors on the technical efficiency of the sawmills.

In a similar way Egbewole, (2014), while working on correlates of lumber recovery in sawmills of high forest tree species in Southwestern Nigeria carried out analysis of time efficiency of sawmills but did not however work on their energy efficiencies.Energy and time efficiency are important components of the overall efficiency of a sawmill hence there is the need to harmonise these two factors with other log conversion factors to be able to have accurate efficiency of a sawmill in relation to lumber recovery.To meet the demand for sawn timber, there is the need for appropriate sawmilling practice that can guarantee high lumber recovery. It is imperative that all the factors that dictate lumber recovery be investigated since all of them combine to determine the overall efficiency of a sawmill. It is therefore important that constant and continuous research findings are embarked upon to improve the efficiency of sawmill production so as to be able to get more value from the logs, block areas of waste and consequently increase revenue generation.

1.3 Objective of the Study

The main objective of this study is to investigate log conversion factors that affect energy and time efficiencies of lumber production in sawmills in Ondo and Ekiti states.

The specific objectives are to:

i. investigate the effect of log variables on the energy and time efficiencies of lumber production in the sawmills.
ii. examine the effect of log conversion methods or sawing patterns on the energy and time efficiencies of lumber production in the sawmills.
iii. investigate the effect of Anthropogenic factors on the energy and time efficiencies of lumber production in the sawmills.
iv. examine the effect of product mix on the energy and time efficiencies of lumber production inthe sawmills.
v. determine the effect oflabour force on the energy and time efficiencies of lumber production in the sawmills

1.4 Justification of the Study

The rate at which the forest resources in the country is diminishing and the downward trend in the numbers and sizes of timber from the forest calls for an urgent attention because of the threat this poses to the wood based industries. Also the level of wastes generated during log conversion is high being as much as 5.2 million tonnes per annum, Fransescato*et al*., (2008).Several studies had in the past been carried out on the lumber recovery efficiency and technicalperformanceefficiencyof sawmills which however did not include energy and time efficiencies as part of the component factors needed to be considered along with others. According to Bryan (1966), sawmill efficiency is dictated by the total production value (sawn wood) of a given sawmills. In order to achieve maximum efficiency the production value (value of sawn lumber) must exceed the value of resources utilized for production.

Egbewole*et al.*,(2011), investigated the technical performance efficiency of twenty seven sawmills in south western Nigeria. The sawmills were classified into small, medium and large sizes based on their level of production, and variablessuch as log sizes, shape, species, and sawkerfwere used. The study concluded with average lumber recovery of 53.69% and technical performance efficiency of 51.38%. It was also concluded that, apart from log parameters,the type of headrig used and theheadrig operator had significant effect on the efficiency of sawmills. The shortcoming of this study is that it did not consider energy and time efficiency of the Sawmills as contributing factors to the overall efficiencyofasawmill.

Olufemi*et al.*,(2012) while studying lumber recovery efficiency among selected sawmills in Akure, Ondo State, only assessed the volume of lumber derived from a log and the waste generated to determine the efficiency of the sawmills .This study did not consider some log parameters,machinefactor,headrig operator and other factors such as energy utilized and time of conversion to determine the efficiency of the sawmills.Phillip H.Steel, (1984) considered product mix along with other factors such as log parameters, kerf, sawing variation, mill maintenance and personnel decision in deciding sawmill efficiency. The study did not however consider the energy and time factors aspart of the factors necessary.

Also Fuwape,(1985)inhis assessment of log conversion efficiency insomesawmillsinOndo–State,worked on time efficiency but did not study the energy efficiency of the Sawmills. Ogunsanwo*et al.*, (2011) examined technical efficiency of chain sawmilling in terms of lumber recovery on ninety logs in 17 families employing variables such as log volume, diameter, species density and saw kerf. The study did not examine the energy consumption rate and efficiency of the machines used

Owusu*et al*.,(2011),while examining the comparative analysis of recovery efficiency of some milling techniques in Ghana using different sawing machines determined the fuel consumption rate of Wood-Mizer machine, which is similar to the Mighty Mite machine commonly used in Nigeria. He did not however examine the fuel or energy consumption efficiency of the machines.

There is the need to quantify the contributions of individual factors that collectively dictate the overall efficiency of a Sawmill. This will assist in the optimal utilization of resources and blockage of areas of wastes. This study is therefore aimed at examining the factors that affect energy and time efficiency of sawmills in relation to lumber recovery.

1.5 Scope of the Study

This study was carried out in Ondo and Ekiti States in southwestern Nigeria. The two states were formerly one (Old Ondo-State) until the creation of Ekiti State in 1996. These states were chosen because they fall within the core of southwestern Nigeria where the level of logging activities and number of sawmills are comparatively high. The study employed the use of structured questionnaires and interviews to elicit primary data, while secondary data were obtained from literature reviews. This integrated approach was employed because past experience had shown that sawmill owners and workers are always reluctant to disclose information as a result of fear of taxation and the inherent attitude of hiding information concerning their persons and their finances. A set of eighty-five (85) questionnaires were administered on 17 sawmills in the study area. A total number of five (5) respondents comprising of 1 sawmill manager, 2 headrig operators, 1 saw doctor (Sawmill Technician); and 1 timber contractor were interviewed. The questionnaires were administered to generate data on experience and education level of headrigoperator,labour force and other sawmill efficiency factors. There are however some constraints encountered during collection of data. These include among others, the fact that many respondents were reluctant in disclosing personal information and also, the workers were not always ready to pause and allow necessary measurements to be taken while log sawing was in progress.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Development of Sawmill Industry in Nigeria

Timber conversion is not a new industry in Nigeria. It grew from the oldest but also the crudest method of splitting wood with hand tools, to pit sawing in which a hand-saw is operated by two men, one under and the other over a deep pit on which the log is laid. The first power- driven sawmill was established by Government in1907 at Etchetem in the Delta (Mackey, 1952). By 1939 the number of sawmills established in Nigeria by the government were sixteen and this grew to twenty-one in1946 and thirty-five in1952. Just ten years after, the number of sawmills in Nigeria was eighty (Okigbo 1964).Sawmilling however started as a business in Nigeria in 1940 in the Lagos Colony which is the present Lagos state (Ogunyinka, 1976). The sawmill industry is about the most developed sector of the nation's economy in the 1960's contributing about 70% of the country's Gross Domestic Products (GDP),Ogunwusi, (2012). Since then the number of sawmills established has continued to grow. As at 2002 the number of sawmills in Nigeria had risen to 1325 (RMRDC 2003). By year 2014 Ondo and Ekiti states which had just four sawmills in 1963 (Okigbo, 1964) had a total of 687.

Forest resources have served as an engine of growth and propelled economic activities in Nigeria as far back as 1792 when pit sawing operations commenced followed by the establishment of power sawing mill in the Delta in 1902 (Aribisala, 1993). Forest exploitation which was the main focus of the colonial government started as far back as 1899 (Adeyoju, 1975). The public forest in Nigeria which was acquired between 1900 and 1970 covered 100,000 km^2 or about 11% of the total land area of Nigeria, (Ogunwusi,2012). About 26% of this was in the high forest zone, while additional 90,000km^2 existed outside the reserve (free areas). Deforestation in Nigeria is about 3.5% per year and this is about 350,000 to 400,000 hectares of forest per year. Recent studies show that forest now occupies 923,767km^2 or about 10 million hectares. This is less than 10% of Nigeria forest land area and well below FAO recommended national minimum of 25%. Between 1990 and 2005 Nigeria lost about 21% of its forest land, (Ogunwusi,2012).

The sawmill industry in Nigeria is characterized by small scale operators who constitute more than 90% of the entrepreneurs in the sector (Ogunsanwo 2010, 2012, RMRDC 2009, GWV consultants (1994). Ogunwusi, (2011), noted that a major characteristic of the sub-sector is increasing number of operators and decreasing performance. The capacity utilization in the industry is averaged 37% and the lumber recovery (LR) is 40-60% as a result of old equipment (GWV Consultant, 1994, RMRDC, 2009). According to (Olorunnisola, 2000), the annual rate of return is between 15.2% and 44.3% while over 70% of the workforces arelabourers. Only about 10% use advanced technology. The industry is dominated by the use of CD4, CD5 and CD6 horizontalband-saws usually supported by circular saw machines. Most sawmills in Nigeria are depreciated, have low recovery rate of less than 53% and lack the capacity to process small diameter logs from forest plantations (FOSA,2009). Since the present status of logs from the forest is dominated by small diameter logs, and the machines were originally designed to handle large diameter logs, the capacity utilization ofthe sawmillsand lumber recovery from the logs have been affected.

2.2 Demand and supply of Timber in Ondo and Ekiti States

Due to pressure for wood for the various wood based industries and construction companies the demand for wood in Ondo and Ekiti States continues to be on the increase while supply continues to witness downward trend as a result of massive exploitation of the forest and the inability of governments and loggers to replace the removed trees at the appropriate rate. According to Egbewole, (2014, the total supply from the high forests in Ondo and Ekiti States was estimated to be 3,896,23m^3/year in 1999, and 1,2220,540m^3/year in 2000. It later decreased between year 2001 and 2002 just to rise again between year 2003 and 2006. The total annual demand for sawn-wood was observed to be on the increase and was estimated to be 128,078m^3/year with a sawn-wood timber supply and demand balance of 995,044m^3/year in 1999. In the year 2002, the timber demand was 137,240m^3/year while the sawn-wood timber supply balance was 905,658m^2/year. Also in year 2003 the timber demand was 228,860m^3/year while the sawn timber supply and demand balance was 536,515m^3/year (RMRDC, 2012).

In both Ondo and Ekiti states the total number of trees removed from the forest (both reserved and free areas) was 97,877 in year 2014. (Source: Forestry Department, Ondo and Ekiti States).

2.3 State of Nigerian Forest

The present state of Nigerian forest is not known because the available data is either obsolete or based on extrapolation from very old data. The last national forest inventory was in 1997 and between that period and now the forest estates have been subjected to severe encroachment, vegetation degradation, de-reservation for agriculture, industrial development, urbanization and other purposes. Nigeria forest estate was about 10 million hectares representing almost 10 percent of the total land area of 92,376,700 hectares covering five major ecological zones.

Nigeria has the highest rate of deforestation in the world according to FAO (News.mongabay.com, 2016).Between 2000 and 2005 the country lost 5.5% of its primary forest, and the rate of forest change increased by 31.2% to 33.12% per annum. Between 1990 and 2005 Nigeria lost an average of 409,7 hectares of forest every year equal to an average annual deforestation rate of 2.38% of its forest cover, or around 6,145000 hectares (Rain forest analysis @ mongabay.com, 2016).Uneke (2008), had estimated the annual deforestation rate in Nigeria to be 3,984sq.km per annum. It was also estimated that the country lost about 55.7% of its primary forest between 2000 and 2005. Also,Popoola, 2014, noted that the world lost 3.3% of its forest while Nigeria lost 21%.

2.4 Waste Generation and Utilization in Sawmills

Sawmills by their nature generate a lot of wastes. These wastes are in form of slabs, sawdust, off-cuts, trimmings and plain shavings. According to Sambo (2012), the amount of sawdust generated in Nigeria per annum is 1.5 million tons while Franscescato,(2006) noted that amount of wood wastes runs to about 5.2 million tons per annum. With an average recovery of between 45-55%, the wastes generated in Nigeria sawmills in 2010 was 1,000,000m^3 (Ogunwusi,2014). Wood processing industries include sawmilling, plywood, wood panel, furniture, particle board and flooring among others. The amount of waste generated from wood processing depends on the type of industry, the form of raw material and the end products. In the sawmill, waste generated from logs depend on the diameter of logs, type of saw or the saw kerf, the product mix,pattern of sawing and the skill of the operator to mention a few. Generally, wastes from sawmill include sawdust, off-cuts,trimmings,slabs and shavings. Wastes from the conversion of a given volume of timber may be as high as 52% or even more. Most sawmills burn off the sawdust and barks while a sizeable portion of off-cuts, slabs and barks may be sold as firewood while the remaining may be burnt. At the medium and large sawmills some of the waste may be utilized for wood drying.

In the area of wastes utilization even though part of the wastes generated in sawmills are used as firewood for domestic cooking a large part are burnt off. However, Egbewole, (2014) noted that substantial amounts of panel boards, slabs, trimmings, off-cuts and cores from sawmill operations are utilized for fencing and small wooden items such as boxes, toys, etc. An emerging waste utilization prospect is the use of saw dust and wood shavings as substrate for growing mushroom.

2.5 Efficiency in Sawmilling

Efficiency is the ability to avoid wastes, materials, energy, efforts, money and time in doing something or in producing a desired result. It is a measure of the extent to which input is well used for an intended task or function (output), Longman, DCE, retrieved, (2018).

Increased problems of timber availability have caused many saw millers, industry analysts, and planners to recognize the importance of sawmill conversion efficiency. Timber supply issues have caused resource planners and policymakers to consider the effects of conversion efficiency on the utilization and depletion of the timber resources. Improvement in sawmill conversion efficiency would favourably impact sawmill profits, and would be equivalent in effect to extending existing supplies of standing timber (Wade *et al.,* 1992).

Sawmill efficiency has been described in various ways by different people. Akindele, (1993) described sawmill efficiency as maximization of value from available resources, ratio of output capacity to that of actual output of lumber. Also, Nelson et al, 1970, simply defined efficiency as a measure of various conversion processes that embody aspects of both the raw material and the end product. Also,Egbewole,2014, opined that efficiency is the state of being competent in performance or the ability to produce desired effect with a minimum effort, cost, expenditure of time and waste.

Efficiency in lumber production may be defined as the ratio of total volume of useful lumber to that of all inputs, which may include not only the log converted but other inputs suchasenergy, time and other human and material resources. In simple term, it could be expressed as ratio of useful output (p) to that of total input, which can be expressed with mathematical formula

R= $\frac{P}{C}$http:/:c.n.m Wikipedia.org/wiki/efficiency: anonymous,(2018)

Where P is the amount of useful output (product) produced per amount C (cost) of resource consumed.

Time efficiency is one of the important components of the overall efficiency of a sawmill. It should therefore be considered along with other log conversion factors.

Fuwape, (1985) and Egbewole (2014), described time efficiency as percentage of effective working time over total working time. In other words the total effective working time is the overall working time minus idle time. Idle time is the time used in'logkeating', saw adjustment and other related activities during sawing of logs.

Energy efficiency which is sometimes referred to as "efficient energy use" is the goal to reduce the amount of energy required to provide product and services. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process, or by application of commonly accepted methods to reduce energy losses. There are many motivations to improve energy efficiency. Reducing energy use reduces energy cost and may result in a financial cost savings to consumers if the energy savings offsets any additional cost of implementing an energy efficient technology. According to Steve (2006), energy productivity which measures the output and quality of goods and services per unit of energy input can come from either reducing the amount of energy required to produce something, or increasing the quantity of goods and services from the same amount of energy. Energy efficiency has proved to be a cost-effective strategy for building economy without necessarily increasing energy consumption.

The level of labour efficiency employed in a sawmill will among other factors affect lumber recovery volume. Most sawmills employ unskilled labour for log conversion and this invariably leads to low conversion efficiency. An experience headrigoperator will most likely recover more lumbers from a given volume of log.

2.6 Lumber

The term lumber has been defined in various ways. Lumber has been defined as the product of saw and planning mill, not further manufactured than by sawing and passing length wise through a standard planning machine, cross cutting to length and working. Brown and Smith, (1958).Inthe US and Canada it is a forestry terminology indicating the product of conversion of forest trees (timber)intomarketable sizes. In general the term lumber refers to timber sawn into boards, planks or other structural members of standard or specified length and thickness. In the United Kingdom, lumber is rarely used in relation to wood but timber is universally used in its place. Lumber is mainly used for structural purposes but has other uses as well. Finished lumber is supplied in standard sizes mostly for the construction and furniture industries. In Nigeria lumbers are sold as wood planks in certain convectional sizes.

2.6.1 Lumber Recovery

Lumber recovery refers to the volume of lumber derived from a log after volume of waste generated through slabs and sawdust has been deducted. It can be expressed as a percentage or as a factor. When expressed as a factor, it is the ratio of timber output over cubic meter of logs input Egbewole, (2012).Olufemi*et al*., (2012) described lumber recovery as a percentage of sound lumber produced from a log. He explained that the mode of estimation is by dividing the total lumber product in cubic meters by the total input volume. He also emphasized that this does not however take into account the size, quality or grade of the log in question.

According to Steel(1984), lumber recovery in sawmilling is determined by a confusing interaction of several factors. He asserted that the more one knows about each individual factor, the more one can understand how the factors interact. The factors affecting lumber recovery may play out in different ways from one sawmill to the other. Theknowledge of the variables that affect lumber recovery generally can assist in determining the factors that affect a particular sawmill.

Generally there are different ways of measuring lumber recovery. However, the most common two are (i). The cubical volume of lumber as a percentage of total log volume and (ii), the board feet from a given cubic volume of log commonly referred to as lumber recovery factor (Steel 1984). The two methods measure lumber output but while the board foot method is based on nominal (2 by 4) measurement, the other method measure the actual (1 ½ by 3 ½), thickness and width of lumbers. The figures obtained from the two methods may not be the same but the differences are always negligible.

Lumber recovery (LR) percentage and lumber recovery factor (LRF) can be represented respectively as follows,

% Lumber Recovery = $\frac{\text{Lumber output m3}}{\text{Timber input m3}}$x $\frac{100}{1}$(Egbewole 2014, Ekhuemelo,*et al.,* 2015 andMissanjo et al., 2015)

Lumber Recovery Factor = $\frac{Lumberoutput}{Timberinput\text{m}}$ Egbewole,(2014)

2.7 Timber Sawing Procedures

Timber or log sawing involves the conversion of logs into square edged pieces of lumber into different dimensions depending on the desired end use. Generally, the method of cutting wood depends on the intended use, appearance, and the stability of the wood. There are three major cutting methods of which are plainsawn, Quarter sawn and Rift sawn. The first two are the most common. Logs can also be sawn into different lumber sizes. In Nigeria sawmills, there are conventional or trade sizes recognized by those in lumber trade and end users. There are different methods of log sawing or conversion as shown below.

2.7.1 Plain or through and through Sawing

In this method, which is also called 'flat' sawing, the log is cut into boards by a series of parallel cuts. It is produced by making the first cut on a tangent to the circumference of the log. The log may be squared and sawn lengthwise. Knots that occur are round or oval shaped and have relatively little weakening effects on the lumber. Each additional cut is then made parallel to the one before. The annual rings appear as approximately straight lines running across grains. The lines join at the bottom, forming a U-shape. This part is sometimes cut off. It is the most economical and simplest method. The method produces the widest possible board with the least amount of waste. Wood cut this way shrinks and swells very little in thickness. The disadvantage of this method is that most boards produced have sapwood at the edge which could cup and distort during seasoning.

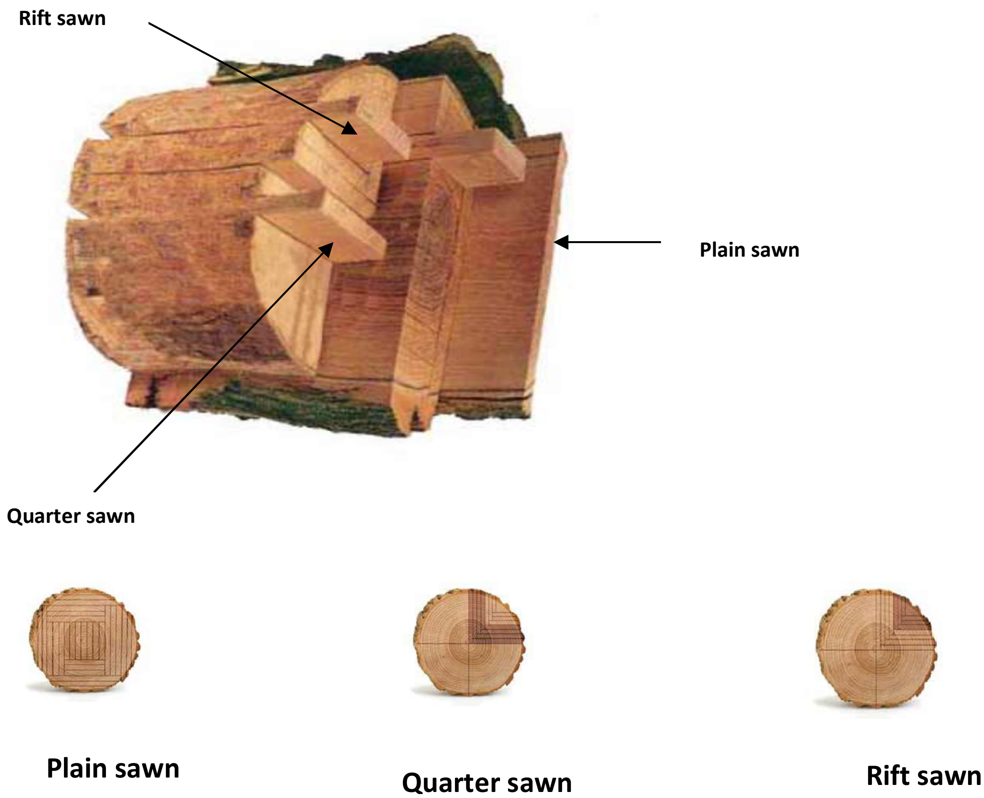

Figure 1: Different log sawing methods

Source: www.hardwoodinfo.com/article/view/pro/23/336

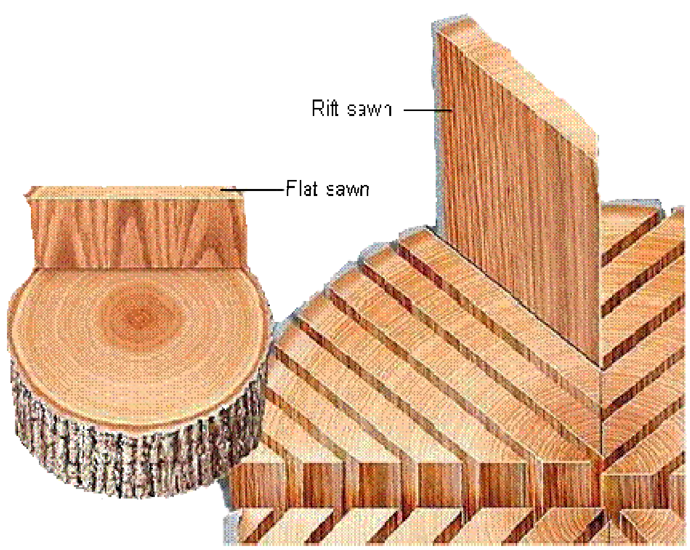

Figure 2: Flat and rift sawing methods

Source: www.hardwoodinfo.com/article/view/pro/23/336

2.7.2 Sawing Round

This is a system of sawing the four sides of the log by turning the log on its four sides as the sawing proceeds. It is also called "Scanting" or to produce "scant". The lumbers produced possess different grain characteristics. It also has the advantage of separating sapwood from heartwood (Bennet,2014). The level of waste from this method is higher than plain sawing.

2.7.3 Quarter Sawing

In this method the lumber is produced by first quartering the log followed by sawing it perpendicular to the annual growth ring. The angle between the cut and the growth rings varies from 90 degrees to about 45 degrees. In such wood, the lines formed by the rings run with the grain. They will also appear as relatively straight or U-shaped, depending upon how much is cut off. Such lumber shrinks and swells less in width and warps less than plain-sawn lumber. This method produces a nice straight grain appearance on the surface of the log. The method however creates more wastes in relation to the plain sawing (Bennet, 2014).

2.7.4 Rift orBack Sawing

In this method the quartered log is turned slightly off perpendicular before cutting to expose the medullary ray. The logs are sawn at not less than 35 or more than 65 degrees to the annual rings, usually at about 45 degrees. The rings appear as longitudinal lines and are longer than in lumber cut by other methods. It produces virtually straight grain appearance on the face of the board with little or no visible "flake". This method also allows separation of sapwood from heartwood with minimum waste (Bennet, 2014).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Location of the study

The study was carried out in Ondo and Ekiti states (Old Ondo State) in the southwestern Nigeria. The criteria for choosing these states were because of the vegetation, the high level of timber resources and the relatively large number of sawmill industries. The vegetation type ranges from mangrove forest in the southern part of the study area, in places like Igbokoda, Ilaje-Eseodo, to that of tropical rain forest at the central part of the states and the savannah which covers the northern zones of both states.

South western Nigeria is located betweenlongitude 2^o12"E and 6^oE and latitude 6^o 21"N and 8^o 37"N (Agboola, 1979).Ondo and Ekiti states are located between latitude 5˚ 45" and 8˚ 5" N and longitude 4˚5" and6˚ 05"E.The total land area of the two states is (Ondo15,500km^2andEkiti 6,753km^2) is 22,253km^2. The study area is bounded in the north by Kwara and Kogi states, in the east by Edo and Delta states, in the south by the Atlantic Ocean, while in the west by Osun and Ogun states. The study area is endowed with high level of biodiversity and fertile soil.

3.2 Materials used for the Estimation of log volume Dimensions and other Variables

Ondo and Ekiti States were randomly selected among the states in South West Nigeria based on the ratio of total number of sawmills in each of Ondo and Ekiti States, for a fair spread. A total of seventeen (17) sawmills were randomly and purposively selected. These 17 sawmills were purposively selected because many of the sawmills were not on continuous production because of epileptic power supply and high cost of machine maintenance. Also a total of 204 logs of varying diameters, forms and species were sampled for volume estimate. The study employed the use of structured questionnaires and interview to elicit primary data, while secondary data were obtained from literature reviews. A set of questionnaires was administered on 85 respondents to obtain information.Five (5) persons made up of 1 sawmill manager, 2 Headrig operators, 1 Saw doctor (mill technician) and 1 Timber contractor were interviewed in each sawmill to elicit information on age of sawmill, experience of operators .remuneration of workers and other variables.

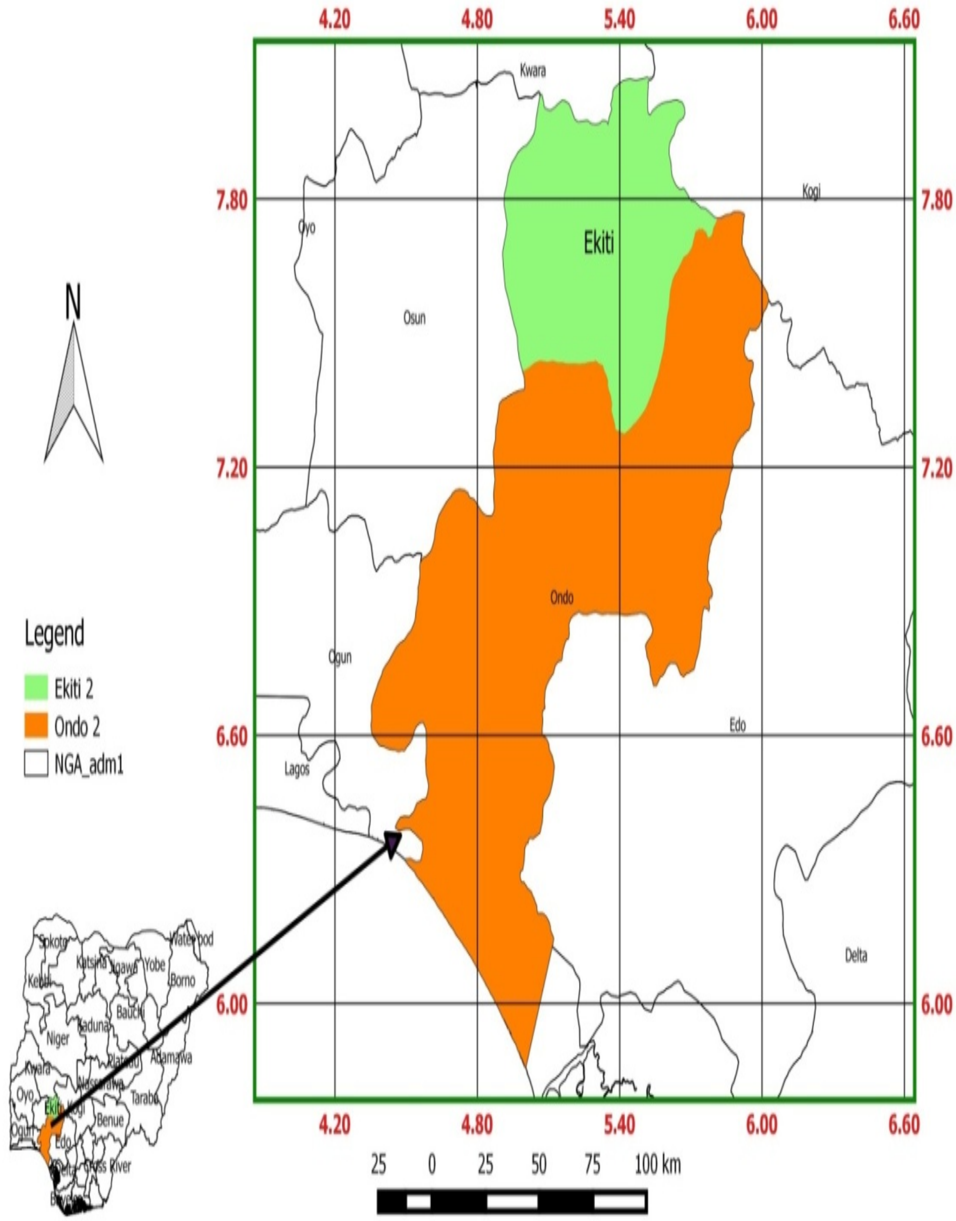

Figure 3:Map of Nigeria highlighting Ondo and Ekiti States

3.2.1 Sampling Procedures

Twelve (12) logs were randomly chosen for observation in each of the 17 sawmills giving a total of 204 logs.

For ease of data collection and to elicit necessary information on log characteristics some classifications were carried out as shown in table 1.

Table 1: Classification of some Variables

S/N	Variables	Classifications
1	Experience of Headrig Operator	0-5yrs
		6-10yrs
		Above 10years
2	Education of HeadrigOperator	Below pry education
		Pry to Sec. education
		Above Sec. education
3	Saw Kerf Thickness	Small Kerf ($\leq$ 2.0mm)
		Medium Kerf (2.01 – 2.50mm)
		Large Kerf ($\geq$ 2.51mm)
4	Log Diameter	Small Diameter ($\leq$ 40cm)
		Medium Diameter (40.1 – 56cm)
		Large Diameter ($\geq$ 65.01cm)

3.3 Log dimension and volume estimation procedures

Selected logs sawn into required lumber dimensions were measured taking measurements of the length, breadth and thickness of each lumber derived. The volume of the slab and that of the sawdust were estimated. The following instruments were useful in the process. They are measuring tape, ruler and veneer caliper.

3.3.1 Determination of log input

Measurements obtained from the log, i.e. length, diameter at the base, middle and top were used to determine the log volume. Newton formula or equation was employed to determine the log volume. This formula was chosen in preference to others like Heber's, andHohenald's formulae because of its simplicity and accuracy.

Newton formula is as follows:

V= L(Ab + 4 (Am) + (At) $\frac{\pi}{24}$(Missanjo *et al.*, 2015).

V=volume of log(m^3)

Ab, Am and At = cross sectional area of log at base, middle and top (m)

h = length of log (m)

π = Constant (3.142)

To estimate total volume of all logs we have

$$Vlog = \sum_{i=1}^{n} vlog = vlog_1 + vlog_2 + vlog_3 \ldots\ldots\ldots vlog_n \ldots\ldots (ii)$$ (Egbewole*et al.*,2011)

Where vlog = Total volume of all logs

vlogi = Volume of individual log

n = total number of logs

3.3.2 Determination of volume of sawdust

$$Vsd = b.l.\int_{i=1}^{n} w \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (iii)$$

(Olufemi*et al.,* 2012)

Where Vsd = volume of sawdust (m3)

b = Kerf of the saw blade (m)

l = Length of the log (m)

w = width of each lumber at the point of cut (m)

n = number of saw lines

3.3.3 Determination of volume of lumber

The volume of lumber produced was calculated from the nominal sizes of individual lumber that is, 1'x12'x12" (2.54cmx30.48cmx3.65m)etc, from each of the logs after calculating the trimmings and edgings from the circular machine from equation (iv) (Olufemi, 2012).

$\sum$ Vlm = Total volume of all lumbers produced.

Where Vlm = volume of each sawn lumber (m^3)

L = Length of sawn lumber (m)

b = breadth of sawn lumber (m)

h = thickness of sawn lumber (m)

n = no of lumbers produced from each log

3.3.4 Determination of volume of slab

Vslab = Vlog – (Vsd + Vlm) …………………………. (v)

3.3.5 DeterminationofPercentage of Lumber Recovery (LR) and lumber Recovery Factor (LRF)

$$\% LR = \frac{\sum Vlm}{\sum vlog} \times \frac{100}{1}$$

$$LRF = \frac{\sum Vlm}{\sum vlog}$$

3.3.5 Determination of Energy Efficiency of the Sawmill

Two methods were employed to measure the amount of electrical energy consumed during log conversion. The conversion factor for fuel to electric energy is 1litre = 35.9MJ.(Ag. Decision Maker, 2008).When the source of energy was through a generator, the following steps were taken:

i. An electric meter was attached to the source of power (generator) and the energy consumed read off directly.
ii. A conversion factor was employed to convert the volume of fuel utilized during log conversion.

In caseswherethe sawmills used direct electricity, the energy consumed were read off from the sawmills electric meter. A combination of all these methods was used for the study.

To estimate the energy efficiency the procedure is as follows:

Energy consumed during effective log conversion = EE

Energy consumed during down time (Keating etc) = IE

Total energy consumed = TE =EE + IE

Energy efficiency is the percentage of energy consumed for actual log conversion over that of total energy consumed.

$$\text{Energy Efficiency EEF} = \frac{EE}{TE} \times \underline{100}$$

3.3.6 Determination of Time Efficiency

Time efficiency was calculated by adopting the equation established by Fuwape, 1985 and adopted by Ebgewole, 2014. It is given by the equation below.

Time Efficiency TEF= $\frac{ET}{TT}$(Fuwape,1985,Egbewole,2014)

% TEF = $\underline{ET}$ x 100

TT

Where %TEF = Percentage time efficiency

ET = effective sawing period

IT = idle sawing period

TT = time from commencement to completion of sawing of log(Total sawing time).

Effective sawing period is the actual time used in sawing logs, whereasidle sawing period is the time used in keating, saw adjustment and any other activity apart from actual sawing.

3.3.7 Determination of Product Mix and Lumber Recovery

The relationship between product mix and lumber recovery was determined by deducting the volume of lumber of specified dimensions 1'x12'x12" (2.54cmx30.48cmx3.65m) etc, derived from volume of log converted to derive such product mix or specifications. It is represented as:

$$\% \text{ LR for Product Mix } (y) = \frac{Vlm\ (y)}{Vlog(y)} \times \frac{100}{1}$$

Where Vlog(y) = Volume of lumber of specification y

Vlog(y) = Volume of log processed.

3.3.8 Determination of Product Mix and Energy Efficiency

The relationship between product mix and energy efficiency was determined by calculating the actual quantity of energy utilized during the production of certain dimension of lumber.

$$\text{Energy efficiency of product mix}(y) = \frac{EE}{TE}$$

Where EE = Effective Energy i.e. actual energy utilized in producing product mix (y)

TE = Total energy utilised during conversion of (y)

IE = Energy expended during idle time.

3.3.9 Determination of Product Mix and Time efficiency

$$\%TEF = \frac{ET(y)}{TT(y)} \times 100$$

ET(y) = effective sawing period of product (y)

IT(y) = idle sawing period of product (y)

TT(y)s= total sawing period of product(y)

3.3.10 Determination of energy consumption rate (ECR)

Energy consumption rate (ECR) was determined by dividing the totaleffectiveenergyutilized by the total volume of all logs (3.5.1) sawn. This is given by

$$ECR = \frac{\sum_{c=1}^{n} Ef}{\sum_{c=1}^{n} Vlog} \text{ kw/m}^3$$

3.3.11 Determination of Wood Conversion Rate (WCR)

The rate of log conversion in cubic meter was determined by dividing the total effective time of all logs converted (3.5.1)by the total volume of all logs converted.

This is given by

$$WCR = \frac{\sum_{i-1}^{n} ET}{\sum_{i-1}^{n} Vlog} \text{m}^3\text{/ Min}$$

3.4 Statistical Tools

3.4.1 Hypothesis

A number of tests were carried out to test the significance of the selected variables on energy and time efficiency of sawmills in Ondo and Ekiti States.

The Null hypotheses (Ho) areviz:

i. Variation in log diameter has no significant effect on energy and time efficiencyof sawmills.
ii. Variation in log volume has no significant effect on energy and time efficiency of sawmills.
iii. Variation in log form has no significant effect on energy and time efficiency of sawmills.
iv. Sawing pattern has no significant effect on energy and time efficiency of sawmills.
v. Experience of headrig operator does not have significant effect on energy and time efficiency of sawmills.

vi. Educational level of Headrig operator does not have significant effect on energy and Time efficiency of sawmills

vii. Variation in age of machine has no significant effect on energy and time efficiency of sawmills.

viii. Product mix has no significant effects on the energy and time efficiency of sawmills.

ix. Variation in saw kerf has no significant effect on energy and time efficiency of sawmills.

x. Labour force has no significant effect on energy and time efficiency of sawmills.

3.5 Data Analysis

Both descriptive and inferential statistics were employed in analyzing the data collected. The following data analysis were carried out.

i. The useofstatistics of mean and standarddeviation was employed to calculate the average energy and time needed to convert a unit volume of timber (log).

ii. Regression analysis was employed to determine the predictability of energy and time efficiencies of the sawmills from the selected variables

The model is given as

$Y = a+b_1x1+b_2x2+b_3x_3\ldots\ldots\ldots\ldots\ldots\ldots\ldots b_nx_n+e$

Where ni………..xn = independent variables i.e. factors considered.

Y = Dependent variable (i.e. predicted variable)

X_1 = Experience of Headrig operator

X_2 = Education level of Headrig operator

X_3 = Product Mix

X_4 = Labour force

X_5 = Experience of saw doctor

X_6 = Educational level of saw doctor

a = intercept

b1-bn = regression coefficient or slope (i.e. the change in Y per unit change in X)

e = Error term

Source: Adesoye (2004)

iii. Also, correlation coefficient was employed to investigate the degree of association and the direction of relationship between the variables that were measured. Multiple linear regression analysis was carried out to determine the effect of each factor on energy and time efficiency. Also coefficient of determination (R^2), Standard error (SE), and Mean square error (MSE) were employed to explain or determine the proportion of variation explained by the regression equation. Data for the variables werefitted into a forwardstepwise multiple linear regression equation to determine the variables influencing energy and time efficiency. The average of the mean square errors was used to determine the performance of the equation. The Mean Square Error (MSE) for all the models employed were compared to select the most suitable equation.

3.5.2 Achievement of Objectives.

Objective (i): Investigation of effect of log parameters on energy and time efficiencies was carried out through the use of regression analysis and correlation analysis.

Objective (ii): Effect of log conversionmethodson energy and time efficiency was carried out by the use ofstudent t- test.

Objective (iii): Effect of anthropogenic factors was carried out through the use of regression analysis.

Objective (iv): Effect of product mix on energy and time efficiency was carried out by the use of regression analysis.

Objective (v): Effect of labour force on energy and time efficiency was carried out by employing regression analysis.

CHAPTER FOUR

4.0 RESULTS

4.1 Characteristics of Respondents

It was discovered in this study that out of the 85 workers interviewed 13 workers (15.29%) fell within work experience of under five years, 52 (61.18%) were within the experience of 5-10 years while the remaining 20 (23.53%) workers had experience of over 10 years. Out of these workers 17(20%) were Mill Managers, 21(24.7%) Headrig Operators, 18(21.2%) Sawmill Technicians and the remaining 29 (34.1%) were Labourers.

It was observed that only 30 (35.3%) of the workers had formal training and only 36 (42.4%) attained up to the level of secondary school education (Table 2).

The remuneration of Headrig Operators ranged from N12, 000.00 –N28, 000.00 per month while that of Sawmill Technicians were from N10, 000.00 –N25, 000.00 per month. Some Labour hands earned as low as N5,000.00 per month (Table 3).

4.2 Characteristics of Sampled Logs

A total of 204 logs were sampled in the study area. These logs were made of 25 different species of different forms and sizes (Table 5) Twenty two logs (11%), fell under small diameter class, (<40cm), 92 (45%) were medium diameter class (40.1 – 65cm), while 90 (44%) fell under large (≥ 65.01cm) diameter class. The logs were also classified into three classes of straight, 59(29%), tapered, 124(61%) and crooked, 21(10%) (Table 4).

It was observed that *Ceibapentandra* was the most sawn species with 24 logs being 11.5% of total while *Funtumiaelastica* was the least sawn with only one (0.49%) log

Table 2:Characteristics of Respondents based on Experience, Status and Educational Level

S/N	Variables	Options	Number	Percentage
1	Experience	<5yrs.	13	15.3
		6-10yrs.	52	61.2
		>10yrs.	20	23.5
2	Status	Manager	17	20
		Headrig Operator	21	24.7
		Sawmill Technician	18	21.2
		Labour	29	34.1
3	Education	<Pry.Schl.	25	29.4
		Pry-Sec.Schl.	48	56.5
		>Sec.Schl.	12	14.1

Table 3: Average Monthly Remuneration of Workers

S/N	Status	Amount (N:K)
1	Manager	55
2	Headrig Operator	22
3	Sawmill Technician	15
4	Labour	8

Table 4:Characteristics of Sampled Logs based on Diameter Class and Log Form

S/N	Variables	Options	Number	Percentage
1	Diameters class	Small < 40cm	22	11
		Medium 40.01cm-65cm	92	45
		Large >65cm	90	44
2	Log form	Straight	52	29
		Tapered	152	61
		Crooked	21	10

Table 5: Frequency Distribution and Percentage of Sampled Logs

Species Name	Frequency	Percentage (%)	Cumulative Percentage %
Funtunmiaelastic	1	0.49	0.49
Afzelia Africana	2	0.98	1.47
Masoniaalticsima	2	0.98	2.45
Brachystegiaeurycoma	3	1.47	3.92
Cordiamillenii	3	1.47	5.39
Khayasenegalesis	4	1.96	7.35
Ricinodendronheudelotii	4	1.96	9.31
Terminaliaivorensis	4	1.96	11.27
Anogeisusleiocarpus	6	2.54	13.81
Entandropragmamicrophylum	6	2.54	16.35
Ficusmucuso	6	2.54	18.89
Albizialebbeck	8	3.92	22.81
Steculiarhinopetala	8	3.92	26.73
Dinelliaogea	10	4.9	31.63
Pycnanthusangolensis	10	4.9	36.53
Celtismildbreadii	10	4.9	41.43
Terminaliasuperba	10	4.9	46.33
Alstoniacongensis	12	5.88	52.21
Chrysophyllumalbidiun	12	5.88	58.09
Erythrophyllumivorense	12	5.88	63.97
Holopieliagrandis	12	5.88	69.85
Milliciaexcels	15	7.35	77.20
AntiarisAfricana	16	7.84	85.04
Ceibapentandra	24	11.76	96.80
Total	204	100	

4.3 Result of Hypothesis Testing

This section presents the results of the hypothesis tested in the study.

4.3.1 Hypothesis 1: Variation in log diameter has no significant effect on Energy and Time Efficiency of lumber production in the sawmills.

The result of the study showed that the total number of logs sampled was 204. Medium diameter class was the highest with 92 (45%) logs, followed by large diameter class, 90 (44%), and lastly small diameter class logs numbering 22 (13.4%). This result also indicated that the mean for the three diameter classes were 19.8, large 11.2 and small 5.7.

The result of one-way Analysis of Variance (ANOVA) showed that the effect of log diameter on Energy Efficiency was significant at $p \leq 0.05$, and since Ho ≠ Ha we reject the Ho (Table 6).

Also the result of correlation analysis showed that there was strong positive correlation between energy efficiency and log diameterclass (0.65), log volume (0.91), idle energy utilized (0.86), volume of slab (0.83), volume of sawdust (0.86) and lumber volume (0.91) at $p \leq 0.05$ (Table 8).

The result also indicated that there weresignificant differences between small, medium and large diameter classes.

The result of Duncan means and means separation values showed that there was significant difference in Energy Efficiency of small (5.7), medium (11.2) and large (19.8) diameter classes (Table 9).

Also, the mean Time Efficiency for the three diameter classes are 16.4 for Large, 15.1 for medium and 11.2 for small diameter classes respectively (Table 9).

The result of one-way ANOVA indicated that the influence of log Diameter on Time Efficiency was significant at $P \leq 0.05$ (Table 7).

The result of Duncan analysis also showed that while there was no significant difference between Time Efficiency of large and medium diameter logs, the small diameter logs, were significantly different (Table 9).

Table 6:Effect of Assessed Variables on Energy Efficiency

S/N	Parameter	Source of variation	Sun of Square	DF	MS	F	P. Value
1	Log diameter	Diameter class	5633.480	2	2816.70	98.762	0.000*
		Error	5875.215	202	28.520		
		Total	11508.695	204			
2	Log volume	Volume	36.4512	1	36.451	51.841	0.000*
		Error	145.550	203	703		
		Total	182.001	204			
3	Log form	Form type	52.463	2	26.231	0.462	0.618NS
		Error	11211.374	202	54.424		
		Total	11263.837	204			
4	Experience of headrig operator	Experience	1171.984	1	1171.984	23.470	0.000*
		Error	10336.711	203	49.984		
		Total	11508.695	204			
5	Education	Level	53.434	2	26.717	0.586	0.557NS
		Error	9384.665	203	45.557		
		Total	9438.099	204	4		
6	Age of machine	Age	1068.372	1	1068.372	21.183	0.000*
		Error	104440.323	203	50.436		
		Total	11508.693	204			
7	Product mix	Mix	278.397	1	278.399	5.131	0.025*
		Error	11230.298	203	54.253		
		Total	11508.695	204			
8	Saw kerf	Kerf	6.257	1	6.257	111	0.739NS
		Error	11641.265	203	56.238		
		Total	11647.522	204			
9	Labour	Number group	27.957	1	27.959	498	0.481NS
		Error	11619.562	203	56.133		
		Total	11647.522	204			
10	Product mix	Dimension	278.397	1	278.397	5.131	0.025*
		Error	11230.298	203	54.253		
		Total	11508.695	204			

Note: *Significant at 1% probability level, P<0.05, NS = not significant.

Table 7: Effect of Assessed Variables on Time Efficiency

S/N	Parameter	Sourced variation	Sun of Square	DF	MS	F	P. Value
1	Log diameter	Diameter class	621.854	1	310.927	20.097	0.000*
		Error	3666.765	203	15.472		
		Total	4288.619	204			
2	Log volume	Volume	36.4512	1	36.451	51.841	0.000*
		Error	145.550	203	0.703		
		Total	182.001	204			
3	Log Form	Form type	52.463	2	26.231	0.048	0.618NS
		Error	11211.374	202	54.424		
		Total	11263.837	204			
4	Experience of headrig operator	Experience	122.544	1	1222.544	6.597	0.011*
		Error	3845.449	203	18.577		
		Total	3967.993	204			
5	Education	Level	53.434	2	26.717	0.586	0.557NS
		Error	9384.665	202	45.557		
		Total	438.099	204	4.0		
6	Age of machine	Level	233.841	1	233.841	13.102	0.000*
		Error	3676.616	203	17.848		
		Total	3910.456	204			
7	Product mix	Mix	95.868	1	95.868	5.125	0.025*
		Error	3872.125	203	18.706		
		Total	3967.993	204			
8	Saw kerf	Kerf	60.255	1	60.255	3.219	0.074NS
		Error	3875.257	203	18.721		
		Total	3935.512	204			
9	Labour	Number of group	240.873	1	240.873	34.495	0.000*
		Error	3694.639	203	17.848	5.125	0.025*
		Total	3955.512	204			
10	Product mix	Dimension	95.868	1	95.868		
		Error	3872.125	203	18.706		
		Total	3967.993	204			

Note: *Significant at 1% probability level, P<0.05, NS = not significant.

Table: 8: Correlation Table for Log Variables on Energy and Time Efficiency

	Diameter Class	Log Volume	Time Efficiency	Idle Sawing Time	Energy Efficiency	Idle Energy Utilized	Volume Slab	Volume of Sawdust	Lumber Volume
Diameter Class	1								
Log Volume	.725*	1							
Time Efficiency	.377	.375	1						
Idle Sawing Time	.487	.504*	.386	1					
Energy Efficiency	.647*	.912*	.484	.442	1				
Idle Energy Utilized	.610*	.907*	.291	.434	.856*	1			
Volume Slab	.663*	.873*	.345	.401	.832*	.811*	1		
Volume of Sawdust	.613*	.896*	.364	.422	.859*	.833*	.909*	1	
Lumber Volume	.714*	.992*	.361	.489	.905*	.903*	.859*	.833*	1

* Correlation is significant at 0.05 level

Table 9:Means Values and Duncan's Mean Separation Values of Variables Assessed

S/N	Educational level	Lug input	Slab	Sawdust	Planks	TE	EE
1	Below Pry	0.67^{a}	0.25^{a}	0.08^{a}	0.35^{a}	14.8^{a}	13.3^{a}
	Pry –Sec	0.78^{a}	0.28^{a}	0.1^{a}	0.41^{a}	15.7a	15.3^{a}
	Above sec	0.82^{a}	0.27^{a}	0.1^{a}	0.46^{a}	16.7^{a}	15.2^{a}
2	Diameter class						
	Small	0.25^{b}	0.12^{a}	0.04^{a}	0.13^{b}	11.17^{c}	5.69^{c}
	Medium	0.52^{b}	0.20^{a}	0.07^{a}	0.27^{b}	14.94^{b}	11.19^{b}
	Large	1.22^{a}	0.54^{a}	0.3^{a}	0.73^{a}	16.69^{a}	19.74^{a}
3	Age of machine						
	1-7yrs	0.85	0.3^{a}	0.10^{a}		16.8^{a}	17.0^{a}
	8-15yrs	0.64	0.25^{b}	0.08^{b}		14.1^{b}	12.7^{b}
	15 yrs above	0.61	0.22^{b}	0.07^{b}		14.1^{b}	11.4^{b}
4	Labour						
	3yrs	0.71^{a}	0.26^{a}	0.09^{a}	0.37^{a}	15.61^{a}	14.04^{a}
	4yrs	0.79^{a}	0.28^{a}	0.1^{a}	0.41^{a}	14.61^{a}	14.61^{a}
	5yrs	0.68^{a}	0.25^{a}	0.08^{a}	0.36^{a}	14.42^{a}	13.71^{a}
	6yrs	0.75^{a}	0.27^{a}	0.09^{a}	0.39^{a}	15.58^{a}	14.97^{a}
5	0-5yrs		0.23^{b}	0.076^{b}	0.28^{b}	13.45c	10.98^{c}
	6-10yrs		0.24^{b}	0.079^{b}	0.31^{b}	14.96^{b}	12.67^{b}
	Above 10yrs		0.31^{a}	0.11^{a}	0.46^{a}	16.17^{a}	17.71^{a}

Mean with the same letters are not significantly different at ($p<0.05$)

Table 10: Effect ofSawing Pattern on some Assessed Variables

Sawing pattern	N	Mean	Std error	Df	Sig
Log	207	0.71	0.028	206	0.00
	2	1.05	0.002	1	0.01
Vol. of slab	207	0.26	0.11	206	0.00
	2	0.37	0.003	1	0.005
Vol. of sawdust	207	0.09	0.003	206	0.000
	2	0.14	0.001	1	0.005
Lumber	207	0.37	0.015	206	0.000
volume	2	0.55	0.006	1	0.008
Time	207	15.09	0.30	206	0.000
efficiency	2	24.75	4.05	1	0.103
Energy	207	14.05	0.52	206	0.000
efficiency	2	20.94	0.48	1	0.0151

4.3.2 Hypothesis 2: Log volume has no significant effect on Energy and Time Efficiency

The result of regression analysis indicated that log volume has significant effect on both Energy and Time Efficiency at $P \leq 0.05$ (Table 6) and (Table 7).

4.3.3 Hypothesis3: Variation in log form do not have significant effect on Energy and Time Efficiency

The logs were grouped into three categories of Straight, Tapered, and Crooked. A total of 52 (29%) of the logs were straight, 124 (61%), were tapered while 21(10%) were of crooked form (Table 4)

The result of one-way ANOVA showed that log form had no significant effect on both energy and time efficiency at $p \leq 0.05$. Since Ho =Ha, we therefore fail to reject the null hypothesis (Ho),(Tables 6 & 7).

4.3.4 Hypothesis 4: Sawing pattern has no significant effect on Energy and Time Efficiency

There were only two sawing patterns observed, hence the student t-test was employed for data analysis.

The result showed that the effect of sawing pattern was significant on Energy and Time Efficiency at $P \leq 0.05$ (Table 11).

The mean for Energy Efficiency for plain sawing was 11.96 while that of quarter sawing was 20.94.The mean for Time Efficiency for plain sawing was 12.65, and that of quarter sawing was 24.75 (Table 12).

Table: 11 Effect of Sawing Pattern on Energy and Time EfficiencyPaired Sample Correlation

	N	Correlation	p-value
Pair 1 plain sawn & Quarter Sawn	2	-1.000	.000*

* Significant at $P \leq 0.05$

Table 12: Sawing pattern sample Statistics

	Mean	N	Standard Deviation	Standard Error Mean
Plain Sawing	11.9600	2	0.73539	0.5200
Quarter Sawing	20.94	2	0.67882	0.08000
Plain sawing	12.6500	2	1.48492	1.0500
Quarter Sawing	24.7500	2	5.72755	4.0500

4.3.5Hypothesis 5: Experience of Headrig Operator has no significant effect on Energy and Time Efficiency.

The result of ANOVA indicated that experience of Operator has significant effect on Energy Efficiency at $P \leq 0.05$ (Table 6) and (table 7). We can therefore reject Ho as far as experience ofHeadrig Operator is concerned.The result of Duncan analysis also indicated that the means of the energy and time efficiency for the three experience levels were significantly different from one another (Table 9).

4.3.6Hypothesis 6: Educational status of headrig operator has no significant effect on Energy and Time Efficiency. The result of ANOVAshowed that educational status had no significant effect on Energy and Time Efficiency at $P \leq 0.05$ (Table 6). Since Ho = Ha, we therefore fail to reject the null hypothesis Ho.

4.3.7Hypothesis 7: Age of machine has no significant effect on Energy and Time Efficiency

The result of one-way ANOVA showed that age of machine has significant effect on Energy Efficiency at $P \leq 0.05$ (Table 6). Also the result showed that the Age of Machine had significant effect on Time Efficiency (Table 7). It was also discovered that while the mean energy and time efficiencies of machines of ages 8-15 and 15 years and above were not different, those of 1-7 years were significantly different from others (Table 9).

4.3.8 Hypothesis 8: Product mix has no significant effect on Energy and Time Efficiency. Product mix refers to the various sizes of lumbers derived from a log. The result of one-way ANOVA indicated that product mix has significant effect on both Energy and Time Efficiency at $P \leq 0.05$. The null hypothesis Ho is therefore rejected (table 6) and (table 7).

4.3.9 Hypothesis 9:Variation in saw kerf has no significant effect on Energy and Time Efficiency

The result of Analysis of Variance indicated that saw kerf has no significant effect on both Energy and Time Efficiency (Tables 6 and 7).

4.3.10 Hypothesis 10:Labour force has no significant effect on Energy and Time Efficiency

The result of ANOVA showed that labour has no significant effect on Energy Efficiency but has significant effect to Time Efficiency (Tables 6 and 7).

4.4 Energy and Time Efficiencies on the Basis of States

In Ondo State, 131 logs were sampled while 73 were sampled in Ekiti State, making a total of 204 logs. A student t-test analysis was carried to determine if there were significant differences between the means of Energy and Time Efficiencies of the two States.

The results of t-test analysis indicated that there was significant difference in energy efficiency and time efficiency between Ondo and Ekiti States at $P \leq 0.05$. (table13). However, there were not much differences between the mean of energy efficiencies of ondo (13.48) and Ekiti (14.81). Table 13.

Also there were not much differences between the mean of time efficiency for Ondo (15.2) and Ekiti (14.8). Table (14).

Table 13: Energy Efficiencies of Ondo and Ekiti States

	T	Df	Mean	p-value
Energy Efficiencies Ondo State	25.401	131	13.4812	0.000*
Energy Efficiencies Ekiti State	13.561	7.4	14.8158	0.000*

* Significant at $P \leq 0.05$

Table 14: Time Efficiencies of Ondo and Ekiti States

	T	Df	Mean	p-value
Time Efficiencies Ondo State	36.815	130	15.1955	0.000*
Time Efficiencies Ekiti State	34.888	72	14.7733	0.000*

* Significant at P≤0.05

4.5 Prediction Equations Employed for Energy and Time Efficiency

The prediction equation employed for Energy Efficiency in the study area is as follows:

EEF =0.680+0.912Lv+0.860Sdv +0.32Hex +0.855Ti -0.32Mag + e

Where EEF=Energy Efficiency, LV =Log Volume, SDV =Sawdust Volume, EHO =Experience ofHeadrig Operator, IT = Idle Sawing Time and, AM =Age of Machine.

Coefficient of determination (R^2) =0.856. Mean Square Error (MSE) =2.861.

This means that at any given log volume, volume of sawdust, experience of headrig operator, idle sawing time, and age of machine, the average Energy Efficiency can be estimated (Table4.4a).

Also the prediction equation for Time Efficiency is as follows:

TEF = -1.378+0.798TT +1.807Spt-0.75IT-0.178MA -78.03PM.+ e

Coefficient of determination (R^2) =0.536. Mean Square Error (MSE) =2.996.

This also indicate that at any given total sawing time, sawing pattern, idle sawing time, age of machine, and product mix, the average Time Efficiency can be estimated (Table 4.4b).

In order to get the equation with the best fit, the model with the highest Coefficient of determination (R^2) and the lowest Mean Square Error (MSE) will be selected. The best equation is usually selected by comparing the mean square error (MSE) and the highest R^2.

The result of this study therefore showed that the model with the highest R^2 (0.856) and lowest MSE (2.861) for Energy Efficiency is as follows:

EEF = 0.680+0.912LV+0.860SDV+0.321EHO+0.855IE-0.32MA+e ------- (table 4.5a)

Where EEF =Energy Efficiency, LV =Log volume, SDV =Volume of sawdust, EHO =Experience of headrig operator, IE =Idle energy utilized, AM =Age of machine, MSE =Mean square error and R^2 =Coefficient of determination.

Also for Time Efficiency the model with the lowest MSE(2.998) and R^2(0.532) is as follows:

TEF = -1.378+0.797TT+1.807Spt-0.756IT-0,178AM-78.031PM +e (table 4.5b)

Where TEE = Time Efficiency, TT =Total sawing time, SP =Sawing pattern, IT =Idle sawing time, AM =Age of machine, PM =Product mix, R^2 =Coefficient of determination and MSE =Mean square error.

Table 15:Forward Stepwise Multiple Linear Regression Models for Variables Influencing Energy Efficiency

Step	Variable	Equation	MSE	R2	%of individual contribution
1	Predictor (constant) log volume	EEF=2.075+16.768LV+e	3.061	0.832	83%
2	Predictor (constant) log vol. vol. of sawdust	EEF=1.647+13.256LV+33.777SDV + e	2.987	0.841	0.9%
3	Predictor (constant) log vol. vol. of sawdust, experience of head rig	EEF=-0.285+12.833LV+33.803SDV +1.007EHO+e	2.927	0.848	0.7%
4	Predictor (constant) log vol. vol. of sawdust, experience of head rig, idle energy utilized	EEF=-0.782+10.163LV+ 31..010SDV+1.151EHO +0.955IE+e	2.885	0.853	0.5%
5	Predictor (constant) log vol. vol. of sawdust, experience of head rig, idle energy utilized, Age of machine	EEF=0.680 + 0.912LV + 0.860SDV +0.321 EHO + 0.855IE-0.32 AM + e	2.861	0.856	0.3%

Note: Dependent variable (Y): % EEF = energy efficiency, LV = log volume, SDV = volume of sawdust, EHO = experience of headrig operator, IE = idle energy utilized MSE = mean square error, R^2 = coefficient of determination

a. Predictor (constant) log volume.
b. Predictor (constant) log volume, volume of sawdust.
c. Predictor (constant) log volume, volume of sawdust, experience of headrig operator.
d. Predictor (constant) log volume, volume of sawdust, experience of headrig operator, idle energy utilized.
e. Predictor (constant) log volume, vol. vol. of sawdust, experience of headrig operator, idle energy, age of machine.

Table 16:Forward Stepwise Multiple Linear Regression for Variables Influencing Time Efficiency

Step	Variable	Equation	MSE	R2	individual contribution %
1	Predictor(constant) total sawing time,	TEF=3.946+0.524TT + e	3.413	0.386	3.9%
2	Predictor(constant) total sawing time, sawing pattern	TEF=5.774+0.523TT+1.927SP+e	3.288	0.433	4.7%
3	Predictor(constant) total sawing time, sawing pattern, idle sawing time	TEF=-6.761+0.801TT+2.025SP – 0.723 IT + e	3.143	0.485	5.2%
4	Predictor(constant) total sawing time, sawing pattern, idle sawing time, age of machine	TEF=-3.0902+0.807TT+ 1.866SP–0.788IT–0.172 AM + e	3.061	0.514	2.9%
5	Predictor(constant) total sawing time, sawing pattern, idle sawing time, age of machine product mix	TEF=-1.378+0.797TT+1.807SP- 0.756IT+0.178AM+78.031PM+e	2.998	0.536	2.2%

Note: Dependent variable (y) % TEF = time efficiency TT = total sawing time, SP = sawing pattern Ti = idle sawing time, AM = Age of machine, PM = product mix.

Predictor (constant)totalsawingtime.

Predictor (constant) total sawing time, sawing pattern, idle sawing time.

Predictor(constant) total sawing time, sawing pattern, idle sawing time, age of machine.

Predictor(constant) total sawing time, sawing pattern, idle sawing time age of machine, product mix.

4.6 ENERGY CONSUMPTION RATE

The result showed that the total effective energy consumed to convert all logs sampled was 2777.46kwh and the total volume of logs converted was 150.08m3. The energy consumption rate was therefore 18.5kw/m3 (66.6MJ/M3). The Energy Consumption Rate(ECR) for Ondo was 19.4kwh/m3 while that of Ekiti was 17.5kwh/m3.(Table 17).

4.7 WOOD CONVERSION RATE (WCR)

The result indicated that the total effective time utilized was 2971.43 minutes while the total volume of logs sawn was 150.08m3. The log conversion rate was therefore 19.8Min./M3. However, the Wood Conversion Rate (WCR) for Ondo was 17.9min./m3 while that of Ekiti was 21.7min./m3.(Table 18).

4.8 PERCENTAGE ENERGY AND TIME EFFICIENCIES FOR ONDO AND EKITI STATES

The result showed that the average percentage Energy efficiency was 52.6% while the average percentage Time efficiency was71.3% for the study area. The Energy and Time Efficiency for Ondo was 53.7% and 70.3% respectively while that of Ekiti was 51.3% and 72.3% respectively (Tables 19 & 20).

Table 17: Energy consumption rate

States	Total effectiveenergy consumed (kwh)	Total volume of log m^3	Energy consumption rate (kwh/m^3)
Ondo	1521.33	78.78	19.4
Ekiti	1249.15	71.30	17.5
Average	1388.74	71.04	18.5

Table 18: Wood Conversion Rate (WCR)

States	Total effective energy consumed (kwh)	Total volume of wood m^3	Wood consumption rate mn/m^3
Ondo	14 28.22	78.78	17.9
Ekiti	12 49.21	71.30	21.7
Average	14 81.72	75.04	19.8

Table 19: Energy Efficiency for Ondo and Ekiti State

States	Total Time mins/kwh	Effective Time mins	Energy Efficiency %
Ondo	2846.1	15 28.33	53.7
Ekiti	24 35.0	12 49.15	51.3
Average	2640.06	1388.74	52.5

Table 20: Time efficiency for Ondo and Ekiti state

States	Total Time mins.	Effective Time mins.	Energy Efficiency %
Ondo	20 25. 9	14 24. 22	70.3
Ekiti	21 40 .0	1547.21	72.3
Average	20 82.92	14 81.72	71.3

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Log Diameter on Energy and Time Efficiency

The result of the study showed that out of the total number of 204 logs sampled small diameter class (≤ 40cm was 22 (11%), medium diameter class (40.01-65cm) was 92 (45%) and high diameter class (≥ 65.01cm) was 90 (44%) (Table 4).

The result of one –way (ANOVA) showed that log diameter was significant on energy efficiency at $p \leq 0.05$. The mean energy efficiency for medium diameter class was the highest among the three classes. This may be because much energy was lost in adjusting big logs on the rail because of their sizes and much energy was also lost in adjusting the saw. In the case of small logs much energy was also wasted while packing the logs to allow conversation to be carried out while the mill would be running without actually sawing the logs.

Large diameter classes recorded highest time efficiency, followed by medium diameter class and lastly by the small diameter class. The reason for this may be because headrig operators and other workers usually concentrate more on the job because this class of logs are no longer easy to come by and owners would want to derive maximum profit, hence the much attention paid to their conversation.

5.2Energy and Time Efficiency as Influenced by sawing pattern

There were only two sawing patterns observed in the study. These were plain sawing and quarter sawing. Plain sawn logs were 99% while quarter sawn logs were 1%

This may be because of the type of dimensional lumbers desired and the size of the logs. Only very big log sizes were usually quarter sawn.

The result of t-test showed that sawing pattern has significant effect on energy and time efficiency, $p \leq 0.05$. The result of sawing pattern is in tandem with earlierstudies.Egbewole, (2014) indicated that plain sawing yielded higher lumber recovery than quarter sawing. The fact that different sawing patterns yielded different lumber recovery help to show that sawing pattern will definitely have effect on energy and time utilized.

5.3 Effect of Anthropogenic factors on Energy and Time Efficiency

The Anthropogenic factors considered were experience and educational status of headrig operator. Experience of headrig operators were grouped into three classes depending on number of years spent on the job. The classes are ≥ 5 years, 6-10 years, and 10 years and above. Out of the total, 13(25.29%) fell under less than 5 years' experience, 52(61.18%) were within the experience of 6-10 years while the remaining 20 (23.53%) fell under the experience of over 10 years.

Also, headrig operators were classified according to their educational status. Only 36 (42.4%) of the heading operators attained up to secondary school education while none of them attended any tertiary institution.

The result of one-way ANOVA indicated that experience of headrig operator had significant effect on energy and time efficiency at $p \leq 0.05$. However, their educational status had no significant effect on both energy and time efficiency at $p \leq 0.05$. This shows that experience rather than education matters in attaining high level energy and time efficiency if other factors are held constant. However, the result obtained for experience of headrig operator is not unconnected with the fact that the longer one stays on a job the more he finds it easier to perform that task. This result can also be related to higher lumber recovery recorded by Egbewole, (2014) for headrig operators with higher experience. The result obtained for the effect of education may also be because most of the headrig operators fell within the same educational status. If some of them had acquired higher educational status, it is possible that the result would have been different.

5.4 Effect of Age ofMachine onEnergy and Time Efficiency

The result of one-way ANOVA showed that age of machine had significant effect on time and energy efficiency at $p \leq 0.05$. It is logical that old and obsolete machines will utilised more time and energy during the conversion of a given volume of log than newer ones.

5.5 Effect of Labour on Energy and Time Efficiency

The fact that the number of workers has effect on Timeefficiency (Table 6), indicated that if an appropriate number of workers is not employed during log conversion, a lot of useful time might be wasted. Too many labour hands during log conversion may leads to arguments and other forms of disturbances among workers, and that could increase idle time while too few could also have the same effect.

5.6 Energy and Time Efficiency on the Basis of States

The mean percentage energy efficiency for Ondo State was 53.7% while that of Ekiti was 51.3%. Also the mean percentage time efficiency for Ondo State was 70.3% while that of Ekiti was 72.3%

In Ondo State, 65% of headrig operators had experience of more than 10 years whereas in Ekiti State headrig operators with more than 10 years experience was 57%. This might have allowed for the slightly higher energy efficiency recorded in Ondo State than Ekiti State. The lower time efficiency recorded in Ekiti State might be as a result of weak supervision of workers during log conversion. However, the percentage of headrig operator with former education in Ondo State was lower, 28% while that of Ekiti was 32%. The result had earlier shown that educational status of operator had no significant effect.Twenty five percent (25%) of headrig operators in Ondo State had formal training while only 18% of operators had formal training in Ekiti State. This factor may also be responsible for the higher energy efficiency recorded in OndoState and the lower time efficiency inEkiti State.

CHAPTER SIX

6. 0 CONCLUSIONAND RECOMMENDATIONS

6. 1 Conclusion

This study was carried out to identify some factors that affect the efficient use of energy and time as they affect lumber production in the sawmills in Ondo and Ekiti states southwestern Nigeria. This was done with the aim of providing information that will guide sawmill operators and researchers in the future.

It was revealed in the study that variables such as log volume, volume of sawdust, experience of headrig operator, idle sawing time, age of machine, sawing pattern and total sawing time had significant effect on energy and time efficiency of sawmills. In any business endeavour that entails the use of energy, the use of optimum energy to achieve maximum possible output is very important. In the same manner, adequate time management for maximum achievement is also important in any production.

1. It was shown in the study that the average Energy and Time Efficiency in the study area were 44.9% and 71.3% respectively. Also average effective energy utilized and effective sawing time were 14.1 kwh and 15.3 minutes per cubic metre of wood respectively while the average idle energy utilized and idle sawing time were 2.5 kw and 7.5 minutes respectively.
2. The main factors that had direct and significant effect on energy and time efficiency are log volume, volume of sawdust, experience of headrig operator, idle sawing time,age of machine, sawing pattern and product mix. This actually indicates that the time and energy utilized had effect. Also, conversion of logs should be carried out by experienced headrig operator.
3. It was also revealed that most of the machines used for log conversion were CD series and were obsolete.
4. It was revealed in the study that less than 40% of the workers had formal training for the tasks they were performing.
5. The highest remunerated worker aside the Manager who in most cases was also the Director cum owner earned ₦28,000.00. This is a low wage under the present economic situation in the country.
6. The study showed through forward stepwise regression analysis that the contribution of the following variables to Energy Efficiency are: log volume

(83%), volume of sawdust (0.9%), experience of operator (0.7%), idle energy (0.5%) and age of machine (0.3%).

Also, for Time Efficiency the contribution of the variables are as follows; total sawing time (39%), sawing pattern (4.7%), idle sawing time (5.2%), Age of machine (2.9%) and product mix (2.2%).

6.2 Recommendations

It is important that during log conversion in sawmills, strategies that will employ minimum energy and time to produce maximum output be adopted to prevent wastes and increase revenue generation.

The following recommendations are to enhance optimum utilization of energy and time during log conversion in sawmills.

1. Experienced headrig operators should be engaged in log conversion in the sawmills.
2. Machines that are obsolete should be replaced with new ones.
3. Headrig Operators and other sawmill workers should be more alert to their responsibilities and use less time on other activities during conversion of logs.
4. Sawing or conversion of logs to bigger dimensions should be encouraged to save more energy and time.
5. Headrig Operators should be exposed to formal training to enhance their efficiency.
6. An appropriate number of workers should be engaged during log conversion to reduce the level of idle time.
7. Regular evaluation of Energy and Time Efficiency of sawmills should be carried out by adopting the models established by this study.

REFERENCES

Adeyoju, S.K. (1975): Forestry and the Nigerian Economy. University of Ibadan Press, Nigeria; 308pp.

Adesoye, P.O. (2004): Practical guide to statistical analysis for scientists. Publ. DEBO PRINTS 0834650144, ISBN 978-37965-O-X, P108-112.

Agboola, S.A. (1979): An Agricultural Atlas of Nigeria, Oxford University Press, Nigeria, 248pp.

Akindele, S.O. (2004): Basic Designs in Agricultural Research. Publ. Royal Bird Ventures, Mushin, Lagos Nigeria ISBN 978-32973-8-4.P136-153.

Alviar, G.O. (1993): Sawmilling Industry in Nigeria, Field Documents No. 17. Food and Agricultural Organisation (FAO) Rome.

Aribisala O. A. (`1993): Raw Materials Revolution and Impact on Industrialization in Nigeria Medriet Publications Ltd. ISSN 978-024-004.

Badejo, S.O.O. (1990): Sawmill Wood Residue in Nigeria and their Utilization. Invited paper, proceeding of National Workshop on Forestry Management Strategies for Self-sufficiency in Wood Production; Ibadan 12th-15th June, 1990, pp32.F Research Institute of Nigeria (FRIN).

Bennett, W. (1974): Modern Sawmill Techniques; Proceeding of Third Sawmill Clinic; Portland Oregon, Miller Freeman Publication Incorporation, California, USA; vol. 3, 21pp.

Bennet, Neal (2014) – Sawing Methods for Improving Lumber Yield recovery of out-of-shape hardwood sawlogs. Gen. Tech. Rep. NRS – 130, Newton Square PA, USA.

Bryan (1966) – Economics of Sawmill Operation: A report by Forest Resources Laboratory. Prince RusboroughAylesbury, Buchs. PP.

Civil and Environmental Research ISSN 224-1590 (paper); ISSN 0-2225-0514 (Online)

Dele V.M., Johnson Olanrewaju, R. Bodede and FisayoAdesina: Wood Processing Industries in Nigeria: The way forward. Innovative Systems Designs and Engineering. ISSN 2222-1727 (paper), ISSN 2222-2871 (Online). Vol. 5, No.6, 2014.

Department of Agriculture, Forest Service, Northern Research Station. 8P.

Dobie J (1972) – Guidelines for the Study of Sawmill Performance Information Report VP-X-93.Western Forest Laboratory.Env. Canada Forest Service Vancouver, Canada B.C. Jan 1972 72pp

Egbewole,Z.T (2014): Correlates of Lumber Recovery from high forest tree species in sawmillsof southwestern Nigeria. Unpublished Ph.D Thesis in the Department of Forest Resources Management, University of Ibadan, Nigeria.

Egbewole Z.T., Afuwape M.A. and Ogunsanwo O.Y., Adejoba O.R.,Ogunleye M.B., (2005)Correlates of Lumber Recovery Factor (LRF) in selected sawmills in South Western Nigeria. A Publication of Association of Wood and Paper Technology(ASWOPATECHS) Federal College of Forestry, Ibadan.Published by Eagleman Publishing House. ISSN 978-37853-2-X Vol. 1

Egbewole Z.T, Afuwape M.A. and Ogunsanwo O.Y. (2006). Lumber recovery from High Forest Species in selected sawmill of South Western Nigeria. Bowen Journal of Agricultural Vol. 44 September 2006. Pp 151-162.

Egbewole, Z.T, Ogunsanwo, O.O.Y andOmole, A.O. (2011): Technical Efficiency of Lumber recovery from high forest tree species in selected sawmills in southwestern Nigeria. OBECHE, Scientific journal of the Tree Club; A publication of Faculty of Agriculture and Forestry; Department of Forest Resources Management, University of Ibadan. www.obechejournal@gmail.com ISSN 0078-2912.200-206.

Ekhuemelu D.O. and Atondo T.M. (2015). Evaluation of Lumber Recovery and Waste Generation in selected Sawmills in Three Local Government Areas of Benue State, Nigeria.A Publication of the school of Agricultural Technology, the Federal University of Technology, Akure.

Food and Agricultural Organisation (FAO) (2005).Global Forest Assessment.

FOSA (2009), Forestry Outlook Studying in Africa: Nigeria, Ministry of Natural Resources and Tourism.(Available at http://www.fao.org/docrep/004ab592e/AB592E01.htm).

Franscescato.V, Antonia. E, Bergemi. L. Z, Metchina. S. C, Stanieri. S (2008): in Wood Fuels Handbook. AIEL Halima Agroforestry Energy Association, Legnaro. World Journal of Engineering and Technology, 2014. 2,254-248

Fuwape (1985): Assessment of log conversion efficiency in sawmills in Ondo-State: Nigerian Journal of Forestry, 20(1&2):27-30

G.W.V. Consultants (1994): “Review of wood based sector to Nigeria report” presented to Forest Management, Evaluation and Coordinating Unit; Federal Department of Forestry, Abuja, Nigeria 490pp.

Global Forest Assessment: Country Report:- Nigeria(2015). FAO.

https://www.fao.org/docrep/008/ao400eoo.htm

John J.J. and Vidal E. (1996): Reducing Waste during Logging and Log Processing: Forest Conservation in Eastern Amazonia: UNASYLVA, 19-25 (paper) http://pdxscholar.library.pdx.du/esm_fac.

Lucas, E.B. (1982): Improving lumber recovery from a live sawn log in the Nigerian sawmill situation using a computer programme. Nigerian Journal of Forestry 12:27-39.

Missanjo E. and Magodi F. (2015). Impact of Taper and Sawing Methods on Lumber Recovery for PinusKesiya and PinusPatula Logs in Circular Sawmills: Journal of Forest Product and Industrial, 2015, 4(1), 12-16 ISSN: 2325-4513 (prompt) ISSN 2325-453X (Online)

News.mongabay.com (2016): Environmental Science and Conservation News. https://www.mongabay.com//environmental science and conservation news with a focus on forests, oceans and wildlife.

Ofoegbu C., Ogbonnaya S. and Babalola F.D. (2014): Sawmill Conversion Efficiency and Wood Recovery of Timber Species in Cross River State, Nigeria.Agriculture and Forestry Vol. 60. Issue: 105-113, 2014, Podgorica.

Ogunsanwo O.Y, Aiyedoja A.A, Filani G.S. (2005): Assessment of off –site wastes associated with timber fliching in Ibadan. In proceedings of 30th Annual Conference of Forestry Association of Nigeria (FAN).Pp345-353.

Ogunsanwo, O.Y. (2010): Challenges of wood utilization in Nigeria. In S.K. Adeyoju and S.O. Bada (eds.); Readings in sustainable tropical forest management.Pp.293-303.

Ogunsanwo, O.Y, Adeleye I.G, Ajeh G.M. (2011): Technical Efficiency of Chain Sawmilling in Ogun State, Southwest, Nigeria: International Journal of Biological and Chemical Sciences, Volume 5:3, Pp.861-869

Ogunwusi A.A. (2012) – The Forest Products Industries in Nigeria. African Research Review 6 (4) 191-205.

OgunwusiA.A (2014): Wood Waste Generation in the Forest Industry in Nigeria and the Prospect for its Utilization: Civil and Environmental Research, ISSN 2224 5790(paper), ISSN 2225 0514 (Online).

Ogunwusi A.A. (2011); Wood Waste Generation in the Forest Industry in Nigeria and the Prospect for its Industrial Utilization.

Ogunyinka, O.M. (1976): Sawmilling industry in Abeokuta. Unpublished B.Sc. project report.Department of Agricultural Engineering, University of Ibadan, Nigeria.Pp3-18.

OkigboLawrence(1964): Sawmill Industry in Nigeria: Federal Department of Forest Research, Ibadan.

Olorunnisola, (2000): Workshop structure in the small scale furniture industry in Ibadan metropolis: Journal of Tropical Forest Resources 16(1): 46-57.

Olufemi, B; Akindeni J.O. and Olaniran S.O. (2012): Lumber Recovery Efficiency among selected sawmills in Akure, Nigeria; Original Scientific Paper; UDK 630-832-15.

Owonubi; J.J. and Badejo S.O.O. (2000): Research on sawdust utilization at FRIN; 1980-2000; Development of New Product Technologies; Paper presented at the Technology for small and medium scale enterprise, University of Benin, Benin-City, Nigeria; 21st May, 2000.

Owusu, F.W, Appiah, J.K, Damnyag, L, and Blay, D.Comparative Analysis of Recovery Efficiencies of Some Milling Techniques in Ghana, Ghana Journal of Forestry Vol.27, 2011, 87-100.

Popola L., Azeez I.O., Iponmwoba O.S. and Amusa T.O. (ZON). Analysis of Deforestation Pattern in the Niger Delta Region of Nigeria.

RMRDC 2012-update Report of the Multi-Disciplinary Taskforce (MTF) on the Techno-economic survey of wood and wood products: sponsored by RMRDC, Lagos, 2012 98 PP.

RMRDC 2009- Multi-Disciplinary Taskforce (MTF) on the Techno-economic survey of wood and wood products: sponsored by RMRDC, Lagos, 2012 98 PP., 2009.

Sambo A. S (2012): Renewable Energy For Rural Development: The Nigerian Perspective, ISESCO Science and Technology Vision, 1.12-22.

Scot J.D. Sawmill Census 1946 (Amended),Unpublished.

Steel Phillip, H. (1984): Factors determining lumber recovery in sawmilling. Technical report: FPL 39; Madison WI: US Department of Agriculture; Forest service, Forest Product Laboratory, 8p.

The Raw Material Research and Development Council (RMRDC) (2003): Update report of the multi-disciplinary taskforce (MTF) on the techno-economic survey of wood and wood product sector (2nd update); Sponsored by the RMRDC Lagos, Nov. 2000, 100pp.

Unueke, C.L. (2008); Impact of deforestation on Malaria in South Eastern Nigeria: The Epidemiological, Socio-economic and ecological implications.Journal of Third World Medicine.8 (1).

Utilization of Forest Product in Nigeria (Unpublished, 1952).

Wade M.W., Bullard S.H., Steel P.H. and Araman P.A. 1992. Estimating Hardwood Sawmill Conversion Efficiency based on sawing machine and log characteristics. Forest Products Journal Vol. 42.

White M.S. (1983) Lumber Volume.Grade Yield important to Productivity. Forest Products Journal, 110(5):PP 40-41.

Willston Ed M (1981): Small Log Sawmills. Profitable product selection, process, design and operation. A forest industry. Book ISBN 0-87930-091-4 Publ. Miller Freeman California USA PP 217-243

QUESTIONNAIRE

UNIVERSITY OF IBADAN, IBADAN

DEPARTMENT OF FOREST PRODUCTION AND PRODUCTS

Dear Sir/Ma,

The questions provided below are to be used for research purpose in the University of Ibadan and has nothing to do with tax or related purpose. Please kindly respond to them.

Thank you.

Topic: Determinants of Energy and Time Efficiencies of Sawmills in Ondo and EkitiStates,South Western Nigeria.

1. Name of industry____
2. Location of industry (i) Town_____ (ii) Local government______(iii) State_____
3. Name of respondent_____________________
4. Rank of respondent (a) mill owner (b) band mill operator (c) timber contractor (d) mill technician
5. Age of respondent (a) 0-20yrs (b) 21-30yrs (c) 31-40yrs (d) 41- above
6. How long have you been working in the sawmill (a) 0-5yrs, (b) 6-10yrs (c) 11-15yrs (d) 16-20yrs
7. Are you a member of sawmill industries association (a) Yes (b) No
8. How did you acquire your band mill machine (a) bought new (b) bought as a used machine from other sawmill (c) bought from a local machine building in Nigeria
9. How long have you acquired your band mill machine (a) 0-5yrs (b) 6-10yrs (c) 11-15yrs (d) 16-20yrs (e) 21yrs-above
10. Form of ownership of sawmill (a) sole proprietorship (b) co-operative body (c) partnership
11. When was the industry established_________________
12. Is the industry duly registered with Ondo/Ekiti state government (a) Yes (b) No
13. How do you acquired the land for the industry (a) Rent (b) Lease (c) bought (d) inherited
14. What is the size of the sawmill based on their scale of production:
    a. Small scale (≤10,000m3 log/year)
    b. Medium scale (10,001-20,000m3 log/year)
    c. Large size (≥20,000m3 log/year)

15. What are the various sections in your industry (a) Engineering section (b) Administrative section (c) Workshop section (d) Timber sales section

16. Give an estimated number of workers in each section (a) 0-10 (b)11-20 (c) 21-30 (d) 31 and above

17. Do you have forest estate managed by your industry (a) Yes(b) No

18. What type of species do you process most in the sawmill (a) Obeche (b) Gmelina (c) Afara (d) Mansonia (e) oriro (f) opepe (g) iroko (h) koko-igbo (j) mahogany (j) omo (k) others (specify)______________________________________

____

19. What is the average girth of logs species processed in your industry per week?

Species	Girth size e.g. (7^3)	Number processed
e. Obeche	________________	__________________
f. Gmelina	________________	__________________
g. Omo	________________	__________________
h. Ofun	________________	__________________
i. Mahogany	________________	__________________
j. Mansonia	________________	__________________
k. Iroko	________________	__________________
l. Afara	________________	__________________
m.Oro	________________	__________________

20. Who are the suppliers of your logs (a) timber contractors (g) government plantation (c) free areas

21. Where do you source for your logs (a) forest concession (b) free areas (c) private plantation

22. How often do they supply you (a) regular (b) irregular

23. How many logs did you normally take in per day (a) 0-10 logs (b) 11-20 logs (c) 21-30 logs (d) 31 logs and above

24. Does the shape or size of log has impact on the lumber recovered (a) Yes (b) No

25. If yes in which way (a) reduced lumber quantity (b) have no effect (c) increase lumber recovery volume

26. What is the average number of planks you can get from a standard log of wood (a) 0-10 planks (b) 11-20 (c) 21-30 (d) 31 and above

27. What is responsible for the low or high lumber yield (a) irregular log supply (b) problem of electricity (c) machine breakdown

28. What do you think can be done to improve on your yield level (in brief)______

29. What are the major machines you are using for processing (a) CD-4 (b) CD-5 (c) CD-6 (d) wood mizer (e) circular saw (f) saw doctor machine (g) chain saw (h) crain loader (i) multiple edger machine (j) others_____________________

30. How do you maintain your machine (a) by local technician (b) by foreign experts

31. How often do you maintain your machine (a) preventive maintenance before machine faults (b) Repair machines as soon as it is faulty

32. How do you usually saw abnormal shapedlogs:

   a. Crooked____

   b. Tapered____

   c. Forked____

   d. Sweep____

33. What is the source of your power supply (a) PHCN (b) generator

34. If you are a headrig operator, were you trained to handle the machine you are operating (a) Yes (b) No

35. How long were you trained (a) 0-5yrs (b) 6-10yrs (c) 11-15yrs (d) 16-20 yrs (e) 21yrs – above

36. What is the nature of your training (a) on the job training (b) by bringing technician to train us (c) no form of training at all

37. As headrig operator, what is your wages/salary per month (a) <N10,000 (b) 10,01-15,000 (c) N15,010-20,000 (d) >N20,000-above)

38. Who are the consumers of your product (a)Cooperative bodies (b) Government establishments (c) Individuals (d) Schools (e) Others specify_____________

39. Do you meet your customer demand (a) Yes (b) No

40. If No, what are the difficulties______________________________________

____

41. What is done with sawdust (a) dispose (b) used to fill ground (c) sold to researcher (d) burned

42. What is done with the small pieces of slabs (a) dispose (b) sold as firewood (c) burned

43. What is your future plan towards the sawmill industries? (a) to extend your production capacity (b) to reduce it (c) to close the mill down

44. Are you satisfied with the work of the headrigoperator (a) Yes (b) No

45. If No, what is the reason____

46. Any other information can be stated below_______________________________