KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF ENGINEERING

FACULTY OF CHEMICAL AND MATERIALS ENGINEERING

DEPARTMENT OF MATERIALS ENGINEERING

LUMBER RECOVERY FROM A COMMUNITY – BASED TIMBER PROCESSING MILL USING THE 'LOGOSOL' MACHINE

Thesis submitted to

The Department of Materials Engineering (College of Engineering) of the Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree of Master of Science in Environmental Resources Management

BY:

OSEI OWUSU ANTOBRE

MAY, 2010

DECLARATION

I hereby declare that the work embodied in this thesis is the result of my own investigation. I wish to indicate that it has not been submitted or accepted in whole or part, nor is currently being submitted for any graduate programme.

Signed :……………………………………………………………….

Candidates Name:…………………………………………………..

Signed:……………………………………………………………….

Supervisors Name :……………………………………………………

Signed……………………………………………………………….

Head of Department:…………………………………………………

ABSTRACT

In-situ chainsaw milling of logs is an important economic activity in Ghana since it produces about 80% of the domestic lumber supply. However, chain-sawn lumber production has been banned in Ghana since 1998 partly due to the large waste or residues associated with this operation. There is the need for an alternative in-situ processing method that improves lumber recovery. A study was conducted on the use of the 'logosol' machine which is a chain-saw (Stihl MS660) with attachments to determine its effects on lumber recovery for five Ghanaian timber species: dahoma-*Piptadeniastrum africanum*, esia - *Petersianthus macrocapa*, ofram - *Terminalia superba*, danta - *Nesogordonia papaverifera* and avodire - *Turraenthus africanus*. The objectives were to determine the milling recovery rates of these species and the time input for milling logs. The study also examined how common log characteristics (diameter and tapering) affect lumber recovery when using the logosol machine. The research was conducted in Gyaman and Gyapa communities in the Wassa Amenfi East District in the Western Region of Ghana. A total of 93 logs of the five species with volume 108.94m^3 were processed into lumber using the logosol machine. The recovery was 51.71 m^3 of sawn timber at an average recovery of 48.48 %, a rate substantially higher than the reported recovery (40 %) in chain-saw with free hand. The average lumber processing rate was 8.8 m^3 /day of eight hours. This is also an improvement on chain-saw with free hand. An analysis of variance (ANOVA) showed that at 5 % level of significance, diameter and tapering had significant effect on recovery. It was only in dahoma and avodire that 25% and 36% respectively of variation in recovery could be explained by the tapering factor. In the other species tapering factor accounted for less than 8% of the recovery. Also the relationship between diameter and lumber recovery was weak for all the species (R^2<25%) presumably due to the high incidence of defects on the logs.

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to my supervisor Dr. Kyere Boateng of the Faculty of Renewable Natural Resources (FRNR) for his help in planning and carrying out of this project and for his useful suggestions, criticisms, guidance and encouragement during the course of the project. I am also grateful to Forestry Research Institute of Ghana (FORIG) especially Mr. Wilson Owusu and his field team; and Kwabena Owusu Asubonteng for their assistance with the supervision.

I am indebted to Tropenbos International Ghana for their financial support and Mr. L. B. Antwi – the Dean of Faculty of Forest Resources Technology, Sunyani, whose toil and effort have made my MSc. education a success. I express my sincere gratitude to my dear wife Mrs. Cassandra Osei Owusu Antobre of Simms Secondary Commercial, Kumasi for her moral and spiritual support and who in my absence took great care of our children. Above all my sincere thanks and glory go to God Almighty whose divine grace, wisdom and understanding have enabled me to work enthusiastically and successfully.

TABLE OF CONTENTS

Page

Page

Page

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF PLATES

Page

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

BOF	Best of Face
FAO	Food and Agricultural Organization
FC	Forestry Commission
FORIG	Forestry Research Institute of Ghana
LRF	Lumber Recovery Factor
ITTO	International Tropical Timber Organisation
TIDD	Timber Industry Development Division
FPIB	Forest Product Inspection Bureau
TEDB	Timber Export Development Bureau
WITC	Wood Industries Training Centre

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

In-situ chain-saw milling of logs is an important economic activity for both rural and urban dwellers in Ghana. The two main sources of lumber on the domestic market are supply from conventional sawmills and chain-saw milling with the latter taking close to 80% of the market (Birikorang *et al*., 2007).

In Ghana, it is estimated that the chain-saw activities provide employment for approximately 50,000 people and also supplies about 80% of lumber consumed locally (Otoo, 2004). Currently, the use of chain-saw for processing logs is wide spread throughout the country supplying the bulk of the domestic wood requirements especially in the rural and urban areas for building and constructional works.

In a study by Nketiah (2005), it was reported that, the timber market in Ashanti Region of Ghana receives about 10% of its lumber supply from the conventional sawmills. The remaining 90% comes from reprocessed chain-sawn products. Studies conducted on the origin of wood for government contracts for the purpose of meeting procurement rules, suggest that about 40-50% of the domestic market wood is going into government contracts (Birikorang and Rhein, 2005). A significant proportion of the purchases constituted chain-sawn lumber.

Most chain-saw milling today is carried out freehand, i.e. without the use of any guides, frames or rails that would otherwise help sawyers produce better quality boards with less chance of accidents.

Chain-saw lumber production, though banned in 1998 by Government of Ghana, still remains the major and easily accessible source of lumber on the local market. Thus, the ban action taken by the Government has failed to address the problem (Marfo, 2010). Two main assumptions underline the ban; first, the chain-saw milling is wasteful, and using it to supplement sawmilling will lead to a rapid degradation of forest resources and the environment. Secondly allowing chain-saw milling to take place will lead to enormous monitoring challenges that the Forestry Commission does not have the capacity to deal with. This means an alternative in-situ processing method that has improved recovery and lends itself to easy monitoring could be adopted in place of the chain-saw.

In order to profitably process logs with portable mills into lumber, information on recovery rates, raw material requirements and conversion techniques need to be documented to do objective comparison of the various milling processes adopted in Ghana. Appiah (1983) indicated that lumber yield/recovery is the most single item affecting cost/revenue relationships of a mill and therefore its profitability.

Meanwhile chain-saw milling is gaining widespread acceptance as a means of producing timber in small volumes. Also since the ban on chain-saw milling in Ghana in 1998, no alternative method has been provided to improve upon sawing at stump site.

Therefore many options are being examined to see how lumber production in communities can be improved through the use of alternative technology to make it a sustainable livelihood. Among these is the use of the 'logosol' machine.

The Forestry Research Institute of Ghana (FORIG), with the support of the International Tropical Organization (ITTO) (ie ITTO/FORIG PD 431/06), has developed a draft manual for domestic timber entrepreneurs for use of portable mills (logosol) for timber conversion by communities as an alternative to the chain-saw (Wilson *et al.*,2010). The 'logosol' machine has been identified as a potential alternative to the chain-saw but we need to know its milling efficiency under Ghanaian conditions.

The aim of this study is to assess the efficiency of the 'logosol' machine in wood processing under Ghanaian conditions and its potential for use by local communities for livelihood.

1.2 OBJECTIVES

The objectives were to:

1. determine the milling recovery rates of logs processed with 'logosol' machine.
2. determine the effect of log diameter and tapering on lumber recovery when using the 'logosol' machine
3. determine the production rate of lumber using the 'logosol' machine.

1.3 RESEARCH QUESTIONS

Research questions deduced from the objectives were:

- What percentage of timber can be recovered as lumber from milling logs using the 'logosol' machine?
- How do various log characteristics (diameter and tapering) affect lumber recovery when using the 'logosol' machine as a mill?
- What is the time input?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 WOOD SAWING

Sawing is defined as a process of converting logs into lumber with sawdust, slabs and off-cuts as by-products. Sawing technology is the mechanization of man's earliest activities towards human settlement and development by cutting wood into sizes useful for the satisfaction of human demand (Martyr, 1973).

In Ghana, it started in the early 1950's by foreign entrepreneurs and about 214 or more sawmills operate currently in Ghana (TEDB, 2007). The first truly production method used to breakdown by rip sawing into planks was the pit sawing. This comparatively primitive method, even though laborious and slow to modern standard, produced good surface sawn lumber.

2.2 ARTISANAL MILLING OF WOOD

Before the introduction of chainsaws in Ghana, manual methods were used to fell trees. The most widespread tool was the axe which was used for felling, delimbing and cross cutting. This was time and energy consuming and caused several fatal accidents.

After felling with the axe, Akrasi (1997) reported that cross-cutting and conversion of logs into lumber was undertaken by a gang of pit sawyers using two-man handsaws. This mode of conversions was practiced until the late 1970s in Ghana. Comparing pitsawing with other mode of processing round wood example frame sawing with portable mills and chainsawing, Martyr, (1973) found pitsawing to be most suitable for in situ conversion of timber in the Himalayans (FAO, 1985). Akrasi (1997) observed that with the application of manual tools about 20% of the trees were left in the forest as stumps, branches, etc.

2.3 TYPES OF SAW MILLING

Conversion of logs to sawn lumber employs a number of methods; these have been grouped into three classes:

- Pit sawing
- Portable sawing
- Mechanical sawing (conventional sawmills)

2.3.1 Pit sawing

A saw pit or sawpit is a pit over which logs are positioned to be sawed with a long two-handled saw by two men, one standing above the timber and the other below. It was used for producing sawn planks from tree trunks, which could then be cut down into boards, pales, posts, etc. Many saw pits were built at convenient sites in woodlands which provided shelter from the rain as well as the timber for cutting into planks (ITTO, 2007). The paper continued to report that, the increased efficiency of the sawmill and the back-breaking nature of the work mean that saw pits generally went out of use in the United Kingdom at the time of the industrial revolution.

Pit sawing according to Okai (1998) was once practiced extensively in some parts of the world including Ghana. This crude method of sawing used obsolete and inefficient saws, which resulted in wood waste and low productivity.

2.3.2 Portable saw mill

This machine is designed to convert logs from the spot where they are felled and moves forward as more trees are cut. The mill is a transportable one, which is made of circular saw blades, one horizontal and the other vertical. The *woodmizer, logosol* and the mobile *Tom Sawyer* are kinds of portable sawmill. These machines are intended primarily to save transportation of waste materials. The mobile Tom Sawyer can be towed into the jungle and set-up in minutes to convert logs, which have previously been considered uneconomic to move from the forest floor to the mill. As a result more logs can be utilized offering benefits in terms of conservation and extra profit for operators. The machine is powered by an electric or diesel motor. It also has a hydraulic log loading and turning, squaring and dogging which allow increase production and also permit one-man operation (TEDB, 1991).

Portable sawmills became popular in the United States starting in the 1970s, when the 1973 energy crisis and the back to the land movement had led to renewed interest in small woodlots and in self-sufficiency (Wenger, 1984). He also asserted that, the first portable sawmills were the one man farmer's sawmills. These mills featured large circular blades and were marketed during the early twentieth century.

2.3.2.1 The Logosol

Logosol which is a brand name is a small scale sawmill designed for village use. It is used at the logging site to manufacture sawn timber straight from the felled logs. The machine itself consists of separate parts that can be hand carried to the site without any transportation equipment. The milling concept is based on the chainsaw technology mounted on light aluminum guide rail and log carrier.

2.3.2.2. Types of Logosols

There are several models of logosols. These include logosol M5, logosol M7, Big Mill Basic and Big Mill LSD

2.3.2.3 Mode of operation of Logosol

After positioning a log on the bed of the sawmill, slabs are first removed and a block is produced from which planks of desired dimension are sawn off. The power source for this sawmill is a chainsaw, the engine is started and then with one hand of the operator on the handle of the saw and the other hand crank of the sawmill, one then controls the throttle of the saw and the speed at which the saw cuts the log.

The mill uses the crank mechanism for two reasons; first, it makes it easier to carry out the sawing operation. Second, occupational safety and health regulation require both hands to be occupied during operating to keep them away from the saw chain. The common or professional chainsaw model STIHL MS660 is used. The chainsaw cuts when moving along the fixed log which is mounted on a sledge/carriage assembly that slides along the guide rail. The saw cuts horizontally.

2.3.4 Modern mechanical sawmill

This, as compared to portable mills is more sophisticated and is set-up on a permanent site. The degree of mechanization and sophistication depends on their size and large differences in practice generally exist depending on the country of location (Anglaaere, 1988).

The mills are equipped with band head rigs, which are for the preliminary cutting. The head rigs may include band saws, gang saws and circular saws. The band saws are the ones commonly used in most Ghanaian timber industries. Two types of band saw can be found at the mill, they are the log band saw/head rig and the re-sawing band saws.

The log band saws are for repeated sawing of blocks or board from large logs; its blade may work horizontally or vertically producing the same product quality; the difference lies in the orientation of the cut (Anglaaere, 1988). The resawing band saw may be single or in groups and are for sawing planks or boards from blocks or smaller logs. Use of band saws is common in timber firms due to their numerous advantages, some of which are: small kerf losses, adaptability to large diameter and unsorted inputs, capacity for high and uniform feed speed and good surface quality in the sawn timber. Despite these advantages, there are also a few disadvantages like: high machine cost, large space requirement for machine groups and more elaborate blade maintenance.

2.4. HISTORY OF SAWMILLING

Sawmilling has been defined as the process of converting round wood from the forests into lumber by using a variety of machines (Amoako, 2008). The history of sawmilling dates back to the 18th century with pit-sawing as the earliest form of log conversion while the first power-driven sawmill was installed at the beginning of the 20th century (Tetteh, 2009.)

2.5 CONVERSION EFFICIENCY OF LOG INTO LUMBER

Log conversion efficiency in the sawmilling industry is commonly expressed as the yield or recovery of sawn wood milled from a given log (Adams, 2007). He asserted that, the yield of sawn wood is generally expressed as a percent of the log volume, thus a log of 10.0 cubic metres yielding 4.0 cubic metres of sawn wood would be described as having a yield or recovery of 40 %.

In engineering terminology, efficiency normally means output divided by input, resulting in a number that is less than one. Rickford and Gene (1973) mentioned the operating or conversion efficiency as simply the ratio of actual recovery to theoretical recovery over the operational shift. They continue that the closer this ratio approaches one, the more efficient the operation and that the improvement in conversion efficiency can be measured by management's ability to increase the actual recovery factor as close as possible to the theoretical optimum, within the limitations of log quality.

Conversion efficiency of logs into lumber is commonly expressed as lumber recovery factor (LRF) or as over run. LRF is the nominal board meters of lumber divided by the cubic volume of logs. Over run is the nominal lumber board feet divided by the board feet log scale. Over run is a relatively poor measure of conversion efficiency because there is little relation between the log scale and the potential lumber volume recovery, and because of differences in board footage for the same log among the various log scales, LRF is a more direct measure of conversion efficiency (Wenger, 1984).

2.6 GHANA'S SAWMILLING INDUSTRY AND ITS CONVERSION EFFICIENCY PERFORMANCE

TEDB (1997) report asserted that, almost all woodworking industries in Ghana experience low efficiency in their production. This is due to usage of very poor quality logs, obsolete machines and inexperienced machine operators (Brimpong, 1975) and as a result do have an average conversion percentage of 44.8 (Danso, 1975). The need for skills to raise efficiency and improve on quality is obvious. Although machinery reduces the need for highly skilled craftsmen, it increases the need for skilled operators and maintenance staff. A sawmiller often does not use appropriate saws for different types of timber, and the teeth on bandsaws are not always set for different degrees of hardness, thus resulting in a loss of quality giving rise to low efficiency of conversion of logs into lumber. Addo (1975) mention that lack of skilled operators and supervisory staff in sawmills also lowers standards with respect to size and precision of cut.

Today, most of the sawmillers are still using obsolete and inefficient machines as well as unqualified personnel to meet the very strong competitive market demands of the present. This attitude of ignorance has resulted in the production of excessive waste in the sawmills (Amoako, 2008).

According to Amoako (2008), Ghana's forest and wood processing sector is generally characterized by under-capitalization, labour intensiveness and obsolete equipment. There is a realization within the industry that the processing sector cannot continue to expand simply by extracting more trees because of the diminishing resource base. To address this challenge, government policies emphasize more efficient use of harvested wood resources. At present, there is far greater interest in minimizing waste and utilizing off-cuts in further processing, to provide exports in shaped and machined moldings, flooring, furniture components, dowels and similar added value items (TEDB 2007).

2.7 FACTORS AFFECTING EFFICIENCY OF CONVERSION OF LOGS INTO LUMBER

Wenger (1984) mentions that lumber recovery factor vary with log diameter and taper. White (1974) mention major factors affecting yield as, end-use requirement, the quality of personnel, sawing methods, sawmill machinery and sawing accuracy. Petro (1984) and Williston (1988) recommended good storage practices if efficiency of conversion of logs into lumber is to be improved.

To get maximum profit from a sawmill, the overall strategy must be correct and each machine center must be operated optimally. Decisions must not only be correct, but they must be properly executed. Good decision making requires information about raw material, machine capability and product line (White, 1973).

One objective in the mills is to minimize the sum of kerfs, sawing variation and surface roughness. Kerf may have to be increased to control accuracy, but the sum of the three must be minimized. Aspects of a machine center that affect conversion efficiency include; inability to position the log properly before the saw, inability to convey it straight during cutting, inaccuracy of cutting tool alignment and machine vibration (Ackah, 2004).

2.7.1 Log storage practice

Williston (1988) observes that logs should not be kept too long after felling before sawing. This is to avoid insect attack, stains and decay. Excessive exposure to the sun can also cause checks on logs. All these will affect the recovery and final quality of lumber. Storage of logs in the yard must be as short as possible ensuring that logs that come first are fed into the mill first. Longer storage of logs result in biological deterioration and these in turn lead to excessive flitching of the defective portions. At times flitched materials are stored in the open for a long time awaiting gang sawing. This causes biological deterioration especially of the white and or yellow woods.

2.7.2 Log quality

Petro (1984) defines log quality in terms of its size or diameter, form and taper, length and straightness. Defects such as rotten heart, worm and pinholes, splits and shakes affect log quality.

2.7.3 Log diameter/size

Log size, both diameter and length has also been found to affect sawn wood recovery and as a general rule, large diameter gives a higher recovery. For logs in the range of 30-70cm in diameter, recovery rates have been seen to drop to about half when the log diameter is halved (Tetteh, 2009). Today, few millers of tropical hardwoods can secure logs as large as they had a decade ago. Tropical log diameters have been steadily decreasing in Asia and the Pacific, and will continue to decrease even further in the future. Under these circumstances, FAO has stated that "investment in even the most efficient technology would hardly improve recovery from the best levels at present, but it would slow the inevitable decline in recovery rates" (Adams, 2007).

Doyle (1960) observes that the percentage of log volume converted into lumber increases slightly with log size for both balsam fir and spruce and the rate of increase for the two species is almost identical. He, however, noticed that smaller diameter logs generally produce higher percentage of high grade lumber recovery, and attributes this to the knot size and frequencies admitted in the grading rules for the lumber grades used. Petro (1984) observes that log diameter has a linear relationship with lumber yield since amount of defect-free wood contained in the periphery of a butt log is closely related to diameter. As the tree grows, it increases in size and the proportion of clear wood also increases.

The maximum potential lumber recovery factor (LRF) varies with log diameter and taper and the effect of taper on recovery is less pronounced in larger diameter logs (Wenger, 1984). It must however be emphasized that effect of log diameter on recovery depends on the type of timber species, its age and the percentage of sap wood. White (1973) is of the view that sorting of logs to diameter (size) permits close flow and eliminates the need to reset heads or saws between logs. These make for better utilization and improve lumber recovery. The use of optics, minicomputers and electronics to measure the diameter and determine the best opening face (BOF) for the sawing pattern will increase yield.

2.7.4 Log taper

Tree taper is defined as the rate of change of diameter over a specified length (Wenger, 1984). He points out that taper is small along the lower part of the bole but large where both the bole is affected by root swell and in the crown. The amount of taper in the log has a dramatic effect on potential lumber recovery. Increase in log taper results in lower recovery per cubic meter of log volume. This effect of taper on recovery is less pronounced in larger diameter logs (Wenger, 1984).

Williston (1988) mentioned that for logs with taper, the small end of log should be fed first to avoid sudden overload. This gives maximum width cants and therefore high recovery. White (1973) recommends taper sawing for trees with more taper to obtain maximum recovery.

2.7.5 Log defects

A defect in wood may be defined as any abnormality or irregularity that lowers its commercial value by decreasing its strength, or by affecting adversely it's working and finishing qualities or its appearance (Brown *et al.*, 1994). Log defects could be natural or artificial. Among the natural defects are knots, reaction wood, shakes, pitch streaks, pitch pocket, mineral streaks, chemical stains and rotten heart. Natural defects, by their very nature, are not subject to direct control by man. Some of the artificial defects include splits, end-checks and log damage (breakage).

Both natural and artificial defects affect lumber quality, value and recovery since such defects are not supposed to be included in the lumber. The core (heart) of the older trees may yield poorer grades because of the presence of rot, shakes, and other defects that develop in the centre of the stem. Knots are the commonest cause for lowering the value or recovery of lumber (Brown *et al.*, 1994). They also affect considerably the working qualities of wood, since they are much more refractory under tools than the wood surrounding them. (Brown *et al.*, 1994).

2.7.6 Percentage of sapwood

The percentage of sapwood in a tree species affects recovery since lumber is not expected to contain excessive sapwood (Brown *et al.*, 1994). Sapwood is usually less durable, lower in strength and can be easily attacked by insects and fungi. During sawing all or most of the sapwood is flitched off as slabs and hence the narrower the width of sapwood in a tree species, the better the recovery and vice-versa. Brown *et al* (1994) observe that within a given tree, the sapwood is wider in the upper (younger) portions of the trunk than toward the base. Wide variations in width may also be noted in different species.

2.7.7 Log (wood) density

A work done by Wilson *et al.* (2009), depicted that variation in wood densities affected lumber recovery. Very low density wood can be difficult to peel except when the moisture content is high and the cells are filled with water; this gives mechanical support to the cell wall during cutting (Tetteh, 2009).

2.8 TIMBER QUALITY STANDARDS- GRADING RULES FOR GHANA

In order to satisfy the requirement of the law establishing the TIDD (formally the Forest Products Inspection Bureau (FPIB) and Timber Export Development Board (TEDB)) an ad hoc committee known as the Grading Rules Consultative Committee was formed to formulate rules for standard use by timber producers in Ghana (Awuni, 2003). The committee comprises representatives from:

- The Ghana Timber Association (GTA)
- Timber Export Development Board (TEDB)
- The Ghana Timber Millers Organization (GTMO)
- The Ghana Furniture Manufacturers Association (GFMA)
- The Forest Products Inspection Bureau (FPIB)
- The Forestry Research Institute of Ghana (FORIG)
- The Forestry Department (FD)

During the period of April 29-30, 1997, there was a National Workshop on Wood Quality Standards at the Wood Industries Training Centre (WITC) at Akyeawkrom in Kumasi organized by the FPIB (now TIDD). The theme of the programme was 'Grading Rules for Quality Timber in Ghana: A case for standardization'. The aim of the programme was to promote the image of Ghana Timber and Industry Trade, introduce timber grading rules for standard use in Ghana and to ensure that they were applied by the timber industry and trade. Including the ideas which came up as a result of the programme were that the forest should be managed in a way that will be economically, socially, politically, ecologically and culturally friendly. Also the timber trade and industry were suggested to be transformed from high volume-low value to low volume-high value income, and that the standards coming out should satisfy producers and buyers. The draft grading rules were studied. At the end of the programme, some few corrections were made and draft grading rules were accepted.

2.9.1 Log Grading Guidelines

Grading is based on the nature and importance of defects, relating to the shape of the log and structure of the wood and does not take into account, the physical, mechanical or chemical properties of the timber, such as the specific gravity and strength (Mensah, 1982), however, the logs need to be fresh and no opaque end coating are allowed.

2.9.2 Log Grading

According to Awuni (2003), Logs are classified into three main grades (A, B and C) and two intermediate grades (A/B and B/C). To arrive at some forms of basis, it is essential to start by reasoning, how much latitude can be allowed in determining what is to be a

Grade A log. No log can be perfect and it is therefore necessary to decide from experience at what point a log will have to be graded to A.

It is fair to think of a Grade B log as being 80% of a Grade A log, and Grade C 60% of Grade A, having in mind that these percentages are in terms of useful wood on conversion and the presence of defects on the surface of the log such as crook, cracks, etc.

First Grade Log (A)

A grade A log must have straight and cylindrical bole. It should be free from visible defect except such as are too slight to impair the conversion value of the log to an appreciable extent.

Second Grade Log (B)

The grade of log may permit bends and irregular shaped to a moderate extent; it may show defects at ends and sides which in the aggregate, impair the conversion value to a moderate extent.

Third Grade Log (C)

This comprises logs which do not qualify for inclusion in second grade.

Five Points Grading (A, A/B, B, B/C and C)

It is useful to think of five point grading. Thus, the inclusion of intermediate grades, A/B and B/C enables logs to be more readily classified. It has become desirable to enlarge upon these principles in view of the diverse characteristics and increasing number of species available for export market and for processing.

Several of less utilized species with little information on their certain peculiarities which although may affect the appearance of the logs, may not necessarily affect the quality of the timber on conversion.

This, each species must be considered as a separate entity and graded with the knowledge of its peculiarities (Mensah, 1982).

2.9.3 Lumber

Tsoumis (1991) defines lumber as a solid wood product made from lengthwise sawing of logs. Hoadley (1980) has however defined lumber as the product of the saw and planning mill, not further manufactured other than by a sawing, re-sawing, passing lengthwise through a standard planning machine, crosscutting to length and matching.

The word lumber further carries the connotation of thickness; say 1 inch (25mm) or more, in the contrast to pieces glued together as in plywood and laminated veneer lumber. The cell structure is usually industrialized from its original state in the tree, in constrast to the oriented cell arrangement in composite products.

Lumber is therefore a solid rectangular chunk of wood that has been separated from the log, usually by sawing (Hoadley, 1980).

In No. 1C 25% of the pieces in a bundle may have grain deviating up to 20cm per running meter by 75% of the pieces may not have grain deviating more than 15cm per running meter.

In No.2C there is no limit to grain deviation (Grading Rules for Sawn Timber).

In practice, an experienced grader can assign grades to most boards or pieces with rather brief inspection. Very often within a time limit of some few seconds. However, boards at borderline of a grade category must be measured individually. Because the hardwood rules are specific, the grade of each board can be assigned by precise numerical measurement rather than by depending on subjective judgment alone (Hoadley, 1980).

2.10 YIELD MAXIMIZATION WITH IMPROVED TECHNOLOGY

Today with the increase price of logs, high processing manufacturing cost, coupled with the demand for high quality grade lumber, developed countries are integrating advanced or sophisticated equipment in sawmilling. Examples of such equipment are computer-scanners and the best opening face (BOF) programme is a model of the sawing process aimed at maximizing yield. It considers dry finished lumber size, planning allowance, shrinkage, sawing variation, kerf width, log diameter range, diameter measuring increment and equipment's capability to produce a given opening face (White, 1974). White (1975) observes that when BOF programme was used on live log sawing, there was an increased recovery from 6 to 90 percent whilst the best cant sawing solutions exceeded the worst by 12 to 100 percent.

Scanning systems measure the geometry and evaluate the grade of lumber and logs. They can be classified as follows: ocular estimate by humans; mechanical by scale stick, calipers and rule; optical, including light-emitting diodes, lasers, and cameras; ultrasonic and electromagnetic radiation in the x-ray/gamma wavelength (Williston, 1988). Logs, cants, flitches and lumber are scanned for sorting, bucking, log and cant breakdown, cant and flitch edging and ripping and trimming. Also for locating natural and manufacturing characteristics for grading, edging, ripping, trimming and sorting.

Steadman (1974) mentions the use of precision carriage by computer to improve sawyer's efficiency. The computer can produce a number of sets for various cutting programmes and can calculate allowance for pieces to be resawn downstream. The sawyer is therefore relieved of mental arithmetic calculations and can concentrate on grade. Cutting decisions are based on what the sawyer sees. Inaccuracies in his information reduce conversion efficiency and profit. Ultrasonic can be used to detect irregularities such as compression wood, knots and changes in slope of grain and can be visually displayed for a computer to read and evaluate. Hence clear cuttings may be located to improve the efficiency.

White (1975) talks about scanner as being the common denominator in all recent effort to upgrade recovery from sawing. Computers have high value in selection of cutting patterns. However, many mill operators have been negative toward computer-scanners because: they feel they lacked the operating and maintenance staff to use them properly, cost and lack of conviction that it would work.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The research was conducted in Gyaman and Gyapa communities in the Wassa Amenfi East District. Below is the map of the research area (Fig. 3.1).

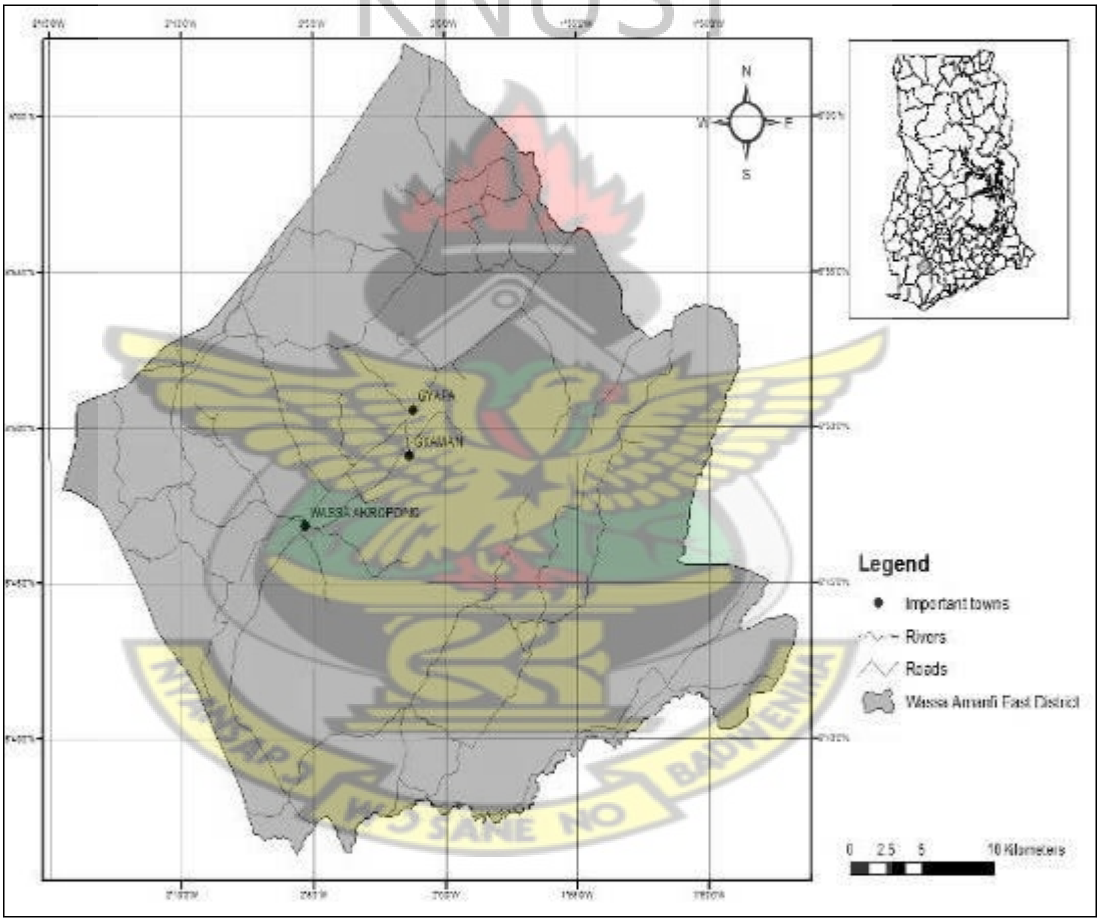


Figure 3. 1 Map of Wassa Amenfi East showing Gyaman and Gyapa communities (AGTARC,2009)

The Wassa Amenfi East District is found in the Western Region of Ghana and lies between latitudes 5^{o} 30’’ N, 6^{o} 15’’ N, longitude 1^{o} 45’’W, and 2^{o} 11’’W. It has an estimated total land area of about 1600 km^2 about 8% the size of the region. It is bounded to the West by Wassa Amenfi West; to the East by Mpohor Wassa East, to the North by Upper and Lower Denkyira and to the South by Prestea Valley District. The district capital is Wassa Akropong.

3.1.1 Topography and drainage

The district is situated in the forest dissected physiographic region of Ghana which is underlined by pre-Cambrian rocks of Birimian and Tarkwaian formations. The area is generally undulating, ranging between 240 – 300 metres above sea level. It is well drained with a number of rivers and streams running through it, some of which are perennial whereas others are seasonal. Prominent among them are Manse, Ankobra and Oppong rivers. Occasional flooding is experienced in the inland valleys along river basins.

3.1.2 Climate

The area has a semi-equatorial climate with a bimodal rainfall pattern. It is characterised by double maxima rainfall lasting from March to July and then September to late November. Average annual rainfall recorded stands between 140 mm to 173 mm. Relative humidity is usually fairly moderate but high during the rainy season and early mornings. The area experiences annual temperatures ranging from 20°C in August to 32°C in March.

3.1.3 Vegetation

The study area lies entirely within the tropical high forest zone of southern Ghana, to be precise the Moist Evergreen Forest type.

3.1.4 Population

The district has an estimated total population of about 115,000 and a growth rate of 2.9% according to the 2000 population census figures (Ghana Statistical Service, 2007). This is made up of about 64,400 males and 50,600 females, accounting for about 56 % and 44 % respectively. Majority of the people are farmers who are engaged basically in the cultivation of cocoa, oil palm, cassava, and some food crops (Ghana Statistical Service, 2007).

3.1.5 Choice of Communities

Gyaman and Gyapa communities were selected for the study for reasons such as:

- Relative ease of acquisition of their farmlands for the project.
- Availability of timber trees.
- Interest of the Forestry Commission in the project.

3.2 Choice of Species

The species used for the study were selected after looking at the availability of the different species in the area. Twenty forest trees of five species were selected for the study. These were dahoma-*Piptadeniastrum africanum* (3 trees), esia - *Petersianthus macrocapa* (7 trees), ofram - *Terminalia superba* (3 trees), Danta - *Nesogordonia papaverifera* (4 trees) and avodire *Turraenthus africanus* (3 trees). In all ninety-three (93) logs were worked on.

3.3 Data Collection

Twenty trees were felled and cross cut into logs and then processed into lumber using the 'logosol' machine. The diameters of felled logs were measured using diameter tape and the lengths of the logs were also measured using linear tape. Logs volumes were determined using a standard formula (Appendix 3.1- 3.5). The cross-cut logs were processed into lumber using 'logosol' machine as described. The volume of each of the lumber produced was determined using the steel tape to measure the width, length and thickness (Appendix 3.6 – 3.10).

3.3.1 Log production and conversion

After a tree had been felled, it was crosscut into logs. Cross-cutting decision was based on log characteristics such as defects, form and size. After a desired log was crosscut and for easy processing, a monkey jack was used to lift the logs on benches derived from the slab or from other trees. The log was then measured using a linear tape and marked. After positioning the log, the ray of the 'logosol' was fixed and attached in the adjacent direction to the log acting as the bed of the sawmill, a slab was first produced from which boards of desired dimension were sawn off using the chainsaw fixed with the timmer jigg (Plate 3.1).

Plate 3. 1 Production of block from logs after cutting the planks/slabs

3.3.2 Lumber production

On the flat surface of the log produced, a desired dimension (was taken using a diameter tape to represent the thickness of the flitch. Lines were drawn to guide the sawing operation. The distance between the lines shows the thickness of the flitches. A twine was dipped in used oil (dirty-oil) and used to mark parallel lines corresponding to specific lumber width of the flat surface. As the sawing operation took place along the lines, the sawdust was swept on the surface of the log to make the line conspicuous. The timmerjigg was then fixed to the chainsaw and set to the required size (thickness) for sawing.

3.3.3 Log volume measurement

Log measurements were made for calculating log volumes and as a basis for planning the production process for maximum utilization of the whole tree. The volume of the log input was determined based on the Newtons system by measuring the length and the two perpendicular diameters under bark at both top and butt ends (Plate 3.2).

Plate 3. 2 Researcher taking measurements of a log

The volumes of logs were determined from the following relationship:

$$V = \frac{\pi D^2 L}{4}$$

Where V = volume of log (m^3)

D = mean log diameter from readings at both ends of log (m)

L = length of log (m)

3.3.4 Lumber volume measurement

Individual pieces of lumber from each log were measured as and when they were manufactured. It was ensured that all lumber from a particular log had been measured and tallied prior to processing the next log. The identification mark was put on the lumber in a location which was unlikely to be removed when parking.

The volume of green lumber was determined by measuring the length and then thickness and width at three points of every piece (Plate 3.3).

Plate 3. 3 Researcher taking measurements of a lumber

Specific dimensions were then tallied. The total volume of green lumber produced was obtained by the formula:

$$V = L \times W \times T \times N$$

Where V = total volume of lumber produced in m^3,

L = length of lumber in m

W = average width of lumber in m,

T = average thickness of lumber in m, and

N = total number of pieces tallied for each log.

Lumber recovery or conversion efficiency of logs into lumber for different logs was calculated using the formula:

$$= \frac{\text{Total volume of lumber produced } (m^3)}{\text{Log input } (m^3)} \times 100\%$$

3.3.5 Time measurement

The total time (which was not segregated) required for crosscutting and positioning and sawing off of planks/slabs of the log was included in the processing and recorded for about 50 percent of the sawn logs. Time used to process the logs into lumber/boards was measured. The zero-stop watch method was used, in which the time is recorded at the end of each lumber production process. The stopwatch was then reset to determine the time for the next lumber production. The time required for the processing of the entire log(s) was determined at the end of each phase by adding the times recorded for each lumber produced.

The production rates for the logosol machine were measured through time, work studies and analysis of data for about forty (40) logs (Table 4.9). Production rates were measured in output per unit time (m^3/hour). The actual lumber production rate (P_{rate}) of the machine was determined using the formula: $P_{rate} = V_{LP} / (t_2 - t_1)$, where V_{LP} is the total volume of lumber produced and t_1 and t_2 are the initial and final times respectively.

3.3.6 Data analysis

Microsoft excel was used to compute the mean, minimum, maximum and standard deviations values. Scatter graphs were used to determine the relationship between lumber recovery and diameter and tapering of logs using Microsoft excel. Least significant difference was also used to determine the significant differences between the recoveries of the five species. Data was subjected to Analysis of Variance Test (ANOVA). Results were presented in Tables and Graphs.

CHAPTER FOUR

4.0 RESULTS

4.1 Characteristics of logs used for the study

A description of the logs of the various species used for the study is shown in Appendices 3.1 – 3.5. From Table 4.1, the minimum diameter of the logs ranges from 28.50cm to 61.25cm and the maximum ranges from 65.00cm to 101.75cm. Danta had the lowest mean diameter of 45.44cm and dahoma had the highest mean diameter of 79.80cm. Average taper values were (2.70) cm/rm for dahoma, (1.80) cm/rm for esia, (1.85) cm/rm for ofram, (0.88) cm/rm for danta and (2.28) cm/rm for avodire.

Table 4. 1 Comparison of log characteristics for the five species

Species	No.of logs	Min.dia. (cm)	Max. dia (cm)	Mean dia. (cm)	MSE	SD	ATV(cm/rm)
Dahoma	19	61.25	101.75	79.80	2.81	12.24	2.70
Esia	23	51.50	91.00	69.35	2.20	10.56	1.80
Ofram	8	50.00	65.00	56.47	2.00	5.66	1.85
Danta	29	28.50	69.00	45.44	1.96	10.56	0.88
Avodire	14	37.50	66.25	52.23	2.59	9.69	2.28

MSE – Mean standard error, SD – Standard deviation, ATV- Average taper value.

4.2 Quantity of lumber recovered from processing

Appendices 3.6 – 3.10 shows the description of the lumber obtained from processing. From Table 4.2, the average width of lumber ranged from 12.56 cm to 27.56 cm whilst average thickness ranged from 3.84 cm to 4.95cm. Range of lengths varies between 1.9 – 5.2 m for dahoma, 2.2 – 4.9 m for esia, 2.5- 4.3 m for ofram, 1.5 – 5.0 m for danta and 1.5 – 4.4 m for avodire.

Table 4. 2 Comparison of lumber characteristics for the five species

Species	NL	Av.W (mm)	SEW	SDW	Av. T (mm)	SET	SDT	RL (m)
Dahoma	552	20.81	0.33	7.80	4.54	0.06	1.38	1.9-5.2
Esia	583	12.56	0.14	3.29	4.95	0.05	1.15	2.2-4.9
Ofram	87	27.16	0.71	6.66	3.92	0.07	0.72	2.5-4.3
Danta	307	14.30	0.15	2.68	5.24	0.03	0.56	1.5-5.0
Avodire	159	27.56	0.56	7.09	3.84	0.05	0.65	1.5-4.4

NL- pieces of lumber, Av. W- Average width of lumber, SEW- standard error of width, SDW – standard deviation of width, Av. T- Average thickness of lumber, SET- standard error of thickness, SDT – standard deviation of thickness, RL – range of length

4.3 Lumber recovery obtained for the selected species

The results of lumber recovery from a community- based timber processing mill using the logosol machine is presented below. The analysis was done using the raw data at appendices I and II to find out the various percentage lumber recoveries of dahoma, ofram, danta, avodire and esia. It also shows how diameter and tapering of logs affect the lumber recovery of each species.

Table 4. 3 Comparison of lumber recovery for the five species

Species	No. of logs	Min.% LR	Max.% LR	% Recovered (mean)	SD	SE
Dahoma	19	13.4	82.5	51.2	19.72	4.52
Esia	23	22.6	67.9	42.5	11.07	2.31
Ofram	8	32.2	55.2	47.3	8.97	3.17
Danta	29	22.8	67.1	46.8	12.18	2.26
Avodire	14	24.2	74.7	54.6	16.13	4.31
				48.48**		

** Overall mean of percentage recovered

SE – standard error, SD-- standard deviation, LR – lumber recovered

Table 4.3 shows the results on the minimum, maximum and the mean percentage lumber recoveries of dahoma, esia, ofram, danta and avodire. The minimum recovery for individual logs ranged from 13.4% to 32.2% and the maximum ranged from 55.2% to 82.5% with overall mean percentage recovery of 48.48%. Esia had the lowest mean percentage recovery of 42.5% whilst dahoma had the highest of 51.2%.

Table 4. 4 Kruskal-Wallis non-parametric tests on percentage lumber recovered based on average rank of selected species

Species	No. of logs	Median	Average Rank	Z
Dahoma	19	50.53	52.80	1.06
Esia	23	41.53	37.40	-1.96
Ofram	8	50.35	46.40	-0.07
Danta	29	44.63	44.70	-0.56
Avodire	14	58.59	60.00	1.96
Overall	93			
			DF = 4	P = 0.00

The p-value (0.00) of the Kruskal-Wallis test showed that there is significant difference ($p>0.05$) in the percentage lumber recovered of the selected tree species which means that the variation in the percentage lumber recovered is not due to chance or random error.

4.2 Log Characteristics influencing Lumber Recovery

Log characteristics that were tested for their effect on volume of lumber recovered from the logs processed were diameter and tapering. The influence of defects on lumber recovery could not be tested and was treated qualitatively.

4.2.1 Tapering

The relative change in diameter over a specific length of logs processed did account for the differences in volume of lumber recovery, for two (dahoma and avodire) out of the five species. Table 4.5 shows the results on the minimum, maximum and the mean tapering of dahoma, esia, ofram, danta and avodire. The minimum tapering ranged from

0.0 to 1.0 cm/rm whilst the maximum ranged from 2.8 to 6.5 cm/rm. Danta had the lowest mean tapering of 0.88cm/rm and dahoma had the highest of 2.70cm/rm.

Table 4. 5 Comparison of index of tapering for the five species

Species	No. of logs	Min. tapering (cm/rm)	Max. tapering (cm/rm)	Mean(cm/rm)	SEM	SD
Dahoma	19	0.6	5.5	2.70	0.33	1.44
Esia	23	0.2	6.5	1.80	0.30	1.44
Ofram	8	1.0	2.8	1.85	0.19	0.53
Danta	29	0.0	4.4	0.88	0.17	0.90
Avodire	14	0.6	4.0	2.28	0.29	1.09

SEM – standard error of mean, SD – standard deviation

Assumption of a simple linear regression was used. A scatter diagram and regression line of relationship between tapering factor defined as centimeter per running meter (x) and percentage lumber recovered (Y) of the species was plotted (Appendix 2.1 – 2.5). It was only in dahoma and avodire that 25.6% and 36.4% respectively of variation in recovery could be explained by the tapering factor (Table 4.6). In the other species tapering factor accounted for less than 8% of the recovery. Linear regression equations obtained are presented (Table 4.6).

Table 4. 6 Regression equations of relationship between tapering factor and lumber recovery of logs of species processed

Species	Regression equation	Co-efficient of Determination (R^2) (%)	P- value
Dahoma	Y = 69.82 – 6.92x	25.6	0.03
Danta	Y = 48.15 – 1.59x	1.40	0.55
Avodire	Y = 74.96 – 8.92x	36.4	0.02
Esia	Y = 44.7 – 1.21x	2.50	0.48
Ofram	Y = 56.00 – 4.71x	7.70	0.51

Y - Percentage lumber recovered (%), x – tapering factor (cm/rm)

The results indicate relatively high correlation value (36.4%) for avodire as compared to weak correlation value (1.4) for danta.

4.2.2 Log diameter

Figures 4.1 – 4.5 depict the relationship between diameter and percentage lumber recovery of the logs processed for the various species.

In figure 4.1, the simple linear regression produced a negative correlation between diameter and lumber recovery of dahoma logs. An increase in diameter resulted in a corresponding decrease in recovery.

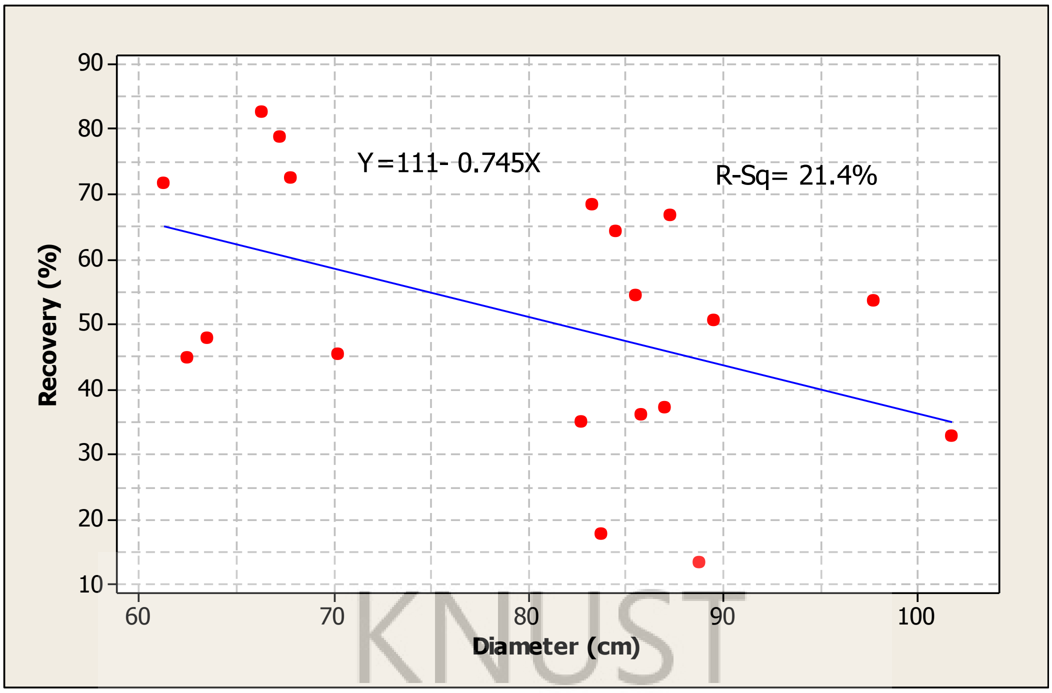


Figure 4. 1 Relationship between diameter and lumber recovery of logs of dahoma

However, in figures 4.2 - 4.5, the simple linear regression produced a positive correlation between diameter and lumber recovery of ofram, danta, avodire and esia logs. The relationships were however not very strong.

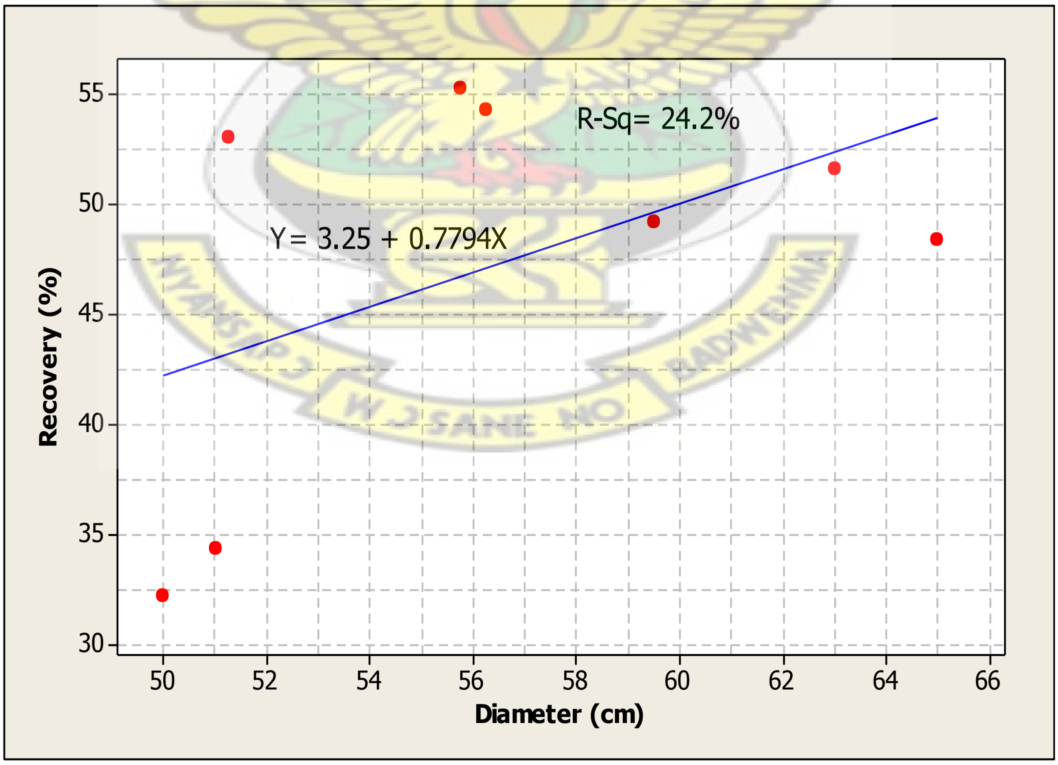


Figure 4. 2 Relationship between diameter and lumber recovery of logs of ofram

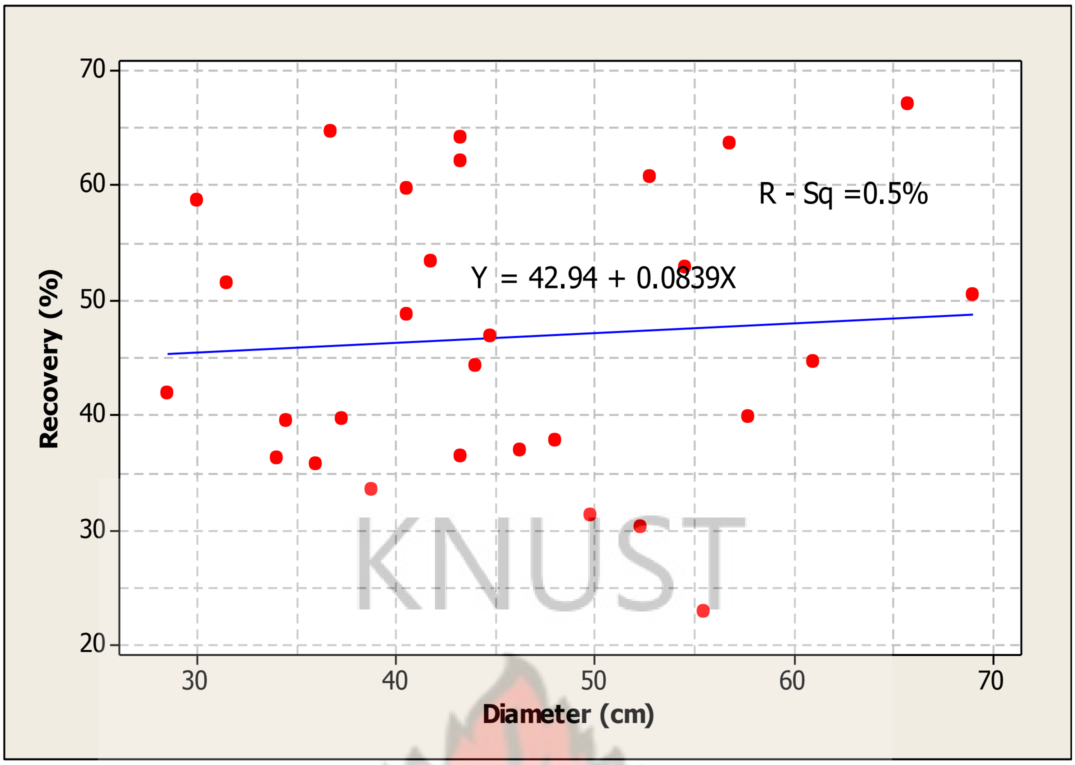


Figure 4. 3 Relationship between diameter and lumber recovery of logs of danta

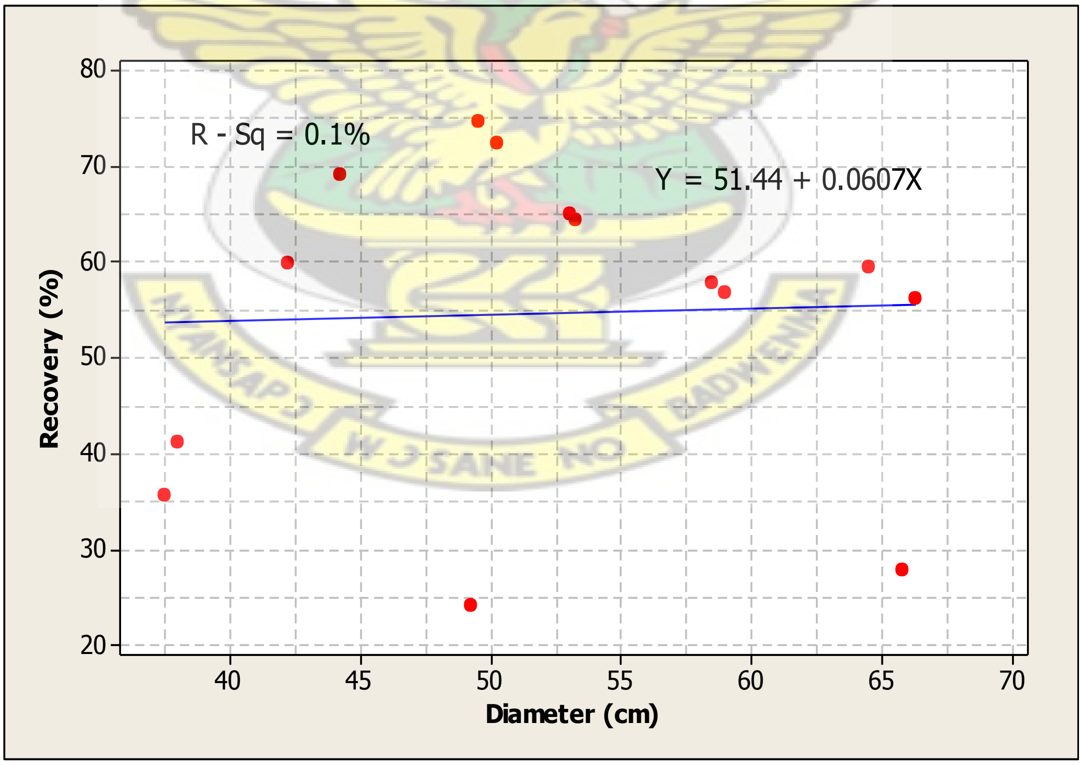


Figure 4. 4 Relationship between diameter and lumber recovery of logs of avodire

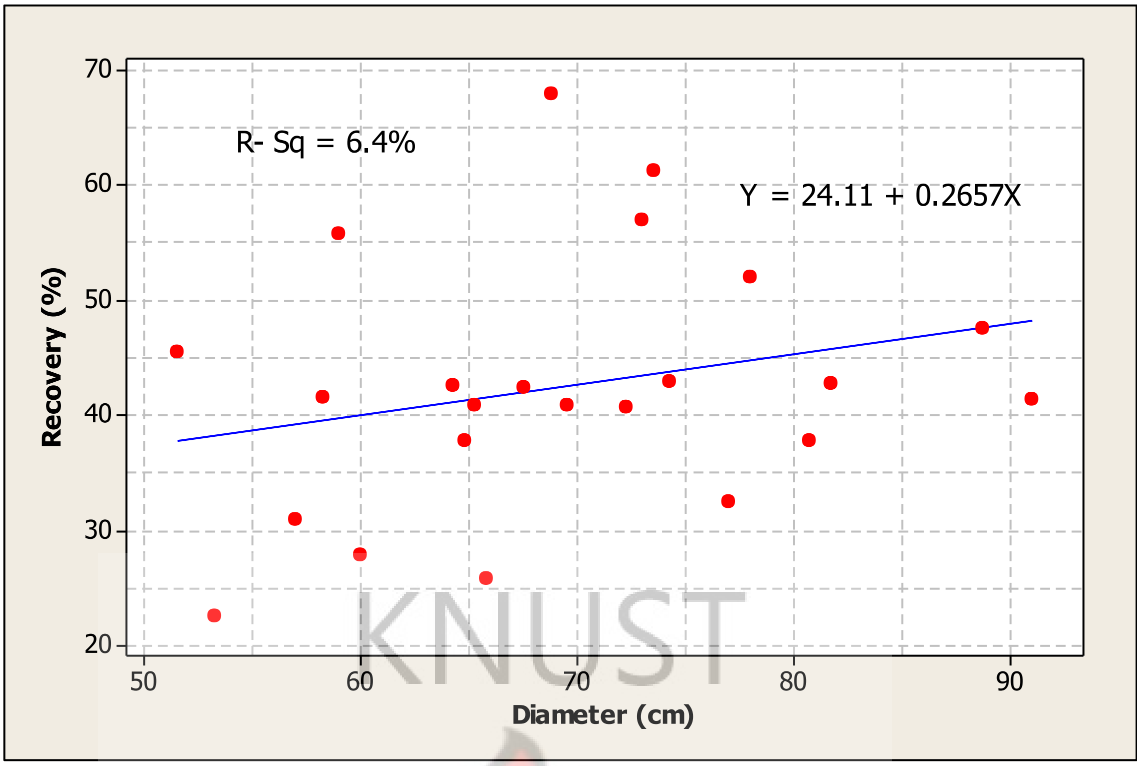


Figure 4. 5 Relationship between diameter and lumber recovery of logs of esia

Table 4.7 indicates correlation co-efficient of determination of 24.2%, 21.4%, 6.40%, 0.50% and 0.10% for ofram, dahoma, esia, danta and avodire respectively. Avodire show weak correlation as compared to ofram which indicates the relatively strong correlation among the selected species.

Table 4. 7 Regression equations of relationship between diameter and lumber recovery of logs of selected species processed

Species	Regression equation	Co-efficient of Determination (R^2) (%)	P- value
Dahoma	Y = 111 – 0.75x	21.4	0.05
Danta	Y = 42.94 + 0.08x	0.5	0.71
Avodire	Y = 51.44 + 0.06x	0.1	0.90
Esia	Y = 24.11 + 0.27x	6.4	0.24
Ofram	Y = 3.25 + 0.78x	24.2	0.22

Y - Percentage lumber recovered (%), x – diameter (cm)

The p-value (0.05) of the dahoma species (Table 4.7) showed that there is significant difference ($p>0.05$) in the diameters of dahoma logs which means that the variation in the recovery is not due to chance or random error.

4.2.3 Log defects

A lot of common log defects were identified in the study and included knots, split, rotten heart and hole. However some were without defects (Table 4.8). In the case of dahoma the extent of heart rot especially in the larger diameter logs was very high in terms of size. This resulted in lower lumber recovery in the large diameter logs.

Table 4. 8 Comparison of index of defects for the five species

Species	No. of logs	Types of Defects	No. of logs with no defect	No. of logs with one defect	No. of logs with two defects	No. of logs with three or more defects
Dahoma	19	K,S,RH,H	1	4	10	4
Esia	23	K,S,RH	0	8	7	8
Ofram	8	K,S,RH	0	2	5	1
Danta	29	K,S,RH	2	8	19	0
Avodire	14	K,S,RH	4	6	4	0

K – Knots, S – split, RH – rotten heart, H – hole,

4.3 Processing rates of some selected logs

Table 4.9 shows the log processing rates for the five species with the Stihl MS660 logosol machine. The individual time periods for cross-cutting, positioning and sawing off planks /slabs of the logs were not segregated because the process was considered as one continuous operation.

Table 4. 9 Processing rates of some selected logs

Species	No. of logs	Mean Diameter Of logs	Total lumber Vol. (m^3)	Total time (hrs)	Processing rate (m^3/hr)
Ofram	8	56.50	3.94	6.48	0.61
Danta	8	42.20	1.55	5.04	0.31
Esia	8	66.20	5.59	4.19	1.33
Avodire	8	52.90	3.11	3.82	0.81
Dahoma	8	80.10	7.96	3.35	2.38
					1.1m^3/hr**

** mean processing rate

The processing rates of some eight randomly selected logs ranged from 0.31m^3/hr for danta to 2.38m^3/hr for dahoma. The mean processing rate was 1.1m^3/hr. dahoma recorded the fastest processing rate (2.38m^3/hr) while danta recorded the slowest processing rate of 0.31m^3/hr.

Figure 4.6 depict the relationship between the volume of lumber recovered and processing rates of the selected logs. The simple linear regression produced a positive correlation between total volume of lumber recovered and processing rates of the selected logs. An increase in total volume of lumber recovered resulted in a corresponding increase in processing rate.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Lumber Recovery

The overall mean percentage lumber recovery (48.48%) obtained in the study is higher than those established with free hand chainsaw milling (47.1%) as reported by Wilson *et al.* (2009). It is also higher than the value established by Frimpong-Mensah (2004) who obtained 40%. Very low lumber recovery of 27% has also been reported by Birikorang *et al.* (2001) for free hand chain sawing.

The highest percentage lumber recovery was associated with avodire (54.6%) with esia obtaining the least percentage lumber recovery (42.50%). The differences in percentage lumber recovery among the five species were statistically significant (Table 4.4). The difference in recovery could be attributed to a number of log characteristics which are associated with species. Smith (1997), Okai (1999), Ackah (2004) and Wilson *et al.* (2009) have noted that, among the characteristics that might affect recovery are wood density, heart rot, tapering of logs, sweep logs and the width of sapwood.

This study revealed that, poor quality of logs of esia species might have contributed to its low lumber percentage recovery (Table 4.8). According to Petro (1984), higher yield of lumber is associated with good quality logs. He also defined log quality in terms of its size or diameter, form and taper, length and straightness, and asserted that, defects such as rotten heart, worm and pinholes, splits and shakes affect log quality.

Ayarkwa and Addae Mensah (1999), noted that lumber yields obtained from logs with different magnitudes of sweep had lower recovery when compared with fairly straight logs. The difference in recovery could also be due to the difference in density of the tree species, as reported by Wilson *et al.* (2009). Very low density wood can be difficult to peel except when the moisture content is high and the cells are filled with water; this gives mechanical support to the cell wall during cutting (Tetteh, 2009).

In Uganda, Odokonyreo (2004) reported a mean recovery yield of 43% when 45 logs of *Strombosia scheffleri* were processed into lumber using logosol machine. The report also indicated a varied recovery from 41% - 67% for different diameter classes of the species processed. The mean recovery (48.48%) obtained in the present study is higher than 43% reported by Odokonyreo (2004) but lower than the 55.8% reported by Wilson *et al*. (2009). The differences could be due to the difference in expertise of personnel used and different species which may have different wood densities.

Recovery of lumber in Ghanaian mills has been generally low (Ackah, 2004). Petro (1984) reported that the mean recovery for Dahoma meant for export and the local market from Log and Lumber Limited a sawmill in Kumasi were 22.5% and 40.1% respectively. Low lumber recovery in Ghanaian mills has been attributed to lack of spare parts resulting in improper functioning of equipment, poor positioning of logs and more than necessary slabbing at the headrig and poor log quality (Ackah, 2004). He also stated that low lumber recovery in Ghanaian mills has been partly attributed to grading of lumber by the sawmills as a result of contract specification by buyers.

5.2 Effect of taper on lumber recovery

The amount of taper in a log has a dramatic effect on potential lumber recovery. Ackah (2004) and Wenger (1998) asserted that, the systematic reduction in size along the length of a log from the butt end to the top end has significant effect on lumber yield and it results in lower recovery per cubic metre of log volume.

Appendix 2.1 indicates that for avodire, an increase in tapering by 1cm/rm would result in 66.1% decrease in lumber recovery, whereas for esia, danta, ofram and dahoma, an increase in tapering by 1cm/rm would result in 43.5%, 46.6%, 51.3% and 62.9%, decrease in lumber recovery respectively (Appendix 2.2. – 2.5). Thus, the effect of tapering on recovery was high in avodire species processed, in comparison with other four species. This may be due to crooked bole form (shapes) of the species.

It was only in dahoma and avodire that 25.1% and 36.4% respectively of variation in recovery could be explained by the tapering factor (Table 4.6). In the other species tapering factor accounted for less than 8% of the recovery. Linear regression equations obtained are presented (Table 4.6).

Ackah (2004) asserted that if tapering exceeded 1 cm/rm, it is considered strong. To reduce the effect of tapering in such a situation, the logs must be cut shorter than the average length of logs (4.0 m). Some of the logs processed in the study exceeded the tapering rate of 1 cm/rm and this affected the recovery. A lot of the logs were also longer than the 4.0m recommended by Ackah (2004).

Observations made during the study were in line with what Castaneda (1988) and Ackah (2004) noted with techniques to improve sawmilling productivity. They asserted that bucking techniques which is a process by which a tree is cut into log lengths, improves sawmill productivity. It is important that before marking the tree length for bucking, the bucker should consider the length, grade and value of the log. Bucking is said to reduce the effect of tapering on log recovery (Petro, 1984).

5.3 Effect Of Log Diameter On Lumber Recovery

It is observed that log diameter has a linear relationship with lumber recovery since the amount of defect-free wood contained in the periphery of a butt log is closely related to diameter (Petro, 1984). As the tree grows, it increase in size and the proportion of clear wood also increases. Kewilaa (2008) working on *Terminalia* species showed that species and log diameter have highly significant effect and their interaction has a significant effect on recovery if species are defects free. In the present study except in the case of dahoma bigger logs had better recoveries. This may be due to defects such as hole in heart and heart rot in some dahoma logs. Logs of diameter above 100cm that were defective free gave better recoveries than those below 100cm. This may be due to the reduction of juvenile sapwood and an increase of the heartwood proportion in trees as they increase in diameter through growth (Zobel and Talbert, 1991).

Generally higher lumber recoveries are associated with bigger diameter logs. Kewilaa (2008), noted that, log diameter has a linear relationship with lumber recovery. However, if the heartwood is defective (hole in heart, heart rot) this could affect the amount of wood that can be obtained from the log as depicted in logs of dahoma.

In figure 4.1, the relationship between diameter and lumber recovery of logs of selected species indicates that for dahoma, an increase in diameter by 1cm would result in 110.25% decrease in lumber recovery, whereas for ofram, esia, danta and avodire an increase by 1cm would result in an average increasing order of 4.03%, 24.38%, 43.02% and 51.5% in lumber recovery (figures 4.2 – 4.5). Thus, the effect of diameter on recovery appeared high in avodire, in comparison with the other four species.

In this study although some relationships were established between log diameter and recovery, the relationships were not very strong as indicated by the low R^2 values. This may be due to the strong effect of defects which were very common in the logs.

5.4 Effect Of Log Defects On Lumber Recovery

A defect in wood may be defined as any abnormality or irregularity that lowers its commercial value by decreasing its strength, or by affecting adversely it's working and finishing qualities or its appearance (Brown *et al.*, 1994).

The effects of defects on lumber recovery were not quantified in this study. However due to the high prevalence of defects notably knots, splits, rotten heart and hole found on the logs it is very likely that the observed recoveries would have been influenced by defects.

5.5 Processing Rate

In the study using a 3-man team, the average lumber processing rate was $1.1m^3$ per effective hour. This means that working for eight (8) hours in a day, one operator and his two assistants with one Stihl MS660 machine with logosol attachment will produce a lumber volume of $8.8m^3$. Sawmill productivity is the mill production rate i.e the volume of sawn wood produced per effective hour of sawing time (output per unit time) Odokonyerro (2004). In his study the processing rate in cutting and feed speed of chain-saw mill (Stihl MS660 with logosol attachment) in milling *Strombosia scheffleri* in

Uganda was 5-6 meters per minute with a cutting width of 15cm. He obtained average lumber production rate of 1.2 m^3 per effective working hour. This value is higher than the value obtained in the present study. The difference could be due to several factors including species characteristics, skills of the operators and the work environment.

Wilson *et al.* (2009) found out that, milling with logosol attachment with Stihl MS880, the average lumber production rate was $0.48m^3/hr$. meaning working for eight hours in a day, one operator and his two assistants will produce a lumber volume of $3.85m^3$ of any of the four species studied. This value ($0.48m^3/hr$) is lower than the value ($1.1m^3/hr$) obtained in the study; hence under the same working conditions with the same operators, the Stihl MS660 machine with logosol attachment seems to have an advantage over milling with logosol attachment with Stihl MS880.

Table 4.9 shows that the highest milling rate was achieved with logs of dahoma. It is important to note the effective processing time was lowest in sawing danta. This difference may be attributed to log size as it appears bigger logs had faster processing rates. This was despite the greater amount of time required for handling large heavy logs which usually have pipe rots in the centre as observed by Wilson *et al.* (2009).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

During the study a total 93 logs of volume 108.94m^3 were processed into 51.77 m^3 of sawn timber at an average recovery of 48.48%. The recovery varied from 42.50% to 54.60% depending on species. The average percentage recovery (48.48%) found in the study was substantially higher than the reported recovery in chain-saw with free hand which is 40%. The average lumber production rate was 8.8m^3 /day for eight hours.

The study revealed that diameter, defects and tapering have effect on lumber recovery. Apart from the case of dahoma, bigger diameter logs with minimum defects appeared to yield higher recoveries. To reduce tapering effect logs must be cut in shorter lengths. Also tapering rate should not exceed 1 cm/ rm.

The quality of lumber produced from milling with logosol attachment may be comparable to that of conventional saw mills whilst lumber produced by chain-saw with free hand is of lower grade.

The results from the study indicate that milling with logosol attachment is a very appropriate technology for sawing logs from the forest. This provides a strong reason for Forestry Commission to allow milling with logosol attachment to operate and phase out the chain-saw with free hand.

6.2 Recommendations

- Studies should be done to test the effect of log length on lumber recovery.
- The technology of the 'logosol' machine should be tested for other species. This can serve as a guide for policy makers in the review of the current policies on the use of mobile mills to process logs.
- Chain-saw operators in rural communities should be organized into viable cooperatives and technology of the 'logosol' machine introduced to them and also build their capacity to improve the recovery rate.
- There is the need to conduct further studies (based on grading) to quantitatively assess the effect of the 'logosol' machine on lumber quality.
- Studies should be conducted to assess the effect of the 'logosol' machine on the health of workers.

REFERENCES

Ackah, J. R. (2004). Recovery of Lumber from some plantation grown timber species – *Tectona grandis* and *Gmelina arborea*. Graduate thesis submitted to Institute of Renewable Natural Resources – Kwame Nkrumah University of Science and Technology. Pp. 42- 43, 56 – 60.

Adams, M. J. (2007). Improving Utilization Efficiency and attracting Investment in the Wood Industries in the Pacific Region. Strategy and Policy Options, pp54-76.

Addo, S. (1975). Some problems in the utilization of wood resources in Ghana; seminar paper No. 10, pp. 108-117.

Amoako, D. (2008). Yield Maximization. Project submitted in partial Fulfillment of the Requirements for the B.Sc. Wood Science at the Institute of Renewable Natural Resources, U.S.T. Kumasi. Pp 28-40

Akrasi, P. (1997). The Activities Of Chainsaw Operators In Ghana. A Case Study At The Goaso Forest District. Project submitted in partial fulfillment of the requirements for the B.Sc. Forest Management at the Institute of Renewable Natural Resources, U.S.T. Kumasi. Pp 13-20

Anglaaere, L.C.N (1988). Sawing Accuracy in a Ghanaian sawmill. BSc. Thesis, UST Kumasi, 1988.

Appiah, S.K (1983). Analysis of the effect of percent sawn wood recovery on log cost, mill-roof productivity and profitability of a mill. FRPI Technical Bulletin Vol.3.

Awuni, S. J. (2003). The role timber industry development division in ensuring quality standards in the lumber and veneer processing mills, BSc Thesis, KNUST. Pp. 6-12

Ayarkwa, J. and Addae Mensah, A. (1999). Processing of small diameter logs. Effect on log diameter, sawing pattern and some bole variables on lumber recovery. Ghana Journal of Forestry Vol.8. pp 43-51

Birikorang, G., Okai, R., Asenso-Okyere, K., Afrane, S. and G. Robinson (2001). Ghana wood industry and log export ban study. Accra, Ghana, Forestry Commission, 55 pp.

Birikorang, G. and M. Rhein (2005). Reforming Ghana's Forest Fiscal Regime: Phase 1 Report. Accra, Ghana, Forest Sector Development Project 2, 28 pp.

Birikorang, G., Hansen, C.P. and Treue, T. (2007). Review of the current taxation system relevant to the forest sector in Ghana. VLTP Background Paper No. 1. Validation of Legal Timber Programme, Forestry Commission, Accra, Ghana.

Brimpong, S.O. K. (1975). Utilization of wood residue from reforestation areas. Seminar paper No. 11, pp. 119-126.

Brown, H.P.; A.J. Panshin and C.C. Forsaith (1994). Textbook of Wood Technology Vol.1; New York; McGraw- Hill Book Company, INC; pp.40-43; pp. 283-309.

Castaneda, F (1988). Proper felling and bucking techniques to improve sawmill productivity. In proceedings of the Workshops held in Chittagong, Bangladesh on Sawmill Productivity Improvement, pp 1-10.

Danso, J. (1975). Wood working industry in Ghana and its prospects. Office of the Planning Commission, Accra. Mimeographed, 15 pp.

Doyle, J.A. (1960). Small sawlogs and the production of spruce lumber. F.P.L.C. April, 1960, pp. 1-3.

Frimpong-Mensah, K. (2004). Chainsaw lumber production is wasteful, fact or myth? in Nketiah, K.S., Wieman, A. and K.O. Asubonteng (eds.). Chain-saw lumber production: a necessary evil? Workshop Proceedings 2. Focus group discussion at a workshop held at the Wood Industries Training Centre (WITC), Akyawkrom, Ejisu, Kumasi on 11 November 2003. Tropenbos International - Ghana, Kumasi, Ghana: 62-65.

Ghana Statistical Service (2007). Key social, economic and demographic indicators. www.statsghana.gov.gh/KeySocial.html (Accessed 11/02/10)

Hoadley, B.R., (1980). Understanding wood: A craftsman's guide to wood technology. Taunton press, Connecticut. 256pp.

Kewilaa.B,(2008). Effect of Wood Species and Log diameter on Veneer. Faculty of Agriculture,Pattimura University.Pp49

Marfo, E. (2010). Chainsaw Milling in Ghana: Context,drivers and impacts. Tropenbos International, Wageningen, the Netherlands. pp 1 -54.

Martyr, N. R. (1973) . Introduction to sawmilling Timber Research and Development Association Hughen den, Valley High Wycombe, Bucks HP14 4 ND. Teaching Aid No.8 pp. 1-10

Mensah, A., (1982). Grading guidance on Ghana wood and wood products. Ghana Timber Marketing Board, Takoradi. 51pp.

Nketiah, K.S. (2005). Lumber supply situation for furniture making in Ghana: A case study of Ashanti region. Technical report prepared for Tropenbos International, pp 33.

Odokornyero, G. G. O. (2004). Trial On the Utilization of *Strombosia scheffleri* from Kalinzu Forest Reserve. pp. 9 – 21.

Okai, R. (1998). Recent advances in machining of lesser-used species, ITTO/FORIG/TEDB-VAHPU conference, City Hotel, Kumasi, Ghana. pp 95.

Okai, R. (1999). Assessment of sawing characteristics of three Ghanaian lesser-used timber species. (Unpublished) Forestry Research Institute o f Ghana, Kumasi, Ghana

Otoo, J.E. (2004). Chainsaw Lumber Production and Sustainable Forest Management In: K.S. Nketiah, K.S., A. Wieman and K.O Asubonteng (eds). 2004.”Chainsaw lumber production, a necessary evil”, Tropenbos International, Workshop Proceedings 2. pp 16-18.

Petro, F. J. (1984). How to manufacture quality saw logs. In M. Amoah (1995). Conversion Efficiency of logs into lumber. Project submitted in partial Fulfillment of the Requirements for the B.Sc. Wood Science at the Institute of Renewable Natural Resources, U.S.T. Kumasi. pp.3 – 23, 48 – 83.

Rickford, N. and Gene N., (1973). Trimmer control and lumber tally systems. Modern sawmill techniques. Vol. 1. Proceedings of the 4th sawmilling clinic. Portland. Oregon, Feb. 1973. pp 248-260.

Smith, I. (1997). Wood engineering expands the uses of wood. UNB Forestry Focus 13 (12), pp 1-3.

Steadman ,J.D. (1974). Modern Sawmill Techniques Vol.4 Proceedings of the fourth sawmill clinic, New Orleans, Louisiana, November, Edited by Herbert G. Lambert. Miller Freeman. pp.92-108

TEDB, (2007). Ghana Hardwoods Trade and Industry Directory 1991; London, U.K. pp. 1-20

Tetteh, F. (**2009)** Assessment of wood residue generation and utilization (a case study at scanstyle mim limited), Project submitted in partial Fulfillment of the Requirements for the B.Sc. Wood Science at the Faculty of Forest Resources Technology, KNUST, Kumasi. Pp. 14

Tsoumis, G. (1991). Science and technology of wood structure, properties, utilization. New York: Van Nostrant Reinhold publishers. Pp. 240-260.

Wenger, K.F. (1984). Forestry Handbook 2nd ed., New York John Wiley and Sons. pp. 256-606.

White, V.S. (1973). Modern sawmill techniques. Proceedings on the Sawmill Clinic, Portland, Oregon, February, pp. 95, 176-181, 184-197

White, V.S (1974). Modern sawmill techniques; Vol.1 Miller Freeman, U.S.A. pp 320.

White, V.S.(1975). Modern sawmill techniques; Vol. 3 Miller Freeman, U.S.A. pp. 1-100 and 392.

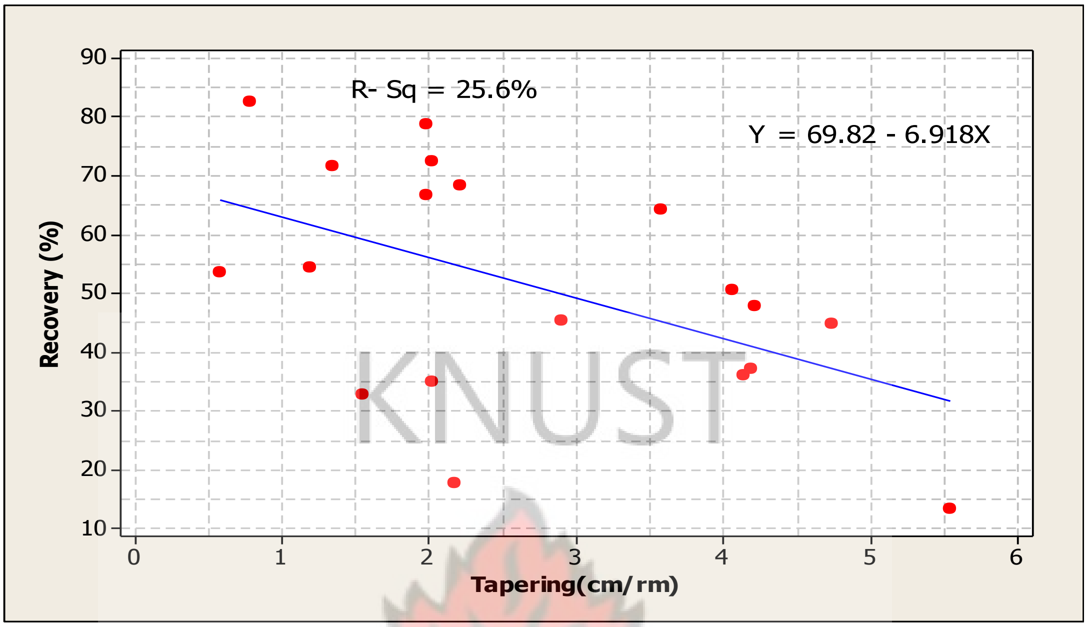
Williston, E.O.M. (1988). Lumber Manufacturing. The design and operation of sawmills and planer mills. Revised Edition; Miller Freeman Publications, Inc. San Francisco, U.S.A. pp. 1- 304.

Wilson, F. O., L. Damnyag and B. Dominic (2009). Processing Efficiency of Milling Techniques: A Comparative Analysis. In E. Marfo, K. A. Adam and B. Darko-Obiri (eds). 2009. Developing Alternative to illegal chainsaw milling through multi-stakeholder dialogue in Ghana and Guyana project: A case study of illegal chainsaw milling. pp.111 – 136.

Wilson, F. O., L. Damnyag, B. Dominic and J.K. Appiah (2010). Improved Chainsaw milling in the small-scale Informal Timber Sector of Ghana, using Logosol: A manual for Domestic Timber Entrepreneurs.

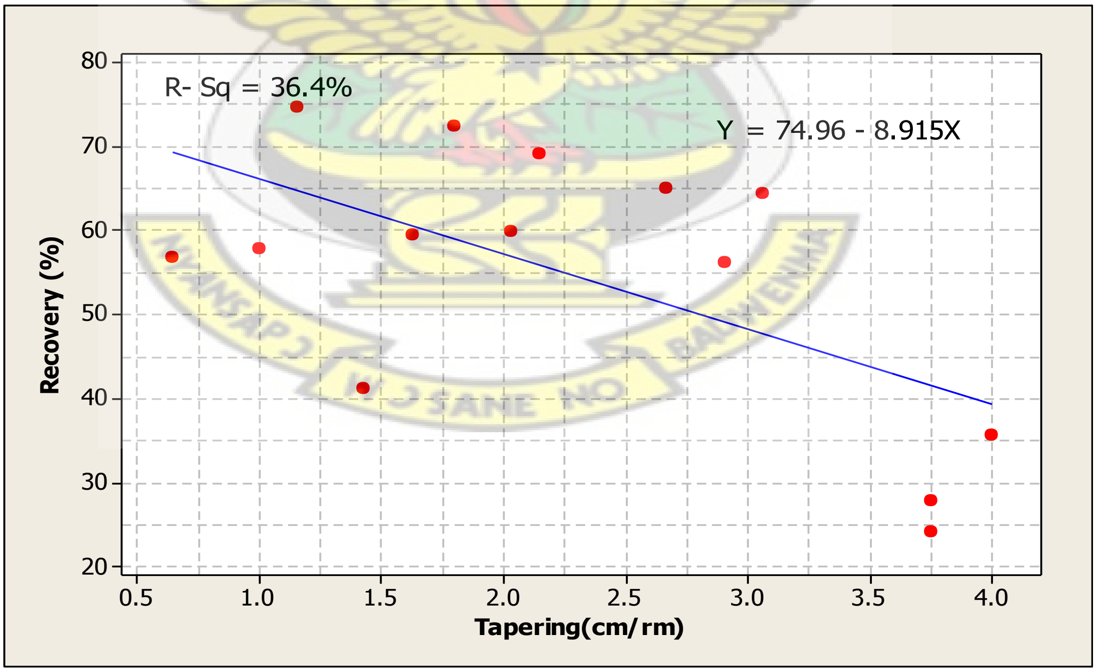
Zobel, B. and Talbert, J (1991) Applied Forest Tree Improvement. Waveland Press, Inc. pp. 376-407

APPENDIX II

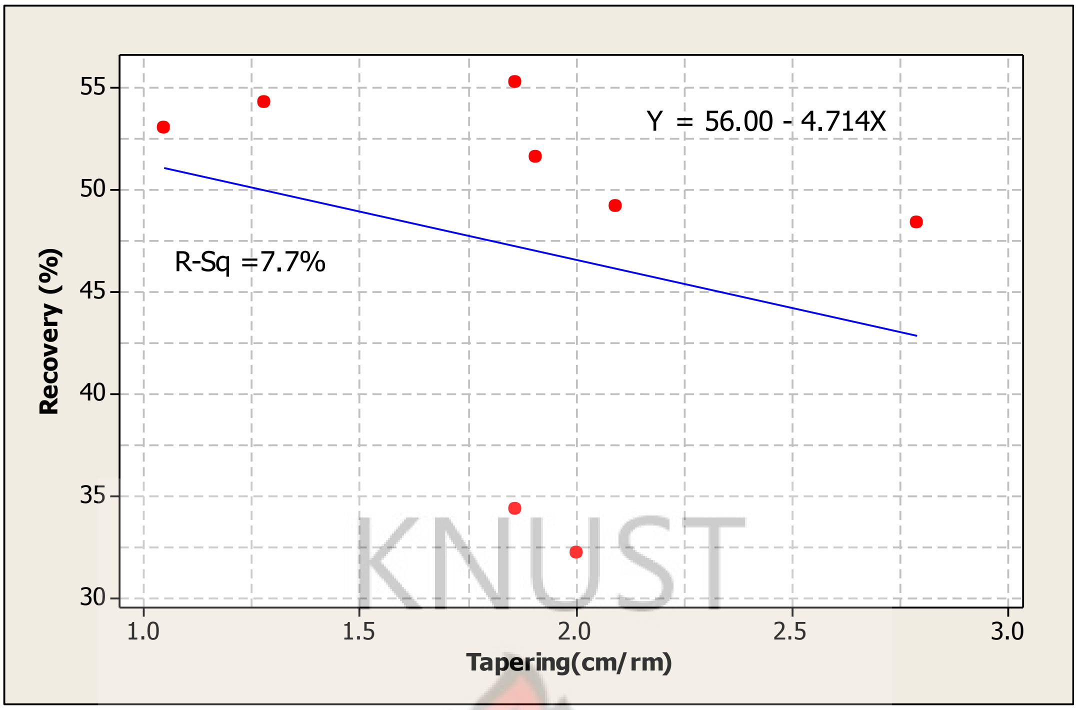


Appendix 2. 1 Relationship between tapering factor and lumber recovery of logs of dahoma

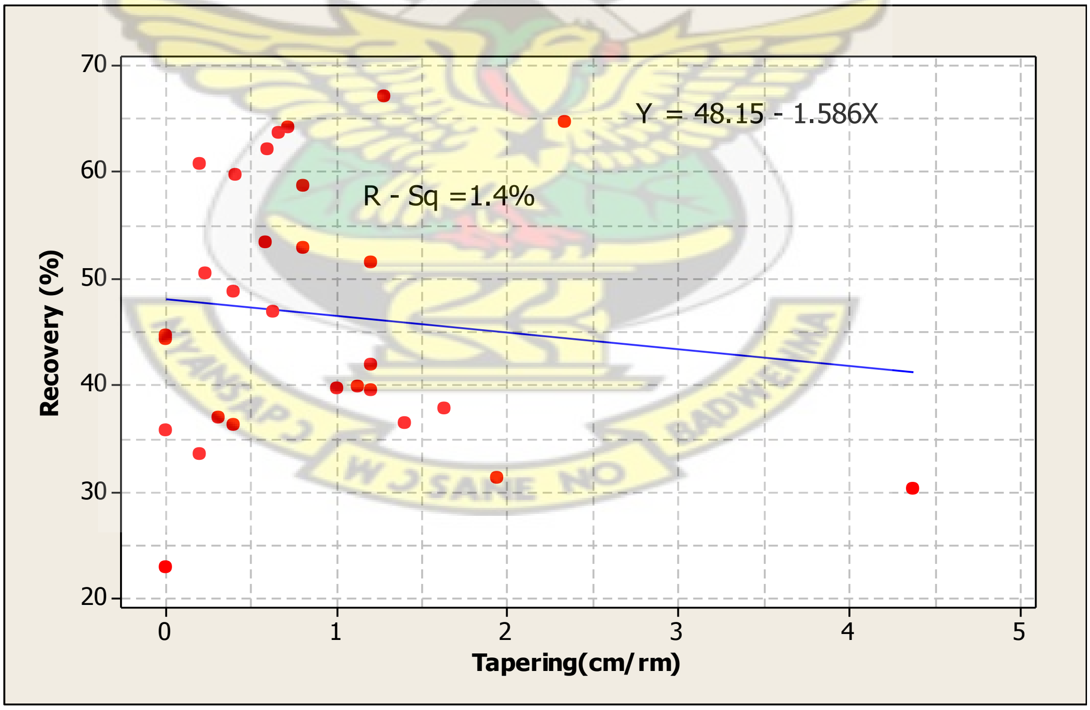
.



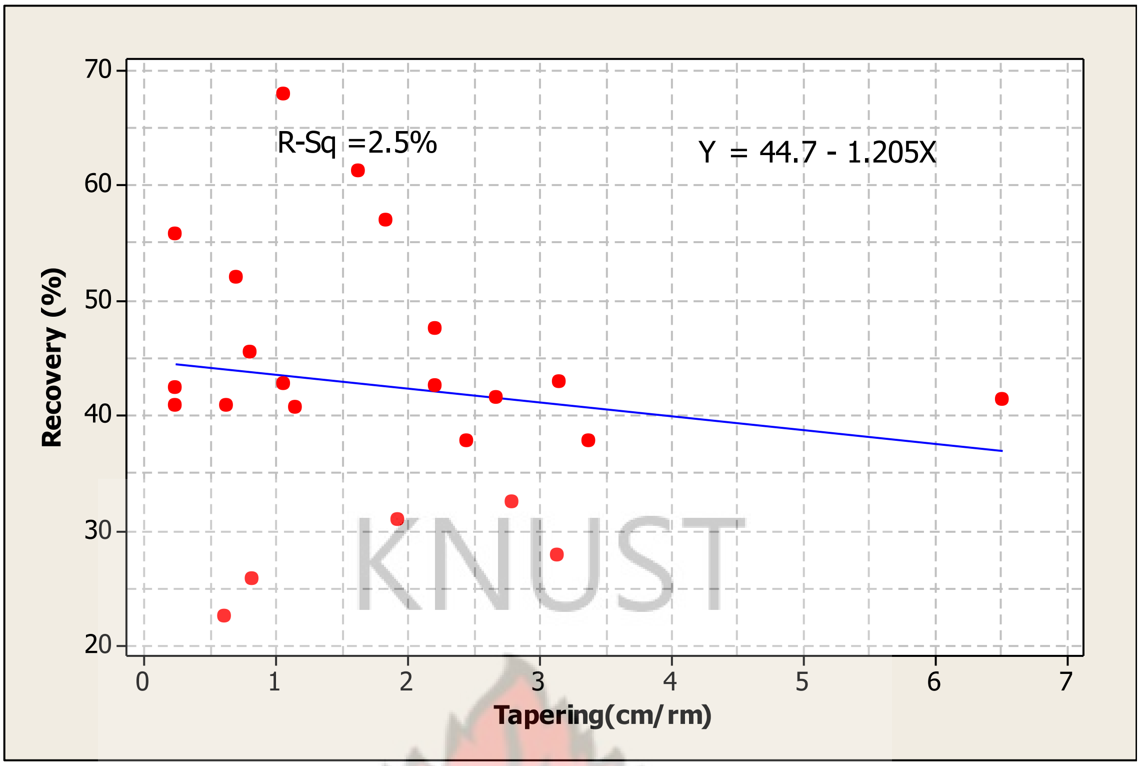
Appendix 2. 2 Relationship between tapering factor and lumber recovery of logs of avodire



Appendix 2. 3 Relationship between tapering factor and lumber recovery of logs of ofram



Appendix 2. 4 Relationship between tapering factor and lumber recovery of logs of danta



Appendix 2. 5 Relationship between tapering factor and lumber recovery of logs of esia