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RENEWABLE NATURAL RESOURCES ENGINEERING

Essays in Honour of Canon Professor E. Babájídé Lucas

Edited by
A. Olajide Olorunnisola

Renewable Natural Resources Engineering

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Primary Wood Conversion and Processing in Nigeria: A Status Report

A.O. Olorunnisola and T.E. Omoniyi

Introduction

Wood conversion is the application of various techniques to separate wood fibres in order to achieve the desired shape, size and surface finish of the products. There are two levels of wood conversion:

- a) Primary conversion processes: These include the harvesting, i.e., felling of trees, de-branching, cross-cutting, debarking, bucking; and saw milling.
- b) Secondary conversion processes: These are the processes carried out on the primary processed wood products. They are largely dependent on the end use of the wood. Examples of secondary conversion processes include: planning, drilling, thicknessing, milling, turning, sanding, spraying of chemicals, chipping and pulping (for paper production).

The focus of this paper is a review of the current status of primary wood conversion and processing, with special reference to timber harvesting and sawmilling, in Nigeria.

Timber Harvesting

Harvesting is an essential and a primary activity in timber processing operations. It is a series of processes involving all operations from tree felling to delivering logs at the mill (sawmill or plymill). The common term used for timber harvesting is logging. Hence, the two terms will be used interchangeably in this book. Logging operations are seasonal. Due to the lack of appropriate logging equipment and facilities, the main logging season in Nigeria spans about seven month period spanning September of one year to March of the following year, i.e., the dry season (Sanwo 1982a, Olorunnisola 1997). Only minimal logging is done during the rainy season. Logging is usually done in the forest, i.e., forest plantations and natural forests consisting of natural forest reserves, secondary forests, farmlands, Taungya farms and derived savanna. Major logging operations are performed in the high forest areas located in the southern one-quarter of the country encompassing the following seventeen states: Abia, Akwa-Ibom, Anambra, Bayelsa, Cross-River, Delta, Ebonyi, Edo, Ekiti, Enugu, Imo, Lagos, Ogun, Ondo, Osun, Oyo, and Rivers.

Sustainability of timber exploitation is now a major challenge in the country. As noted by Enabor (1992), mismanagement and misuse of forest resources commenced in the 1960s, with only the choicest portions of the most valuable timber species extracted for export markets. The logging of a

number of tree species has thus been banned in some states due to their endangered status and concern over their extinction. A list of such trees and the states in which their logging has been banned is given in Table 1. As the surviving natural forests are cut, the wood processing industry will have to be developed based on the wood resource provided by the forest plantations and the opening up of new forest areas by road construction and the development of river transportation. Sustained efforts will also have to be devoted to afforestation and natural regeneration. Besides, as rightly noted by Lucas (1983), another major strategy against wood scarcity, that is already being explored, is the commercialisation of many more wood species.

Table 1: Tree Species Banned from Harvesting Different States of the Nigerian Federation as at 1999

S/No	Species	State
1	<i>Aformosia</i> spp.	Ondo, Imo
2	<i>Aformosia elata</i>	Cross River
3	<i>Borassus aethiopum</i>	Plateau
4	<i>Canarium schweinfurthii</i>	Plateau
5	<i>Diospyros mespiliformis</i>	Ondo, Imo
6	<i>Elias guineensis</i>	Plateau
7	<i>Funtumia</i> spp.	Cross River
8	<i>Irvingia</i> spp.	Cross River
9	<i>Lophira alata</i>	Ondo, Imo
10	<i>Milicia excels</i>	Abia, Osun, Akwa-Ibom, Anambra, Benue, Ebonyi, Ekiti, Enugu, Kwara, Niger, Ogun, Plateau, Rivers
11	<i>Pakia biblobosa</i>	Plateau
12	<i>Triplochton scleroxylon</i>	Abia
13	<i>Uapaca</i> spp.	Ebonyi, Imo
14	<i>Vitellaria paradoxa</i>	Plateau
15	<i>Azelia Africana</i>	Imo
16	<i>Erythrophleum ivorensis</i>	Rivers
17	<i>Erythrophleum</i> spp	Ekiti
18	<i>Garcinia kola</i>	Ebonyi
19	<i>Gossweilerodendron balsamiferum</i>	Ekiti
20	<i>Guarea</i> spp.	Ogun
21	<i>Holoptelea grandis</i>	Ekiti
22	<i>Hyphaene thebaica</i>	Kebbi
23	<i>Irvingia gabonensis</i>	Rivers
24	<i>Isoberlinia doka</i>	Niger
25	<i>Khaya</i> spp.	Benue, Niger
26	<i>Khaya grandifolia</i>	Enugu, Kaduna, Kwara
27	<i>Khaya ivorensis</i>	Rivers
28	<i>Khaya senegalensis</i>	Kaduna, Kebbi, Kwara, Plateau
29	<i>Mansonia altissima</i>	Ekiti, Imo, Ogun, Osun
30	<i>Mitragyna stipulosa</i>	Ekiti, Ogun
31	<i>Nauclea diderrichii</i>	Ekiti, Enugu
32	<i>Nauclea latifolia</i>	Niger
33	<i>Nesogordonia papaverifera</i>	Ekiti
34	<i>Pterocarpus</i> spp.	Cross River
35	<i>Pterocarpus erinaceus</i>	Kano
36	<i>Pterocarpus osun</i>	Kaduna
37	<i>Ricinodendron heudelotti</i>	Kaduna
38	<i>Securidaca longepedunculata</i>	Kano

Source: Beak (1999)

There are basically two types of harvesting systems. These are the "tree-length" and "shortwood" systems. In the tree-length system, the tree is felled and delimbed at stump (felling site); extracted to the roadside; crosscut into sawlogs and stacked for collection by lorries. In the shortwood system, whole tree lengths are cut into about 4 m long logs. Debranching or delimiting and crosscutting are done at stump so that all subsequent extraction handles only saleable products and all waste is left in the forest. A comparison of the two systems is given in Table 2. The shortwood system is the predominant type of harvesting system employed in Nigeria. The logs (Figure 1) are forwarded directly from the stump to the mill by lorries.

Table 2: Comparison of shortwood and tree-length systems of timber harvesting

Shortwood system	Tree-length system
Efficient with small and large trees	Less efficient on trees smaller than 0.1m ³ average
Two-phase system, easier to supervise	Three-phase system, needs good co-ordination
Preferably not more than three products	Several products can be cut. Working space necessary at roadside
Stacking space only required at roadside. (Can be loaded direct on to transport)	Sorting and stacking required at roadside
Fellers pile smaller billets in wood	Lumber dirty in wet conditions
Lower density of rads required for forwarder extraction.	Higher density of rads required to organise skidder extraction



Figure 1: Felled and Cross-Cut Logs

Logging Operations

The key logging operations include

- i. **Tree felling**, including limbing, i.e., cutting the branches off the log,
- ii. **bucking**, i.e., cross cutting the felled log into sections, brushing and slashing, i.e., clearing small trees and branches under 125 mm (5 inches) diameter.

Manual felling, involving the use of axes and different types of hand saws, is still practised in many parts of the country. In many cases, the semi manual logging method, involving the combined use of power chain saws and axes, is employed in directional felling. Chain saws are, however, potentially very dangerous. The hazardous situation is compounded by inadequate training of operators coupled with their usual adoption of poor working methods, and non-availability of protective equipment such as helmets, visors for eye protection, ear protectors, safety gloves, boots, and snag-proof clothing. Saws are also seldom given routine maintenance.

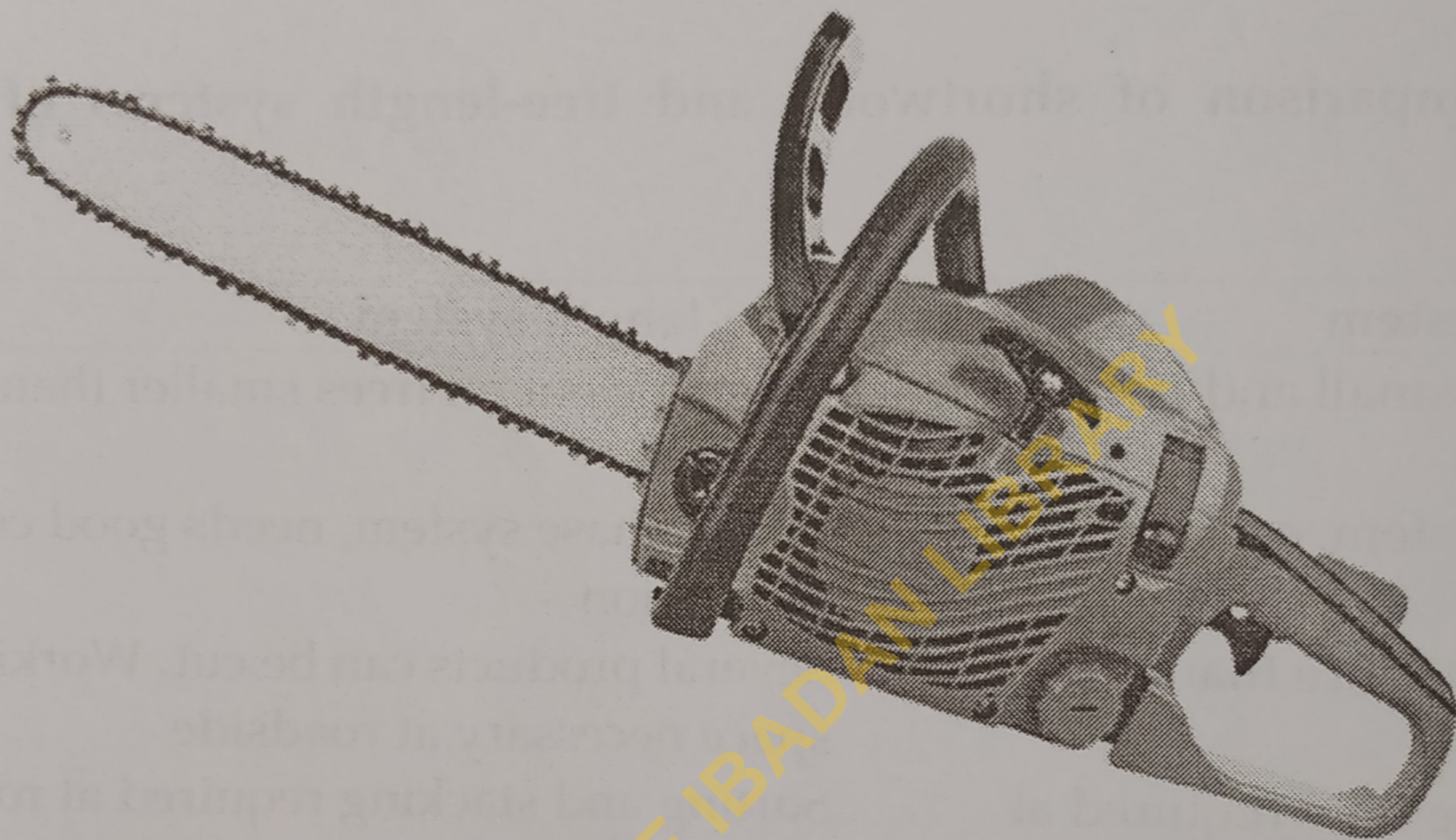


Figure 2: A Typical Chainsaw

Besides the foregoing, several factors tend to affect daily production in felling and crosscutting, when the chain saw is used. The major ones are tree diameter, number of logs per tree, and effective working time. The diameter affects production in that it determines the amount of work needed to fell a tree (i.e., the area to be cut through), and it reflects the volume that might be utilized. For instance, larger trees require more time to be felled and cut into log lengths but also give higher volumes of lumber.

ii. Log Extraction: Extraction involves removing logs from the stump to a point where they are either loaded onto vehicles or are piled prior to removal or conversion. The logs, after delimiting at the stump, are skidded to a loading point where they are loaded on to 5000 Kg trucks, using winch-operated overhead cable system strung across the road. Lop and top cutting is carried out at stump, manually, immediately after logging. Slash and debris are usually left for collection as fuel wood. No pre-transport processing is carried out other than length-wise cutting to fit road transportation needs. No chemical treatment for preservation takes place and logs are usually not debarked before transportation (Olorunnisola 1997, Olorunnisola and Lucas, 2005).

Other forms of log extraction yet to be commonly employed in the country include the use of skidders and forwarders (Sanwo 1982a,

Olorunnisola 2007). Skidders are tractors which extract by lifting one end of the log clear of the ground and pulling it out with the other end dragging on the ground. Forwarders, on the other hand, are tractors which extract logs by lifting it entirely clear of the ground. Cable cranes, i.e., ropeway systems where timber is extracted by means of moving cables, powered by a stationary winch, and animals such as horses and elephants are not used.

iii. Terminal Operations: The two major terminal operations are loading and unloading of logs unto and out of trucks respectively. These are carried out in different ways. For loading, both manual efforts and the winch system are commonly employed. In the manual method, the truck is usually backed into a hole dug for the purpose so that the logs can be pushed onto its deck. In the winch system, a truck-mounted double-drum winch (with two wire ropes running through each bunk to a pulley on top of a stake) is common. Since relatively limited volume of logs are usually harvested per hectare, the tonnage handled on each landing is usually small. Mobility of the loading equipment is usually achieved by attaching loading equipment to the truck itself, e.g., bunks with built-in wires for winch loading.

The most commonly used method of unloading is side dumping sometimes into a river or water storage. This is done by driving the truck onto a side slope, unfastening the binders and letting the logs roll off the deck of the truck. This process is also sometimes accomplished with the use of winches. (In some cases, the logs are pushed sideways off the truck with a tractor). Both mobile and stationary cranes, and loading tractors are also used. FAO (1974) reported that loading and unloading using these methods normally takes an average of 30 to 60 minutes per load, but may reach 2 hours when both operations are manually performed.

iv. Log Pricing: To determine the purchase prices of logs, the volume of the individual log is obtained from tabulated values of log volume derived using the Hoppus method. The Hoppus String Measure, as it was originally termed, is also sometimes known as the Quarter Girth Method, the latter designation arising from its formula. It is a very old system dating back to the 1700s. Under this method, the girth (under bark, at the centre of the log) is measured with a tape. (When logs are not debarked it is necessary to cut away a ring of bark in order to measure the log. Occasionally, to avoid this an allowance is made for bark). The cubic content of the log is then calculated based on the formula:

$$G^2 \times 3/4L, \text{ or } \left(\frac{g}{4}\right)^2 \times \frac{L}{12} = \text{contents in super feet}$$

Where G = mean girth in feet, g = mean girth in inches, L = length in feet. (The imperial units are still widely used in the wood industry for this and similar calculations). The cost of individual logs is obtained by

multiplying the cost per cubic feet by the tabulated log volume. This method of measuring log volume is defective in that it does not take into account the following:

- The possibility that some inner portions of the log may have decayed. Thus, a log with internal defects, but which appears to be sound, is sometimes sold and purchased at the price of totally sound logs, to the disadvantage of the sawmiller who eventually obtains lesser lumber output.
- The moisture content of the log which affects the sawing process and the quality of lumber produced; and
- The shape of the log which also determines lumber output.

v. Log Transportation: Two means of log transportation are generally employed for conveying logs to the sawmill or elsewhere. These are water and road transportation. Water transportation is done largely in the riverine areas. It involves the use of locally built 37.5 KW (50 HP) petrol-engine-powered boats to convey the logs through rivers, lagoons and sometimes the ocean to the mills. Such logs (usually of relatively low density) are bound together in rafts, each being about 6 m³ in volume to form a long chain. (Rafts are either flat, one-layer affairs bound together by chains or pinned cross logs, or they may be enormous cigar-shaped seagoing structures to be towed by a tug). These are then attached to the boats for transportation. This method is usually cheaper and faster than road transportation. Losses due to sinking, battering, and scattering of the loose logs are some of the disadvantages of this method of log transportation (Olorunnisola 1997).

In the other parts of the country, logging can hardly be done without forest roads which are needed for transporting labour and material required for the extraction of the timber crop, and for transporting logs to the mill for conversion. Road transportation of timber in many parts of the country involves the use of timber lorries on which one, two or more logs are mounted, depending on their sizes. The logs are usually tied with a steel rope. Dense logs that cannot be transported on water but are located in places accessible by road are usually transported with this type of lorry. The cost of transportation depends on the travel distance, the size and the number of logs conveyed. Road transportation is generally more expensive than water transportation. It is also very hazardous because logs that are not properly secured could roll off the lorry, resulting in severe injuries to, and in some cases, death of other road users. Adequate training is required for people involved in the logging business in the aspects of log securing techniques and road-safety practices. Such training can help in reducing accident frequency and improving productivity (Olorunnisola 1997, Olorunnisola and Lucas, 2005).

Other means of log transportation that are in use in many parts of the world include the railway, helicopters, agricultural tractors and animals such as elephants and horses. Some of these means are however not practicable in Nigeria currently because of the nature of the natural forests and the level of technological development.

vi. Logging Waste Generation and Management: Logging wastes at the tree stump usually include rejected short logs (i.e., logs that are less than 4 m in length), branch wood, undersized logs from main bole or branch and sometimes butt logs which are rejected because of their irregular shapes. Logs are also often rejected when they are too large for handling by the headrig installed at sawmill. As noted by Sanwo (1982a), this approach to logging is extremely wasteful and the logging wastes can be considerably reduced with the use of proper equipment. Enabor (1992) reported that for many years, only about 10% of the volume of trees felled was extracted, the remaining 90% being left to rot in the forest. Another contributory factor to logging waste generation is the rapid deterioration of especially the low density timber species in the warm, humid rain forests due to the unavailability of requisite logging facilities (Lucas, 1983). This challenge can only be addressed with improved logging techniques

Saw milling

Saw milling is one of the oldest and most important wood processing industries in Nigeria. Its origin dates back to the eighteenth century when the invading Portuguese slave traders established a "pit-sawing" station in a bush somewhere in-between Yaba and Ebute-Metta in the then Lagos colony in 1782. The colonial government later took interest in the industry. This resulted in the establishment of government-owned "pitsawing" stations in places such as Etchetem in the Delta, Benin and Ondo, among others, between 1907 and 1937. Private participation in saw milling began with the establishment of the "Miller Brothers Sawmill" at Koko in 1909. Other investors later came into the business, establishing sawmills such as Oron Sawmills, Oron (1914) and the "United African Company" (UAC) Sawmill at Sapele (1925). There were about sixteen sawmills in Nigeria by 1939. This number had risen to twenty-one by 1946, (about one-third located in the Lagos colony); thirty-five by 1952 and about eighty by 1964. By 1974, there were about one hundred and ninety one sawmills in the Western State alone. As at 1999, there were over one thousand, three hundred sawmills in Nigeria, majority of which were privately owned small-scale enterprises, (NISER 1974, Olorunnisola and Lucas (2005).

The engineering aspects of small-scale sawmilling of significant importance include the following:

1. Sawmill Layout: Oluyide (1975) had noted that a vast majority of the small-scale sawmills in western Nigeria were erected without planning. Hence, to enhance sustainable lumber production in these sawmills, Olorunnisola (1999) developed the design specification for a model sawmill, including infrastructural outlay, optimum production pattern and organisational structure, maintenance policy framework, and a mill layout which could provide a better work flow for greater operational efficiency and close to 50% reduction in overall transportation cost. A set of computer programs for production planning in the mills was also developed by Olorunnisola *et al.* (1998).

2. Log Storage: Two methods of log storage are generally employed in all the small-scale sawmills. These are water storage and open-air, ground surface storage methods. Water storage is predominant in the riverine areas of Lagos, Rivers, Cross-Rivers, Delta and Edo states where sawmills are located close to relatively shallow water bodies. The water body through which the logs are conveyed from their sources of supply is also utilized as the storage medium. The duration of storage usually varies from just one day to as long as three or more months, depending on the rates of log supply and conversion. The logs are allowed to float in a partially submerged position with water covering only about one quarter of the entire body of the logs. This partial immersion pre-disposes the logs to fungi and insect attacks which subsequently depreciate both their utility and economic values. For better preservation the logs should be sprayed with preservatives to prevent decay, stains, and insect attack during storage. They should also be fully submerged in the shallow water to further inhibit the initiation of micro-organism-related activities. In general, water storage system reduces pressure on land as it releases more land for other activities of the mills (Olorunnisola 1997).

In open air storage, logs are usually stored on dry, bare ground, often times packed with sawdust pending their conversion into lumber. Such logs are usually not debarked. Deterioration, occasioned by microbial activities and fungi/insect attacks is therefore a little contained. Their abandonment to the vagaries of weather elements in the open air for several weeks however contributes to the development of end-checks, cracks and often times discoloration after prolonged exposure. The end checks and cracks are a consequence of the variations in the temperature and are intermittent stress build-up and release in the logs. For prolonged storage situations, proper practice requires application of pre-storage treatment measures such as surface coating and provision of sheds for protection against weather elements, and the provision of pilings on which the logs could be placed to prevent potentially destructive contact between such logs and the topsoil.

3. Sawmill Production: Small-scale sawmills in Nigeria typically operate a single shift of about 10 hours daily for six days in a week. The effective operating hours per week in these mills is about 60 hours, while average number of weeks worked per year is 35 weeks or eight months (i.e., mid-September to April when constant supply of logs can be guaranteed). Hence, the average number of hours worked per year is 2100, while the average number of days worked per year is 210. For the remaining 4 1/2 months, the employees are generally underutilized. The estimated average daily log input to each mill is about six cubic metres (Olorunnisola 1997, 1998, 1999, Olorunnisola and Lucas 2005). Most of the mills obtain their logs supply from either or both of two sources: Purchases from, or patronage of timber contractors, and concessions in government forest reserves. The mills that are serviced by timber contractors usually lack forest concession allocation and thus saw on contract at specific rates. A recent challenge is the dwindling supply of large diameter, mature trees with the attendant result of many sawmills either folding up or engaging in the conversion of small diameter lesser-used species as shown in Figure 3.



Figure 3: Small Diameter Logs Stored in a Small-Scale Sawmill for Conversion

In a bid to bring the benefits of modern productions management techniques such as simulation modeling and linear programming to the doorsteps of the small-scale sawmills in the country, a set of computer programs for production planning in the mills was developed by Dada (1985), Olorunnisola *et al.* (1998) and Olorunnisola (2002). A Linear Programming model was also formulated by Olorunnisola (2014) to determine an optimum log input mix to maximize the return from the conversion of small to large diameter logs to rough lumber in a typical contract-sawing small-scale sawmill in the country.

4. Pre-Sawing processes: In a majority of the small-scale sawmills, sawing is commenced with the cross cutting of logs to the required size, which often

times is 3.72m (12 feet). Manually operated cross cutting saws and chain saws are employed in performing this pre-sawing operation. The log to be sawn is then rolled up manually and positioned on the bandmill rail and clogged down firmly, using wooden pegs in place of mechanical dogs in readiness for sawing. The saw blade of the bandmill is then run through the log a number of times thereby sawing it into planks of required and specified thickness (es). The planks are removed manually as each one is produced to the lumberyard for storage.

In a number of sawmills, the bark is removed manually before the logs are sawn. This step in the manufacturing process is usually taken care of before the log is put on the carriage of the bandmill, usually in the log storage yard or an open space adjoining the mill. A major advantage of debarking before sawing is that it removes the hazards of sawblade damage by nails, stones, and other metallic materials that may be embedded in the sawlog. It also reduces the degree of exposure of the sawyers to mal-odorous exudates from the barks of some species (e.g., *Mansonia altissima*) during conversion (Olorunnisola 1997, Olorunnisola and Lucas 2005).

5. Sawing Machines: The French-made CD model series of horizontal bandmills are used for primary conversion of logs in most of the small-scale sawmills in Nigeria (Sanwo 1982b, Fuwape 1990, Udo 1990, Olorunnisola 2007). Other types of sawing machines employed include frame saws and circular saws. There are, however, stumpsite millers who convert roundwood in the forest using chainsaws. There are also sawmillers who engage in ripping and cross-cutting timber flitches obtained from the stumpsite operations into various sizes (Udo 1990). The three types of bandmills usually installed include the CD-4, CD-5 and the CD-6 models. Figure 4 shows the basic features of a CD-6 horizontal bandmill which are basically similar to those of the CD-4 and the CD-5 models. The classifications are based on the widths of the saw blade which are 4 inches (10cm), 5 inches (13cm) and 6 inches (15cm) for the CD-4, CD-5 and CD-6 models respectively (NISER 1974, Olorunnisola 1998, 2007). The log-handling capacities of the three models vary. This variation is based on the maximum diameter of log each of them can handle. The maximum log diameters are 1.2m, 1.6m and 1.9m for the CD-4, CD-5 and CD-6 models respectively. These machines are not really ideal for breaking down logs. The ideal machine should be stationary while the log is moved backwards and forwards mechanically.

The CD machines are also relatively light and cannot withstand for a long period of time the harder species of timber (Sanwo 1982b). This is one of the reasons for frequent breakdowns. They seem to perform quite well when converting softer woods but usually the quality of lumber produced is poor. The advantages of these machines, however, include simplicity of design and

operation and minimum maintenance requirements. FAO (1979) reported that the rate of return on investment in a sawmill employing a horizontal CD bandmill and operating one shift daily could be about 31% if the mill saws under contract and about 70% if the mill has forest concessions and undertakes its own logging operations.

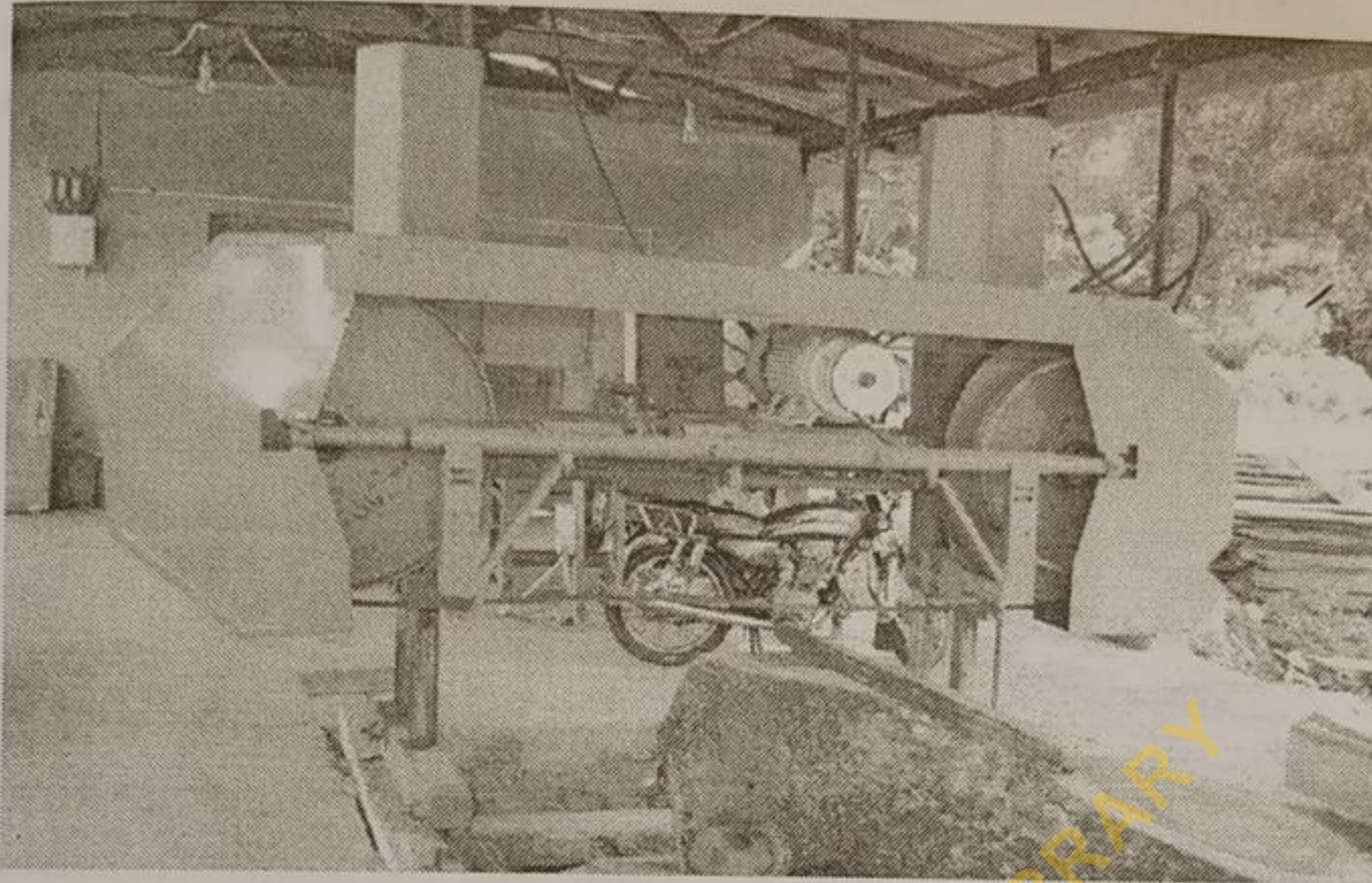


Figure 4: A Typical Horizontal CD Bandmill

Circular saws are used largely for lumber reconversion but also for primary conversion of small-diameter logs especially in the south-west. The circular saw is made up of a metal disc or blade with saw teeth on the edge as well as the machine that causes the disk to spin. They are table-mounted (i.e., bench-installed) as shown in Figure 5 and are used for crosscutting, edging and trimming of lumber in many of the small-scale sawmills. This machine is currently manufactured locally in Nigeria and thus it is relatively cheaper than the bandmill. It however has a disadvantage of producing larger saw-kerf (about 5 to 15mm) than the bandmills (about 3 mm) (Sanwo 1982b, Fuwape 1990, Olorunnisola 1997).



Figure 5: Lumber Reconversion on a Circular saw

6. Sawing Patterns

Sawing method refers to the pattern used to breakdown the log of various shapes and sizes into lumber. Some of the factors that determine sawing patterns include log species, sawing facilities, grade of incoming logs, customer's specifications (aesthetic and/or dimensional stability, however, generate different rates of lumber recovery. Different sawing methods, sawing patterns adopted in the small-scale sawmills are:

(a) **Live Sawing Pattern (or 'Through-and-Through')**: This is a method by which logs are cut into boards by a series of parallel saw cuts. Straight or nearly straight logs are positioned on the carriage with the best face towards the saw, using full taper set-out. The sawn boards are removed until the approximate centre of the log is reached. The logs are then turned 180° and sawn the rest of the way through. Thus, each log is turned only once. For a few logs containing sweep or crook, a slab is removed and the logs are turned to place the flat surface to the headblocks. The logs are then sawn in the same manner as straight logs. For those logs containing sweep or crook, two turns are required. First, a slab is sawn off one face. Then the log is turned 90° to place the flat face against the head blocks and sawn.

This is the most economical cutting method as it does not require any turning of logs or high skills in making cutting decisions. It is also the fastest timber conversion method and yields relatively higher volume recovery from relatively straight logs. Since the method does not take into account pieces of timbers with defects, it is lowest in value recovery. It is, therefore, not a suitable method for sawing crooked and/or large diameter logs, i.e., logs with diameters greater than 50cm. Also, the method results in generation of more wastes at the mill, the one by one removal of wany edges is difficult, and less attractive surfaces are produced.

(b) **Cant Sawing Pattern**: In this method of sawing, an attempt is usually made to first convert the logs into a rectangular form or block before proper sawing commences. The central cant that is produced has a selected thickness. This central cant is then turned 90° and sawn into boards. This results in a minimum of four setting of the log on the carriage during conversion. Cant sawing produces surfaces that are more attractive than those produced by live sawing. The lumber is also usually more dimensionally stable. However, several changes of carriage setting make it more challenging to undertake.

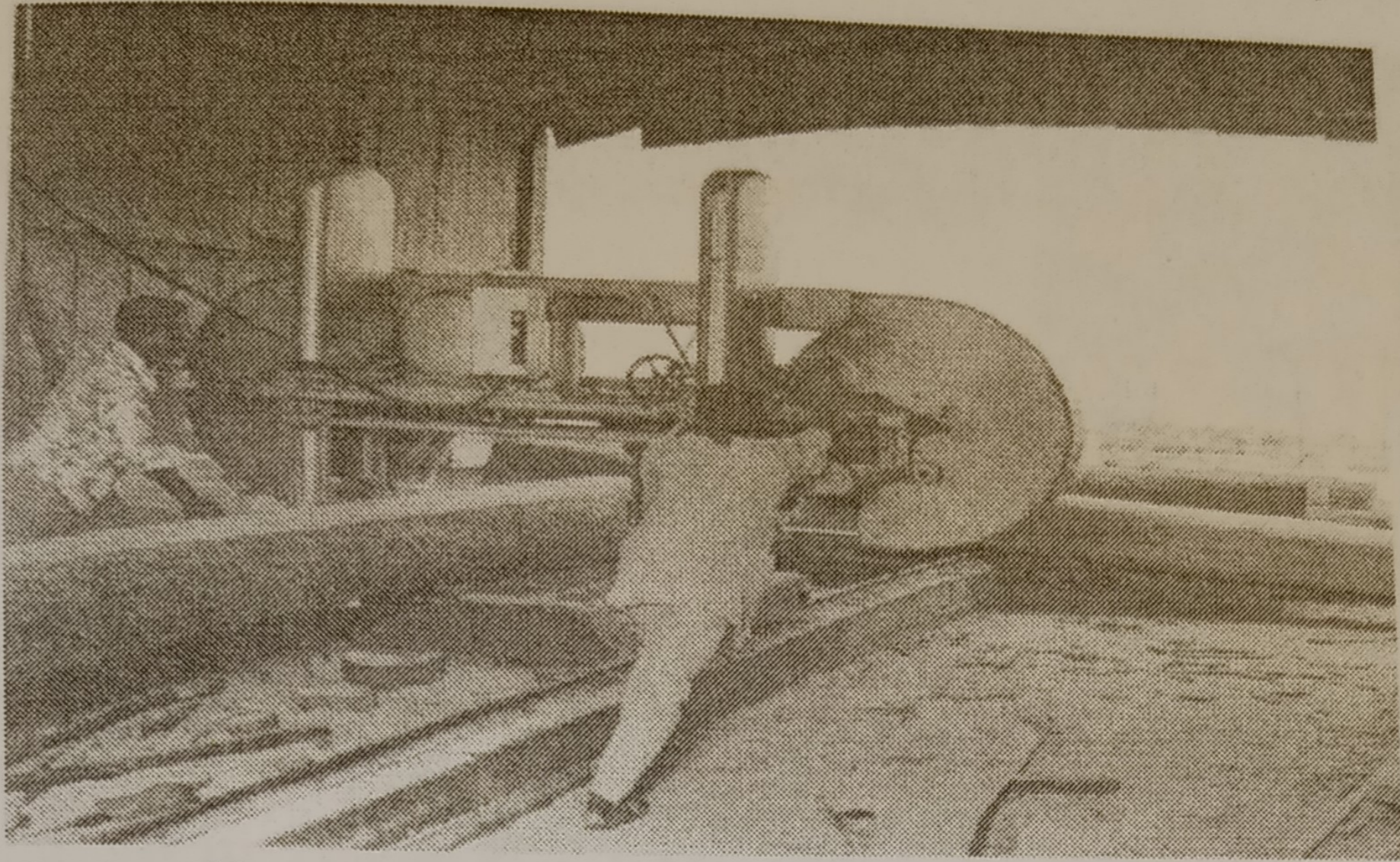


Figure 5: A Log being live-sawn

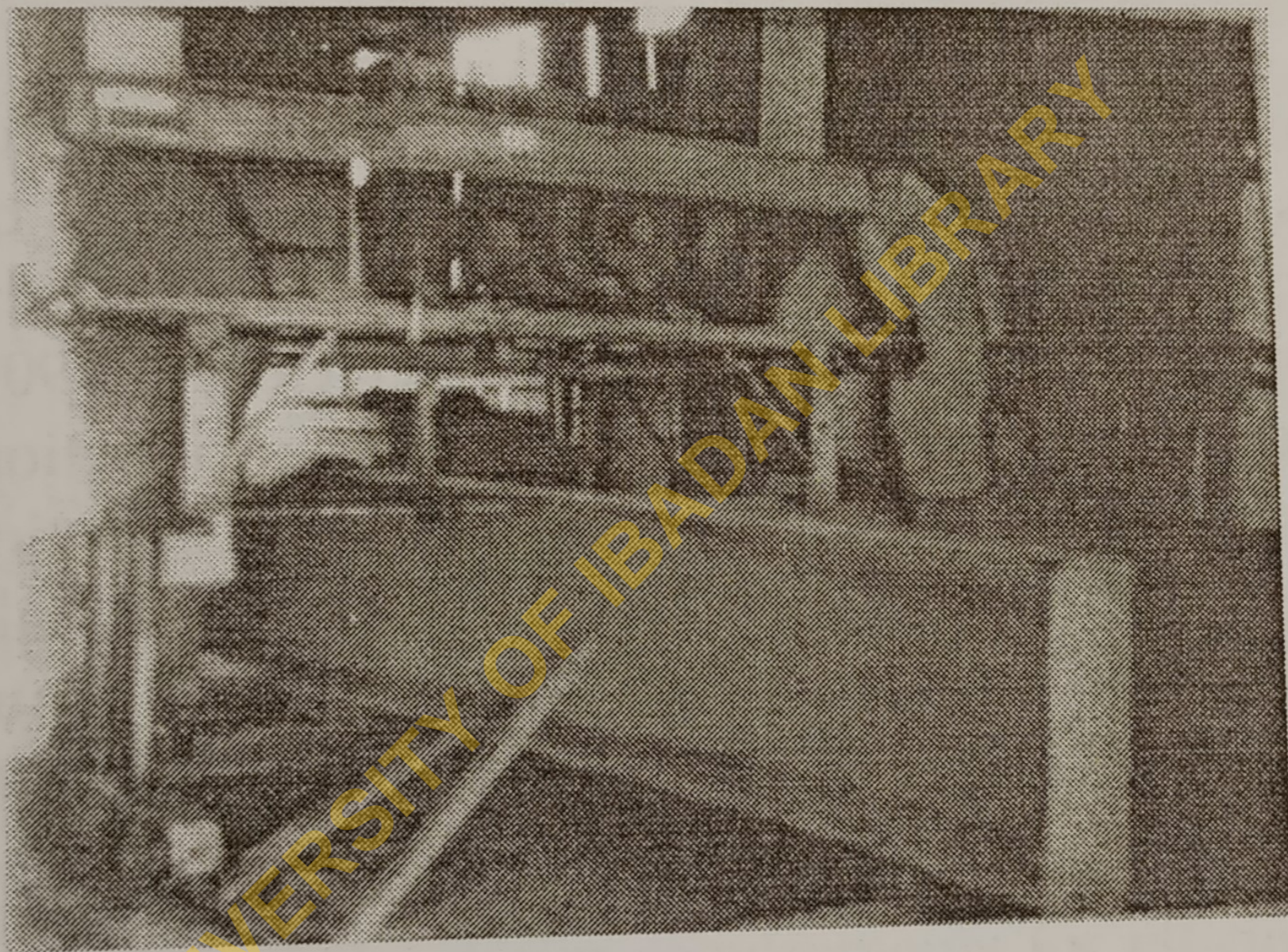


Figure 6: Cant Sawing in Progress

- (c) **Plain-sawing or "sawing around"** is a method by which logs are sawn such that the width of the lumber (boards) is tangential to the annual growth rings of the log. This method requires a lot of handling since the log being cut has to be turned into new positions as sawing proceeds. It, however, produces lumber with more attractive figure. It also ensures the separation of the less-durable sapwood portion of the wood from the more durable, and often times more attractive heartwood. A maximum amount of sound lumber can also be obtained from a defective or "knotty" log by this method.
- (d) **Quarter Sawing:** This is a method by which the lumber is cut perpendicular to the perimeter of the log. The boards produced usually have their widths in the general direction of the wood rays. Lumber cut in this manner tend to shrink less, twist or cup

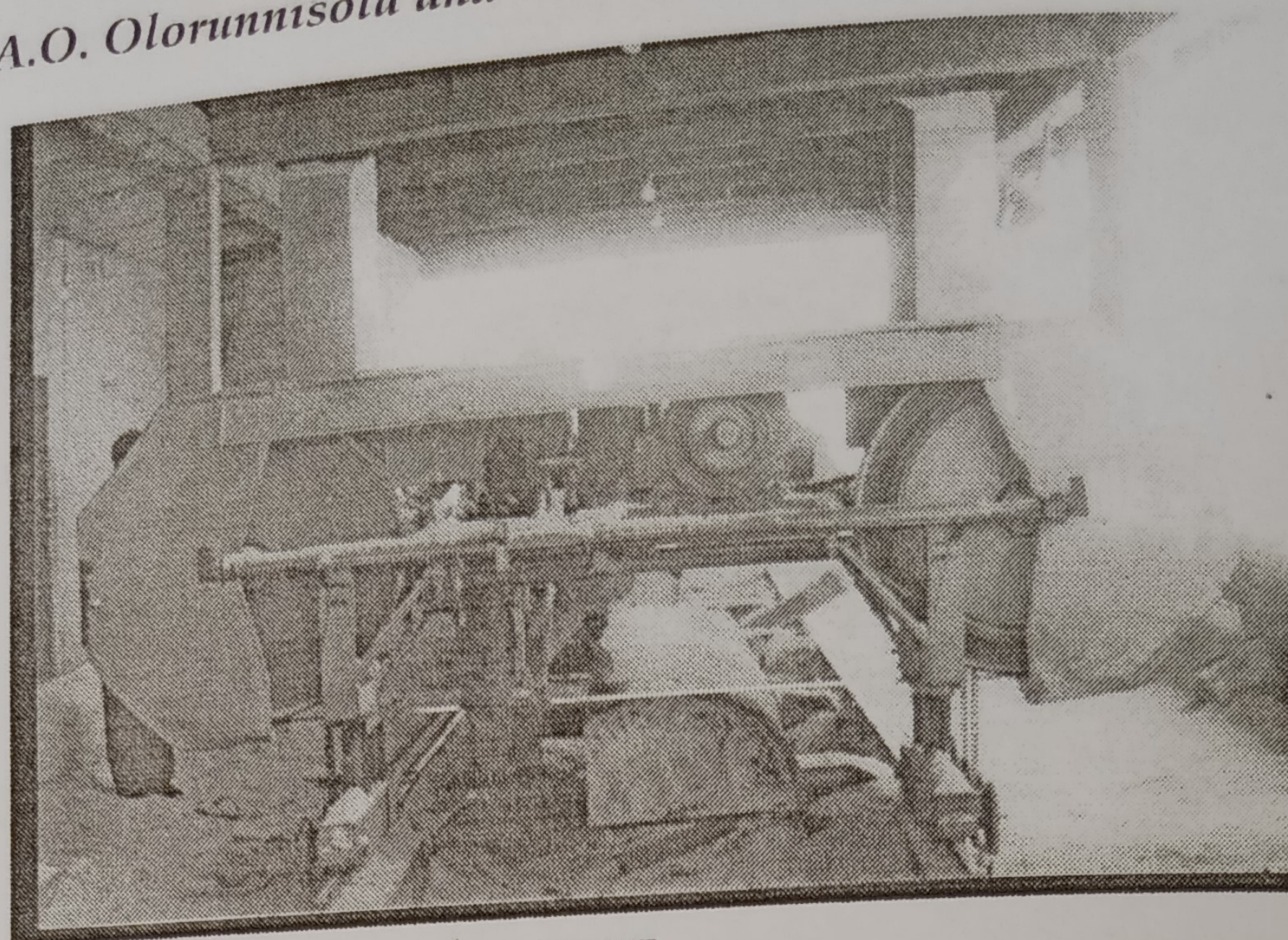


Figure 7: A log being quarter-sawn

less, and is relatively stiffer. Quarter sawing pattern helps to reduce growth stresses in logs, thus reducing warping. It produces the distinctive silver ribbon effect across the whole board. True quartered boards producing the best features will have the angle on or very much closer to 90° . It yields better value recovery compared to live-sawing and faster production rate compared to sawing-around method. It, however, has a lower production rate than live-sawing with a higher cost of production. The method also requires the services of a skilled and experienced head sawyer and the number of experts in this wise is diminishing. It is a more suitable method for cutting high graded logs.

Other log sawing patterns employed in modern sawmills but not commonly employed in these mills include:

- (a) **Quadrant sawing:** This log conversion pattern is highly technical and requires skill and expertise to carry it out. It is a four-sided sawing process during which the log is turned after each cut with 180° turns alternating with 90° turns until the central boxed heart is reached. Boxing the heart refers to eliminating the heartwood from the boards that would otherwise produce shakes, juvenile wood or may even be rotten. The prime concern is to avoid defects and to anticipate embedded defective locations if any. There is minimal waste generation; implying that it guarantees a high recovery value. The process is, however, very cumbersome, time and energy consuming.
- (b) **Radial Sawing:** In this method, timber is cut parallel to medullar rays and perpendicular to annual rings. Because of the cutting pattern, each piece of radially sawn timber is a wedge shape. It has sapwood on the wider edge and pith or core wood at the point. As real logs are not perfectly round and not perfectly straight, each radially sawn board reflects the longitudinal shape of the log. The radial method yields least shrinkage but with much wood wasted, limited rift is adopted. Greater decorative effect is obtained because medullar rays are pronounced. This

method is not very common, and if required would need special negotiation with the mill. However, radial sawing has an efficiency that the other cuts cannot possibly achieve, and makes optimal use of a log.

- (c) **Tangential Sawing:** This is a form of cutting of boards or planks sawn tangentially to annual rings. Planks cut by this method have a tendency to warp and are not suitable for flooring.

The entire sawing operation is crucial to the economic outcomes of sawmilling, and depends largely on the sawing method, the type of sawing equipment employed and the skill of the sawyer. The lumber recovery efficiency values based on wood species and conversion equipment employed are shown in Table 2. Fuwape (1990) also reported that the live Sawing Pattern gave a better lumber recovery factor than cant sawing pattern in small-scale sawmills in Ondo State. He, however, also highlighted the challenge low technical education of the sawyers. Conversion planning decisions involving the determination of both the appropriate opening face and the optimum sawing method have been automated in modern sawmills elsewhere. However, here in Nigeria, they are still left to the judgments of the sawyer, who in turn, relies solely on intuition and past experiences. It is therefore usually difficult to predict with sufficient accuracy the lumber yield from the conversion of any given log since this depends on the experience of the sawyer involved (Olorunnisola 2007). In an effort to address the situation, Lucas (1985) developed a computer program for determining the BOF in a typical small-scale sawmill.

7. Saw Doctoring: One of the major requirements for efficient sawmilling is saw doctoring, i.e., the maintenance of the sawing machines. The routine saw reconditioning and repair operations usually performed in small-scale sawmills include saw sharpening, straightening, tensioning, leveling (i.e., removal of ridges and dents in the saw), spring- and swage- setting, end-joining, and twist removal. The non- or poor performance of these basic operations usually creates negative effects on saw milling efficiency by curtailing the log conversion efficiency and causing substantial increases in avoidable wood waste generation (Sanwo 1982b, Akande 1993). Olorunnisola and Oyelami (1997) and Olorunnisola (1997) reported that though level of illiteracy amongst the sawyers and sawdoctors in selected sawmills in Ibadan and at Ebute-Meta, Lagos, was relatively high, many of these categories of skilled workers lacked access to proper and structured training largely due to the absence of sawmilling training centres in the country. One of the observed consequences of this situation was the poor log conversion planning resulting in relatively low average lumber recovery of about 58%- an indication of high level of wood waste generation. This was a justification of the call for a paradigm shift in the unstructured approach to the training of sawmill operators in the country.

8. Mill Maintenance: "Corrective or breakdown maintenance" is commonly adopted in most of the small-scale sawmills (Olorunnisola 2007). The conversion machines are used to the breakdown point before emergency measures are adopted to put these back to working condition. There is usually no prepared maintenance policy document. Maintenance planning is therefore not usually done. Preventive maintenance involving the regular or periodic check and servicing of the sawing machines, tools and other facilities used in the production process is not in practice. Only minimal routine equipment maintenance involving lubrication of rotating parts and rail track leveling is done. There is no sawmill maintenance mechanic on the staff list in many mills. Thus, the severity of any breakdown, particularly of the bandmill, is usually very high.

Table 2: lumber Recovery Efficiency (LRE) Values of Different to Sawing Machines

S/No	Reference	Log Species Converted	Conversion Machine	LRE (%)
1	NISER, 1974	Not specified	Horizontal bandsaw	40-45
2	Fuwape, 1990	Mixed species	Horizontal bandsaw	56
3	Akande, 1993	Not specified	Horizontal bandmill	60
4	Udo, 1996	Mixed species	Chainsaw	46
5	Tom & Tharian, 1996	Rubberwood	Horizontal bandsaw	35-40
6	Tom & Tharian, 1996	Rubberwood	Gangsaw	62
7	Damodaran, 1996	Not specified	Bandsaw	46

9. Lumber grading and Marketing: Visual lumber grading methods are employed in the small-scale mills across the country (Olorunnisola 2007) whereby visual selection, involving the separation of apparently "good" from the "good rough" and the "bad" lumber pieces is done. The "good" lumber piece is one free from decay, knots, splits and similar major defects on either side of its faces. The "good rough" piece may have few defects but not as much as to greatly impair its end-use for structural purposes. The "bad" pieces are highly degraded and are usually either discarded or sold off to carpenters or fire wood sellers at reduced rates. This method of grading is very subjective. Lucas (1981) developed a quality control system for the industry which is yet to be adopted today, almost thirty-five years later.

Most of the small-scale mills saw mainly for the local market. Some of them are, however, also involved in export business. The average sawing rates charged for sawing different log species usually varies with the wood species and the degree of difficulty encountered in sawing them. The prices of the different dimensions of lumber are usually based on factors such as the popularity and the utility value of the wood species, the cost price of the log, the quality of the lumber, the season, i.e., either rainy or dry season, and the location of the mill.

Species such as *Terminalia superba*, *Entadrophragma candollei*, *Entadrophragma cylindricum*, *Khaya ivorensis*, and *Nesogordonia* species usually attract higher sawing and selling prices while other species such as *Azalia africana*, *Ceiba pentandra*, *Louoa trichilioides*, *Triplochiton scleroxylon*, *Pycnanthus angolensis*, *Khaya senegalensis* are usually the cheapest in terms of conversion charges and lumber selling prices. The "profit maximization" form of marketing strategy is adopted in all the mills. However, "cost-oriented pricing" and "perceived value" pricing procedures are adopted in the contract sawing and log-purchasing, lumber-selling mills respectively.

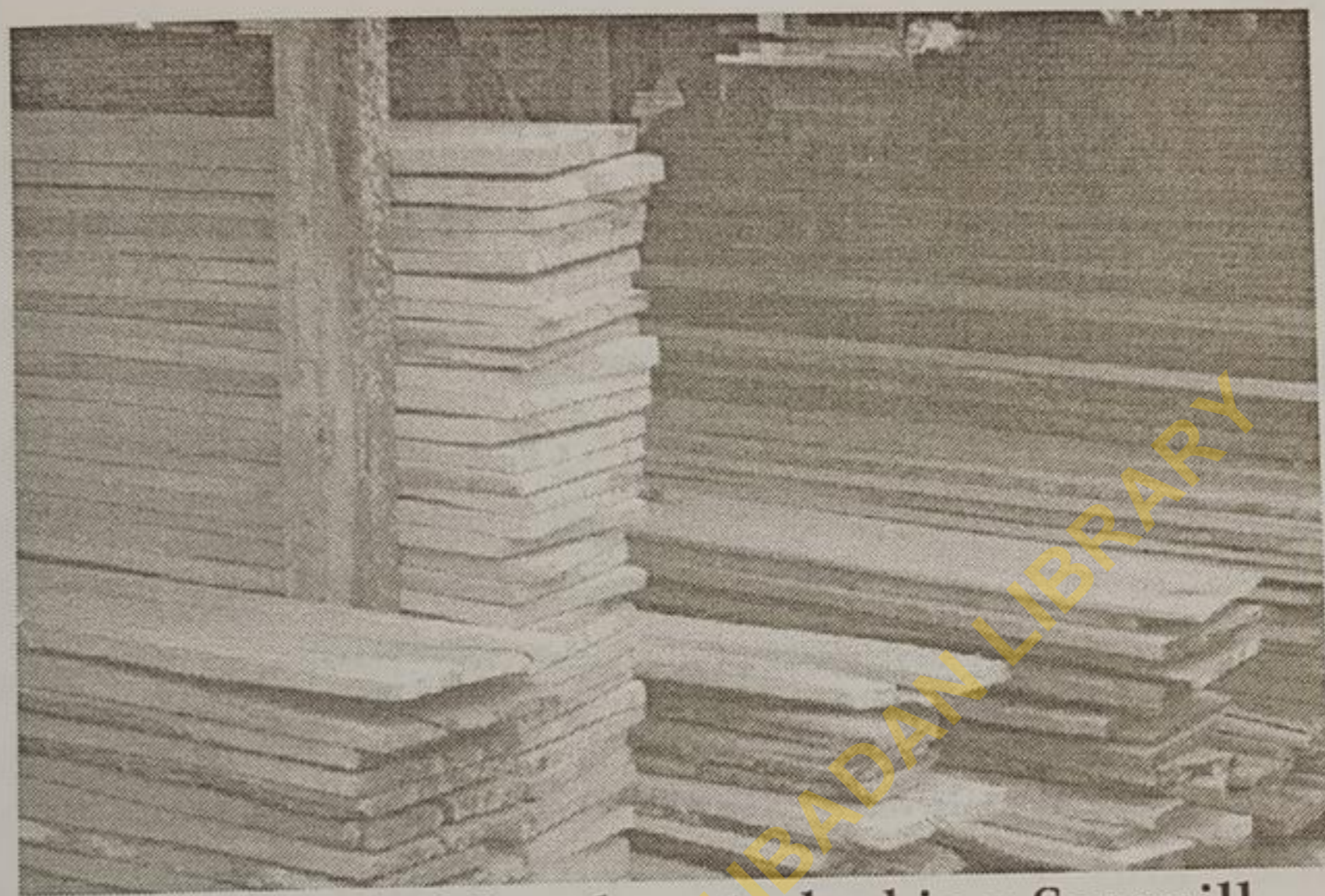


Figure 8: Visually-Graded Lumber stacked in a Sawmill

One of the major end-use problems created by the small-scale sawmills is the adoption of rigid customary timber sizes which are mainly in the one cubic foot (0.027 m^3). Hence, typical sizes converted include $25 \text{ mm} \times 300 \text{ mm} \times 3.6 \text{ m}$, $50 \text{ mm} \times 75 \text{ mm} \times 3.6 \text{ m}$ and $50 \text{ mm} \times 150 \text{ mm} \times 3.6 \text{ m}$. The adoption of this customary sizes results in considerable wastage of wood by the end users who have to purchase such typical sizes even when they requires lesser quantity of timber (Sanwo 1982a). The "market segments" for the mills are undefined since their customers are non-homogeneous but the products are homogeneous, that is, there is no form of product differentiation. Virtually none of the mills feels the need for advertisement or sales promotion. Rather, the personal selling method of promotion prevails (Olorunnisola 1997).

The customers usually perform physical distribution, involving lumber transportation out of the mills, as most of the mills do not have the vehicular means of lumber transportation. The customers in this sense include private individuals, carpenters, furniture makers and other similar wood-users, corporate bodies, etc. Plank sellers, who often act as intermediaries between the lumber-selling mills and their customers often times take over this marketing function (Olorunnisola 1997, 2007). As noted by Sanwo (1982a), the marketing chain of sawnwood from the forest to the

consumer needs to be reduced in terms of the number of intermediaries involved.

10. Waste Generation and Management: The two major types of wastes are generated in the small-scale sawmills are:

- Wood wastes including barks, slab, off-cuts and mis-manufactured lumber and sawdust.
- Metallic wastes including metal dust and chips, worn-out or damaged saws, and similar materials emanating from the saw doctors' workshops.

About 33,000 m³ of slabs, 46,000 m³ of bark and 31000 m³ of sawdust were being generated annually in the small-scale sawmills in Lagos State alone. Sawdust evacuation is a particularly difficult problem for many sawmills. Though most of the sawdust constitutes unavoidable waste, the volume could be reduced if the bandsaw is well sharpened. Vast quantities of the material is usually left at generation site where constitutes a great hindrance to the free movement of the bandmill on its track rails, fire hazard and an agent of log and lumber deterioration. In the absence of protective masks, sawmill workers' exposure to sawdust often results in health problems, especially when species such as *Drypetes paxii*, *Piptadeniastrum africanon* (Dahoma) and *Erythrophleum spp.* (Erun) which have irritant sawdust are converted (Udo, 1990).



Figure 9: Dumped Wood Waste

There is also virtually no local small-scale sawmill that has dust extraction systems (hoods, cyclone fans, et c.) for waste evacuation. Rather, the labourers usually pack the sawdust at random with the aid of shovels into jute bags for disposal. This system is grossly inefficient as it takes about 30 minutes to evacuate sawdust produced from a day's operation (Olorunnisola 2007). The operation itself is usually done perfunctorily.

Disposal of sawdust into water bodies in many sawmills such as those in Ebute-Metta has resulted in extensive water pollution. This water-borne pollutant and the decomposing sawdust left un-evacuated at site produce putrefying odours which make the entire environment a source of health hazard.

Bark, slabs, mis-manufactured lumber pieces and off-cuts are also usually dumped behind the machine shed and other locations in the mills. They are left at these locations until they could be sold off to carpenters, furniture makers, and firewood sellers. Those that cannot be sold are left to rot away thus adding to the stench emanating from the sawmills. The development of secondary wood processing industries that can utilize saw milling waste products is required in transforming the bulk of the bark and saw dust being produced into more competitive products.

Conclusion

A technical review of the timber harvesting and sawmilling sectors of the wood products industry in Nigeria has been conducted. Despite the fact that the two segments have survived many challenges that have led to the demise of other segments of the sector, it is quite obvious from this review that many of the harvesting and sawmilling operations in Nigeria are yet to benefit from modern technology.

References

- Akande, J.A. 1993. Potentials for Growth and Development of the Nigerian Sawmilling Industry. *The Nigerian Journal of Forestry* 23 (1&2): 85 – 90.
- Badejo, S.O.O. 1980. Quantitative and Qualitative Survey of Generated Wood Residues in Lagos State. Paper presented at the 12th Biennial Conference of the Science Assoc. of Nigeria, Univ. of Ife, Ile-Ife, Nigeria July 20-26, 1980.
- Beak 1999. Forest Resources Study, Main Report. A Commissioned Report submitted to the Federal Department of Forestry, Abuja, Nigeria by Beak Consultancy.
- Dada, S.A. 1985. The Potential use of Simulation Modelling as a Management Tool for the Nigerian Sawmill Industry. *The Nigerian Journal of Forestry* 15 (1&2): 3 – 8.
- Damodaran, K. 1996. Technology for Sawing Small Diameter Hardwood Logs. *Wood News* 5(4):34-39.
- Enabor, E.E. 1992. Deforestation and Desertification in Nigeria: The Challenge of National Survival. In *University of Ibadan Inaugural Lectures, Vol. 1 (1992 - 1997)*, 1- 24.

- Fuwape, J.A. 1990. Assessment of Log Conversion Efficiency in Some Sawmills in Ondo State. *The Nigerian Journal of Forestry* 20 (1): 27 – 30.
- Lucas, E. B. 1981. The Design of a Quality Control System Applicable to Tropical Hardwood Lumbers. *The Nigerian Journal of Forestry* 9 (1&2): 35 – 43.
- Lucas, E.B. 1983. Factors Preventing Wider Commercialization of Nigerian Trees. *Forest Prod. J.* 33(5):64-68.
- Lucas E. B. 1985. Improving Lumber Recovery from Live-sawn Logs in the Nigerian Sawmill Situation Using a Computer Program. *Nigerian Journal of Forestry.* 12(1&2): 27 – 39.
- Lucas, E.B. and Olorunnisola, A.O. 2002: Wood Processing and Utilization in Nigeria: The Present Situation and Future Prospects in: Ajav, E.A., Raji, A.O., and Ewemoje, T.A. (Eds) *Agricultural Engineering in Nigeria: 30 Years of University of Ibadan Experience*, Published by the Department of Agricultural Engineering, University of Ibadan, Nigeria. Pp. 98 – 109.
- NISER 1974. A Report on the State of the Sawmilling Industry in the Western State of Nigeria, prepared for the Western State Ministry of Agric. & Natural Resources by NISER Consultancy Services Unit. 39pp.
- Olorunnisola, A.O. 1997. The Structure, Practices and Modelling of the Sawmilling Industry at Ebute-Metta, Lagos State, Nigeria". Ph.D. Thesis, University of Ibadan.
- Olorunnisola, A.O. and D.O. Oyelami 1997. An Appraisal of Sawdoctoring Personnel and Facilities in Selected Sawmills in Ibadan, Oyo State. *The Nigerian Journal of Forestry* 27 (1): 28 – 31.
- Olorunnisola, A.O. 1998. An Appraisal of Bandmill Capacity Utilization in a Small-Scale Sawmill. Proc. Nigerian Institute of Industrial Engineers Productivity Conference. 1:24 – 36.
- Olorunnisola, A.O., Lucas, E.B. Oluleye, A.E. 1998. A Computer Program for Production Planning in the Small-Scale Sawmilling Industry in Nigeria. Proc. Nigerian Institute of Industrial Engineers Productivity Conference 1: 195 – 209.
- Olorunnisola, A.O. 1999. Facilities Re-Design for a Lumber Manufacturing Firm. Proc. Nigerian Institute of Industrial Engineers (N.I.I.E) Manufacturing Conference. 1:24 – 36.
- Olorunnisola, A.O. 2002. Monte Carlo Simulation Modelling of Log Conversion Operations in a Small Scale Sawmill *Journal of Tropical Forest Products* 8(2): 1 – 7.
- Olorunnisola, A.O. and Lucas, E.B. 2005. Sustainability of Forest Industries in Nigeria: A Case Study of Ebute-Metta Sawmills, Lagos State. Proc. Annual Conference of Forestry Association of Nigeria. Held in Kaduna, Kaduna State, Nigeria. 30: 304 – 312.
- Olorunnisola, A.O. 2007. A Characterization of the Small-Scale Sawmilling Industry in Nigeria. A Paper presented at the 2007 All IUFRO All

- Division 5 (Forest Products) Conference held at the Grand Hotel, Taipei, Taiwan, October 29 – November 2, 2007.
- Olorunnisola, A.O. 2013. Harnessing the Forester's Harvest for Sustainable Development. An Inaugural Lecture delivered on May 16, 2013, published by the Publishing House, University of Ibadan, 102 pp.
- Olorunnisola, A.O. 2014. Linear Programming Approach to Optimization of Log Input Mix In a Small-Scale Contract-Sawing Sawmill In Nigeria. A Paper presented at the 68th Forest Products Society International Convention, held at Quebec City Convention Centre, Quebec, Canada, August 10-14, 2014.
- Oluyide, A.O. 1975. A Critical Analysis of Sawmilling Industry in the Western State. A Paper Presented at the 6th Annual Conference of Forestry Association of Nigeria, held in Calabar, December 1-6, 1975. 14pp.
- Sanwo, S.K. 1982a. Wood Utilization in the Small-Scale Sawmill in Nigeria. *The Nigerian Journal of Forestry* 12 (1): 55 – 57.
- Sanwo, S.K. 1982b. An Evaluation of the Performance and Efficiency of Small-Sized Sawmill in Oyo State, Nigeria. *The Nigerian Journal of Forestry* 12 (2): 16 – 23.
- Tom, J. and Tharian, G.K. 1996. Primary Processing of Rubberwood in Kerela, Report of a Sample Survey. *Wood News* 5(4):39-43.
- Udo, E.S. 1990. Ergonomics of the Sawmilling Industry in South-Eastern Nigeria. *The Nigerian Journal of Forestry* 12 (1): 55 – 57.
- Udo, E.S. 1993. An Assessment of Lumber Recovery Efficiency of Portable Chainsaws in Cross River State of Nigeria. *Nigerian Journal of Technical Education* 13(1&2):125-130.