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Increasing Utilization Efficiency and the Reduction of Losses and Waste Throughout the Production Chain

Final Report

Prepared for ITTO

by

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Executive Summary

ITTO PRE-PROJECT PPD 24/99 (I) Increasing Utilization Efficiency and the Reduction of Losses and Waste Throughout the Production Chain

Report on the Review, Survey and Assessment of Information and Data

Introduction: In accord with an agreement with the International Tropical Timber Organization consultants, John I. Zerbe and John R. Erickson with assistance from Robert J. Ross and Xiping Wang conducted a study on wood utilization efficiency and reduction of losses in lumber and plywood manufacturing plants in three tropical countries. The study underway from June 15, 2000 to September 15, 2000 involved an extensive review of the literature, and a survey of mills in Ghana, Malaysia, and Brazil.

The literature review covered study and abstracting of 179 publications. The mill survey consisted of mailing questionnaires to sawmills, plywood manufacturing plants, sawmill associations, and plywood manufacturing associations in the three representative countries and site visits to mills in the three countries.

With the data from the literature search and the survey, an analysis was conducted to determine the efficiencies in sawmilling and veneer and plywood production; technologies to reduce and use waste in the lumber industry; technologies to reduce and use waste in the veneer and plywood industries; policies, practices, measures, and technologies which influence utilization in sawmilling and veneer and plywood manufacture; and advanced technologies and practices in developed countries which may not be as prevalent in sawmills and veneer and plywood manufacturing plants in developing countries.

Major factors considered for influencing efficiency in sawmilling were obsolescence, breakdown of equipment, and shortage of spare parts; timber cutting regulations, land use planning, and enforcement; controlling personnel performance; cooperative ownership of logging and sawmilling operations; taxes and subsidies; national, regional, or local harvesting codes; prohibition of log exports; reduced impact timber harvesting; impact of debarking on residue utilization; plantations; infrastructure; control of insect infestations; increasing demand for lesser-used species; integrated forest products manufacturing; and training.

Major factors considered for influencing efficiencies in veneer and plywood manufacture were some of the same as those in sawmilling, i.e., obsolescence, breakdown of equipment, and shortage of spare parts; timber cutting regulations, land use planning, and enforcement; taxes and subsidies; national, regional, or local harvesting codes; prohibition of log exports; reduced impact timber harvesting; plantations; infrastructure; increasing demand for lesser-used species; and integrated forest products manufacturing. Also considered as influencing plywood manufacture was the shift from plywood to structural flakeboard production.

Conversion Efficiencies in Lumber Production: Yield calculations vary depending on countries, species, final product configuration, size and moisture content, nominal as contrasted with actual size, and different scales for calculating volumes in logs for processing. Log size, crook, and taper are other factors that cause differences in scaling log volumes.

In some cases characteristics of tree or wood use may influence yield. For instance, wood from rubber plantations is from trees grown for rubber production, with less attention to value of logs for products. With current plantation management methods, most of the wood is small diameter and of irregular shape. Where inappropriate tapping methods have been used the value of the first log, which usually is the most valuable, is reduced. It may even have to be discarded because of too low yield in processing to justify transportation to the mill site. The existing rubberwood using industries were often originally built to make use of large logs. This, together with poor log quality largely explains why rubberwood sawmilling suffers from low recovery rates.

Cubic scales as used in most countries are usually more consistent than scales based on board feet as in the U.S.; but, cubic measurements can vary because of different log scales being applied and differences in trees such as fluted boles which are characteristic of some species.

Sometimes yields in tropical countries are quite high, up to 59% and 61% as was reported for kane and khaya in Africa. In another ITTO project in Ghana it was found that the yield of main and by-products from four wood species ranged from 44 to 50%. The mean recovery rates were 44.1% rough green lumber, 4.3% by-products, 6.2% sawdust and 45.4% solid residues (such as boards for packaging, skids, stickers, second grade lumber, slabs, offcuts, edgings, etc. The total yield for wawa (43.7%) was significantly lower than the other three species (49.3 to 50.5%). The low recovery rate for wawa was due to the lower grades of logs used. They had heart rot and felling defects, and also longer storage periods in the mill.

Questionnaire results from Ghana only reported a yield factor of 35%.

Sawmills visited in Ghana had variable product yields. One mill reported 30-40% for teak and 50% for cedrela. Another mill reported a 50% recovery factor,

Malaysia also reported some fairly high recoveries, but wastage also is high. Recovery in the industry was stated to be about 54.5% on the average with Peninsular Malaysia showing a recovery rate of 55.6%, Sabah with 52.9% and Sarawak 45.7%. About 77% of the saw timber is produced in Peninsular Malaysia, 17% in Sabah and about 6% in Sarawak. The sawmilling industry has long been established but there has not been much re-investment and modernization within the industry. As a result mills are relatively small by international standards. There is a low degree of automation and the methods used for sawn timber handling are designed for labor-intensive operation. Quality and consistency of output are necessarily affected while the precision-cut raw materials required by the molding and furniture industry can not always be met. Wastage is therefore quite high throughout the industry.

Another study reported lower yields in Sabah. Logs of Sawmill Quality and Millable Quality produced lumber with mean recovery rates of 30 and 23% respectively.

A host on a site visit in Sabah stated a 50% recovery for lumber. The owner of a small sawmill in Peninsular Malaysia that produced rough sawn meranti claimed an 80% recovery. This may have included blocks and short pieces of product yield that were sold to furniture plants for use in finger-jointing.

In Brazil Flosull Madeiras of Capivari do Sul in Rio Grande do Sul, a eucalyptus lumber producer, has 3 lines that convert about 7000 cubic meters of logs per month (1.55 million board feet) to 2700 cubic meters of lumber (1.15 million board feet). This corresponds to a recovery factor of 38.6%. In correspondence with another small sawmill owner in Rio Grande do Sul, he reported a requirement of 4 to 4.5 steres of logs to produce 1 cubic meter of lumber. This is a low yield, but it was from a small circular sawmill that cuts small pine logs.

On site visits, another sawmill in Curitiba stated a recovery of 30 to 33% for softwoods and 40% for hardwoods. A small sawmill close to Belem in the Amazon area of Brazil
stated having a recovery factor of 45% to 50% for rough lumber, but by using waste from this operation to produce garden stakes the owner was able to raise the total yield factor to 60%.

<u>Conversion Efficiencies in Veneer and Plywood Production</u>: One area that is fruitful for improving yields in both rotary-cut and sliced veneers is in bucking veneer logs to length. Crosscutting volume losses amounted to 8.0 percent in a mill in Ghana and 3.2 percent in a United Kingdom plywood mill.

In Ghana, the total recovery figures for sliced veneer varied from 23 to 35% for asanfena, while that of makore was about 39%. The wide variation in yield of asanfena was due to the variation in log/billets diameters. About 21% of log input volume was lost during the clipping of dry sliced veneer. Losses due to drying of the veneer were about 6%. Based on the two species investigated, about 32.3% of sliced veneer for export and 3.5% of local grade veneer were recovered in addition to some 7.2% of flitch boards (which are marketed locally as by-products or used in the manufacture of pallets). The solid residues include 15.2% of flitching waste (which is the solid residue of slabs, offcuts, edgings, etc.) 15.9% of veneer sheets and veneer pieces, and 20.7% if veneer clippings. The flitching wastes are sold as firewood or used at the mill to fire the boiler, while the veneer sheets or pieces of veneer sheets are incinerated. An invisible loss of about 6.2% representing drying and/or shrinkage is also estimated. The yield of wet rotary veneer ranged from 52 to 77% with a mean yield of about 60%. The quality and grade of the logs greatly influenced the yield. Rounding off residues amounted to about 17%, wet clippings about 8%, and residual peeler core about 15%. Residual peeler cores of mixed redwood species of 30 cm diameter were sawn into lumber for export and the local market.

In site visits in Ghana, one plywood plant reported a 50% recovery; but, it was only that high, because the input logs were of large diameter. A large core was left after peeling.

Another plant in Ghana that makes sliced veneer reported a 50% recovery.

In Malaysia, the plywood industry, the average intake capacity of Malaysian mills is 57,000 cubic meters per annum and the output produced is about 25,700 cubic meters giving a recovery of about 45%. However there are several new mills in Sabah and Sarawak twice as large or more than those in Peninsular Malaysia, which should have enhanced significantly the rate of recovery.

In a site visit in Sabah one plywood mill reported a recovery of 50%,

In a site visit to one producer in Brazil it was reported that the recovery factor for cutting veneers in the North is 60%. For the plywood operation in the South it is 45%. But with steaming for some of the supply the recovery is raised to from 55% to 60%. They could get 85% recovery if they were to use Parana pine which is nice and round.
They could cut to smaller cores in the South and improve recovery. However, going to smaller cores means reducing veneer quality, and they have to discard about 2/3 of the increased volume.

Another producer in Curitiba, Brazil reported manufacture of veneer results in about 33% waste, and conversion of veneer to plywood results in a 25% loss of material in the process. Eighteen mm thickness in plywood lay-up results in 15 mm plywood final product thickness because of compression.

One plywood plant in Northern Brazil peels boles to remnant cores which are about 8” in diameter, but these cores are used to saw lumber for pallets.

In response to our survey questionnaire the Brazilian Association Mechanically Processed Timber – ABIMCI stated the following yield factors: from log to veneer about 55%; from log to plywood about 40%; and from veneer to plywood about73%.

Technologies to Reduce and Use Waste in the Lumber Industry: Improvements to increase recovery from logs have included better scanners to measure log size and shape, computer control for optimum log breakdown based on the best opening face (BOF) concept; saws with thinner blades; longer wearing teeth; better guides to reduce kerf and sawing variation; and more closely controlled drying using improved moisture sensing and removal to reduce energy use and lumber degrade.

A modeling analysis yielded the following results: For small sawmills with current levels of technology, kerf of 0.280 inch was assumed, reflecting the use of heavy circular saws. Dressing allowance was assumed at 0.119 inch. Large mills with current technology typically achieve head saw kerf of ~0.200 inch, resaw kerf of ~0.175 inch, and dressing allowance of 0.114 inch. With current best technologies, it is believed that head saw and resaw kerfs of 0.120 inch can be attained. The use of thin rim circular saw blades for resawing cants for pencil slats has resulted in kerf as low as 0.051 inch. For future technology levels kerf is projected to fall to 0.110 inch, but because of the replacement of planing by touch sanding for board finishing and greater control over sawing variation, dressing allowance is projected to fall to 0.063 inch.

New structural wood products such as wood I-beams and laminated veneer lumber can be manufactured from smaller lower grade timber and yet achieve superior strength.

Computer controlled bucking systems should reduce problems with sweep and crook. Some parameters of an optimized bucking system are 1) debark before bucking, unless scanner can accurately measure under bark log diameter, 2) diameter and sweep scanning be accurate to at least 0.4 cm, 3) length be accurate to 2 cm, 4) logs do not bounce, slide, or roll while being scanned. 5) nominal two-foot spacing be used for transverse bucking systems, 6)hardware be capable of operating in adverse mill conditions, 7)self-diagnostic capability be built in for the computer and scanning systems, 8)lumber output for log segments be determined accurately and classified by diameter, sweep, taper, and length, 9)butt ends be manually squared before scanning or be optimally squared by the scanning system, 10)lumber prices and operating costs be specified accurately, and 11)log trim allowance be reduced to near the minimum required.

Curve sawing is a new technique that is applied in North America to gain greater yield from logs having some crook. It is especially important in sawing small diameter logs. It was being applied very simply through hand feeding logs at the Papan Jaya Sdn. Bhd. Sawmill in Kuala Lumpur, Malaysia.

Important ways of using smaller pieces and lower grades of of lumber include manufacture of finger-jointed lumber, blockboard, packaging and dunnage material, and pallets. In some cases, residue wood can be chipped and used in paper manufacture. Wood in various forms may be used as fuel in the sawmill or sold for other applications such as boiler fuel and application in brick or lime kilns or cement manufacturing.

Technologies to Reduce and Use Waste in the Veneer and Plywood Industries: The veneer and plywood industries have some ot the same opportunities for using wastes as the sawmilling industry. Cores from rotary peeling may be a source of lumber for pallets and packaging. Or cores may be chipped and used for other purposes including fuel. Veneers may be used over blockboard cores or to cover finger joints.

In Brazil mills often pointed out log storage, peeling, drying, and gluing difficulties, as deterrents to the increase of species processed for veneer and plywood production. These fields are good subjects for application of improved technologies.

In the U.S., competition from OSB in sheathing has led plywood producers to add value and manufacture more efficiently. Survivors in the plywood industry are converting a significant proportion of their production to veneers for laminated veneer lumber.

Coe Manufacturing has developed a new conversion process. The process begins by peeling small blocks on an extraordinary 4-foot lathe. The Coe high-speed lathe will peel blocks an initial diameter of 4 inches or less to a 1-inch core. Larger-diameter peelers (7 inches and more) can go to an 8-foot lathe. Veneer from the 4-foot lathe is end-glued into sheets up to 80 feet long. Random width material can also be glued into sheets of the desired width. The package of innovations includes the “Perfect Joint” process as part of the LVL assembly line and the down stream multi-opening hot press.

The Forest Products Laboratory has developed a Veneer Analysis Routine (Veneer Manufacturing Program) to facilitate greater recovery from logs utilizing log information collected by Log Analysis in the FPL IMPROVE computer program.

Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling: A major problem with sawmills in developing countries is obsolescence. Older sawmills are subject to more frequent breakdowns, may be subject to greater structural deficiencies from wear and tear, and have more difficulty in obtaining spare parts when they are needed. Tropical countries may also have to contend with spare parts inventories at locations which are far from productions sites. Mills must be brought up to date so that they have precision cutting tools and operate at speeds consistent with efficient high quality product output.

In many tropical countries conversion of forest land to farming or plantation activities is the main cause of forest destruction. Proper land-use planning and enforcement is thus one of the foremost conditions if the forest resource is to be protected. Ghana has strict cutting regulations, but how far they are observed is difficult to evaluate. Statistics released in Ghana indicated that the total volume of logs produced in 1999 was 1,102,203 cubic meters (including 1% illegally produced logs). This is 10% above the annual allowable cut determined of 1.0 million cubic meters.

In 1992 stringent enforcement and application of forest felling plans in Malaysia, to ensure sustainability of the resource, was to restrict the output of logs at a level some 30% less than what Peninsular Malaysia and Sabah enjoyed previously. With similar moves being afoot in Sarawak there was no raw material abundance, although long term adequacy of raw material for the industry was deemed to remain secure.

Personnel matters are another important area that influence efficiency. Training of machine operators and saw maintenance persons are keys to improved functioning. Performance of management in areas of job knowledge and decision making are likewise important.

Cooperative arrangements could help smaller sawmills in achieving some of the benefits of larger integrated operations in implementing technology and marketing.

Taxes and subsidies are means through which Governments are able to boost sawmilling capabilities and opportunities for employment and economic development.

Considerable progress has been made in recent years in the introduction of environmentally sound forest harvesting practices in many parts of the world. Nonetheless, much remains to be done. There is a continuing need to refine harvesting systems and techniques so that they become fully compatible with the objectives of sustainable forest management, allowing them to contribute in an important way to the economic and social aims of sustainable development. An FAO model code of forest harvesting practice is one response to this need.

Ghana had a prohibition of log exports for 18 primary species. This is a means of providing for more employment and value added products in timber producing countries.

In comparison of an environmentally sound forest harvesting system with traditional systems generally used in the Amazon region, a felling productivity of 19.76 cubic meters/h workplace time was found in the environmentally sound forest harvesting system, whereas the felling-productivity in a traditional logging system was 17.92 cubic meters/h workplace time. Costs with both systems were comparable, and environmental impact with the new system was much better.

A study in Bhutan documented each phase of both environmentally sound road constructions by excavator and traditional road construction by bulldozer and compared environmental impacts of both construction techniques. The results of this study showed that environmentally sound road construction is superior.

In China and India residue utilization was hampered because of no debarking at many mills,

There is a trend for utilization of trees from "farmed forests." Already this constitutes 32 percent of the total volume used according to a 1998 FAO report..

Brazil was cited by FAO as having poor infrastructures such as ports, roads, and energy supply.

Wood debris around sawmills could conceivably a breeding ground for insects. In a situation in Brazil it was recommended that logs be sampled before entering a sawmill that had been troubled with *Scolytidae*, and that logs be stored for less than 30 days, especially during August/September and March/May, the periods of peak scolytid flight. Not enough was thought to be done to prevent *Xylofagus* attacks in Mozambique.

Increasing the demand for lesser-used species has long been a high priority research problem, but progress is being made. In the Amazon area conversation reported utilization of about 8 species in 1982, but on a recent visit about 50 species were said to be used.

In Africa the decline in the availability of principal timber species has forced logging companies and timber industries to seriously consider some secondary species. Fromager, *Ceiba pentandra*; koto (*Pterygota macrocarpa*); and iaiandza, (*Albizzia ferruginea*) are exploited in a few African countries.

Newer integrated forest products manufacturing complexes have more capabilities for using residues from one phase of an operation in another phase, and may be more suited to handle small logs profitably.

Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Veneer and Plywood Manufacture: Many of the aspects of influencing policies, practices, measures, and technologies as they apply to the sawmilling industry apply to the veneer and plywood manufacturing industries as well.

In the United States there has been a marked increase in structural flakeboard production (OSB), with no increase in structural (unsanded softwood) plywood production. In tropical countries similar effects could occur for unsanded plywood production. Malaysia is also feeling the effects of MDF being used in place of some plywood for core material in furniture manufacture. Blockboard also faces competition from other board products.

Shorter rotation faster growing trees in plantations may be of smaller diameter than existing forest stands. Smaller diameter trees are more easily converted to lumber than to veneer.

ABIMCI, the Brazilian Plywood Association, considered the 1997 economic crisis the worst ever faced. One of the factors affecting Brazilian commerce is the so-called Brazil cost or the cost of Brazilian bureaucracy and poor existing infrastructures.

Advanced Technologies and Practices in Developed Countries Which May Not be as Prevalent in Sawmills in Developing Countries:

According to FAO, mills specializing in manufacturing narrow dimension lumber from small-diameter stems are adopting curve sawing. Scanning and optimization at the primary headrig and the secondary breakdown centers (edging, trimming, resawing, cant breakdown) are becoming standard. Developing countries could benefit from implementing more of these technologies.

Live sawing is being applied to advantage in developed countries more than in developing countries. In a study reported in the Forest Products Journal aimed at producing hardwood dimension rather than lumber, results suggested that log grade and log value are relatively poor predictors of lumber value and dimension yield. Live sawing was superior for producing dimension parts in all scenarios.

Results of a study published in 1995 showed that the dimension production rates in mills configured for live sawing average 22 percent higher than those configured for five-part (cant) sawing. The part production rate in mills processing Factory Grade 2 logs averaged 41 Percent higher than those processing Factory Grade 3 logs.

Barcoding is used more extensively for tracking and inventory control in developed countries. In a 1997 Journal article a systematic modeling approach is proposed as a tool to support reengineering sawmills to meet new business demands. Communication between producers and customers is through Electronic Data Interchange. It is necessary to affix barcodes on every piece of lumber and to maintain a self-replenishment stock of lumber at the reload site of the customer. In return a long-term agreement is expected involving the delivery of large volumes of wood.

A new mill owned by Escobois, one of France's largest lumber producers, marks one of the first times that an automated, high production mill is using cutting-edge technology to solve the problem of high speed sawing for lumber quality by using statistical tree modeling. Real tree shape is used to simulate a model of grade distribution within each log. Software will use these data, along with price and product information, to create quality-based sawing patterns.

End dogging is a technology being applied successfully on small logs.

Finger jointing was fairly common in plants that were visited in the site survey; but, according to a new FAO report, not much is known about utilization of mill residues outside of a few of the large developed countries. In the 2000 report it is stated that the manufacture of finger jointed studs from short lengths salvaged from boards and slabs, which would have been chipped in the past, is becoming increasingly common. The New Zealand Forest Research Institute, which was visited during the site studies, is working on finger jointing green structural material. This could be a further advantage in residue utilization.

Machine stress rating of structural lumber is another technology that might be applied to advantage in sawmills in developing countries. At a large sawmill in Quebec which is operated by Indians, a standard is being developed that will allow sawmills to manufacture machine stress rated (MSR) finger-jointed products for horizontal and vertical structural uses. Now, sawmills can manufacture such lumber for vertical use only. The sawmill has already invested C$7 million in a high-production line to make flanges for I-beam joists.

BOF (Best Opening Face) Sawing Simulation Analysis, used for cutting structural lumber since the 70s in the U.S., could be used for greater recovery in developing countries. The program may be used to assess the current level of lumber conversion efficiency and to improve management control in sawmills. It has wide use in planning models, analyzing marketing and product mix decisions, and analyzing many types of lumber manufacturing operations. Sawing simulation models can be used to aid in the design of new sawmill layouts. Performance specifications can also be determined. Perhaps the greatest benefit from BOF is to predict maximum lumber recovery. This information can help pinpoint reasons for not achieving that recovery. Also it can provide justification for necessary changes. Sawing simulation models can be a component of automated control systems. While primarily designed for control of primary breakdown, they are often used at edging, trimming, and log bucking machine centers.

Advanced Technologies and Practices in Developed Countries Which May Not be as Prevalent in Veneer and Plywood Mills in Developing Countries: The new FAO report, dated 2000, states that technology developments in laminated veneer lumber include increasing use of ultrasonic veneer graders so that a substantial quantity of the veneer supply is routinely tested for possible use of laminated veneer lumber, rather than only for plywood. This development has contributed to a 75 percent increase in production of laminated veneer lumber and a threefold increase in I-joists in the United States from 1990 to 1996. Mills producing lumber from small-diameter stems are adopting curve sawing. Scanning and optimization at the primary headrig and the secondary breakdown are becoming common in developed countries.

Another new technology, developed at the U.S. Forest Products Laboratory and applied at North American mills, is the powered back-up roll. Used on a rotary veneer lathe, it comprises a drive roller for applying a rotational force to the outer periphery of a log axially mounted on the veneer lathe, a controllable drive source for driving the roller and a servo-control system for maintaining the static friction between the roller and the log.

Conclusions: The results of the Pre-Project study emphasize the desirability of applying advanced technologies to improve the production efficiency and reduce waste in tropical countries, We hope that support can be provided in helping the mills attain better product yields and meet increasing demands with sustainable forest production. The producers want to make improvements in order to accomplish more with the available resource, and to endorse sustainability.

There needs to be a better approach to surveying the current state of technology with questionnaires. Perhaps simpler forms could be developed. Perhaps it would also be desirable to make follow-up calls by telephone after forms have been sent. Perhaps some of the questions on production quantities and yields were thought to be too prying by some recipients, and could be made optional.

The mills which were visited on-site did not object to answering questions. It may be that some of the recipients of our questionnaires had problems with English, This is not likely in the case of the associations and larger companies, but it may be the case for some of the smaller companies to which we addressed the questionnaires.

More should be done to try and get reliable statistics on lumber and plywood and veneer yields. Mills can use their recovery figures to monitor their own performance, but unless it is known how yields are calculated and the components of the input and output quantities it is difficult to compare different recovery factors.

Strategies and Actions for Draft Guidelines: Strategies and actions for the development of guidelines should focus on increasing the recovery at the mill site, certification of mill efficiency and recovery processes, development of criteria for target recovery factors, subsidizing the replacement of obsolete equipment, and other techniques to enhance the use of secondary species. Based on this study future work in this area should consider the following principles and recommended actions:

1) Just as there is certification for producing timber from forests that are managed for sustainability and adequate observation of environmental values, there should be developed criteria for certified production of saw milling and plywood products over the long term.

2) ITTO should develop criteria for target recovery factors for lumber, rotary-cut, and sliced veneer.

3) For lumber, criteria will be different depending on type of product, i.e., structural lumber, dimension for furniture, or factory and shop lumber. There should be procedures for calculating lumber recovery factors that can be applied uniformly. There should be different acceptance criteria for special situations such as manufacture of lumber from trees harvested from rubber plantations.

4) To determine performance and yield at representative sawmills there should be pilot mill studies sponsored by ITTO. Otherwise if existing yield data developed by plant personnel are relied upon, there will be inconsistencies depending on how different mills calculate their recovery factors. Very successful mill studies were conducted in the U.S. to determine lumber recovery factors in the 1970s. From the results of these studies, technologies were developed and applied that increased overall recovery factors significantly.

5) Similar studies to those for lumber should also be conducted to gain recovery factors for representative veneer and plywood manufacturing plants. Different criteria will apply to rotary-cut and sliced veneer, decorative and structural grades of plywood, and exterior, marine, and interior use grades of plywood. Studies should cover both volume and grade recovery.

6) To evaluate waste reduction, representative and cooperating mills should be studied to evaluate utilization of bark, chips, shorts, sawdust, edgings, slabs, round-up waste, trimmings and flitch boards for such purposes as end and edge glued material; finger jointed material; material for containers, dunnage, and pallets; blockboard; paper; and in-house or externally-used fuel as in the manufacture of bricks, lime, or Portland cement. Such utilization contrasts with incineration or burial (land filling) without benefit. When ash from waste utilization for fuel serves as fertilizer or other purposes such as admixture with Portland cement this should be considered as an added benefit.

7) ITTO should support, promote, and encourage policies, practices, measures, and technologies that influence utilization efficiencies and waste reduction in saw milling and veneer and plywood manufacturing industries. These are enumerated as follows:

    a. Repair, expand, or replace obsolete equipment to obtain up-to-date production capability.
    b. Enhance utilization and marketing of secondary species.
    c. Accommodate utilization of raw material that results from low-impact harvesting.
    d. Work with tropical country governments to determine if tax concessions such as accelerated depreciation and other subsidies such as low-interest loans that reward efficient utilization are possible and desirable.
    e. Develop software to enable manufacturing plants to determine payback times for investments to enhance production efficiency and reduce waste
    f. Explore possibilities for financing improvements through payments for reducing carbon emissions.
    g. Optimize saw milling capabilities through broader application of computerization, use of thin kerf saws, hiring of competent or trainable workers, emphasizing training

especially for such skills as saw doctoring, operating with minimal dressing and bucking allowances, implementing statistical process control (SPC) techniques, and using saws with long-wearing teeth that are properly set for species being cut.

h. In situations where conditions warrant, apply technologies such as Chip-N-Saw.
i. Where small diameter and misshaped logs are common, implement technologies such as curve sawing and end dogging.
j. Improve operations corollary to sawing including molding and drying.
k. Optimize veneer and plywood manufacture through use of up-to-date equipment; particularly veneer lathes that cut to minimal core diameter consistent with production of veneer with acceptable quality.
l. Optimize gluing of plywood; hot-pressing of some glues may not be needed although hot-pressing of interior glue lines appears to be common.
m. Use pretreatment of veneer logs by steaming or soaking where this results in improvement of yield and/or quality and is therefore cost effective.
n. Optimize corollary operations including drying of veneer and sanding of plywood; sanding may not be needed with structural grades of plywood.
o. Strengthen inventory control throughout the production and distribution chains with wider use of barcoding.
p. Implement residue utilization widely in saw milling and veneer and plywood manufacturing operations. Improve and expand technologies for utilizing veneer cores, finger jointing, and blockboard manufacture.
q. Combine residue utilization techniques such as finger-jointing with non-destructive testing (NDT) to select material for structural members for I-beams and laminated veneer lumber (LVL). Expansion of plywood production to manufacture special items such as these may be an effective means for combating loss of structural plywood markets to particleboard products.
r. Pursue avenues for marketing other specialty items such as fence posts and vegetable stakes.
s. For residues in excess or unsuitable for product use, which may include bark and sawdust, use the residues for fuel to the extent possible. Fuel for space heating and cooling, process energy, and electricity should be high priority. Open burning with pollutants escaping to the air should be avoided in all areas, including those where the practice is legal.
t. Consider encouraging lumber purchasers to import lumber in a greater variety of length classes.

Report on the Review, Survey and Assessment of Information and Data

1. Introduction

Consultants John I. Zerbe and John R. Erickson contracted with the International Tropical Timber Organization (ITTO) for the implementation of a Pre-Project Study on wood utilization efficiency and reduction of losses and waste throughout the timber production chain. The study was conducted with the cooperation and assistance of Robert J. Ross, Project Leader for Wood Processing and Drying Systems at the U.S. Forest Products Laboratory (FPL), and Xiping Wang, a Michigan Technological University employee stationed at FPL.

The study carried out a comprehensive review of previous work related to guidelines on increasing timber utilization efficiency and the reduction of losses and waste with a focus on sawmilling and plywood manufacturing processes and products. The literature review was conducted largely at the FPL library with additional access to publications through data bases which included FSINFO, Agricola, CABI; Interlibrary Loan; and the Internet.

A survey was undertaken to determine conversion efficiency in a representative sample of producers' tropical timber-based export saw milling and veneer/plywood industries. The survey was aimed specifically at representative industries in three countries, Ghana, Malaysia, and Brazil. The survey was conducted through the circulation of questionnaires via Email and international post and on-site visits.

With the data from the literature search and survey at hand, producers' efficiency was compared vis-a-vis efficiency in countries which are more advanced in log conversion and in utilization of main products and waste. Some policies, measures, and technologies which contribute to increase utilization efficiency and to reduce losses and waste throughout the production chain are compiled and assessed

2. Literature Review

The sources of information from the literature as well as abstracts of many of the publications which were reviewed are shown in the Bibliography section at the end of this study report.

Summaries of references to conversion efficiency, technologies to reduce and use waste, comparisons of producers' efficiencies in developing and more advanced countries, and policies which affect utilization efficiencies are tabulated and analyzed on the following pages.

<u>Conversion Efficiencies in Lumber Production</u>: The literature search shows various statistics on conversion efficiencies for different lumber and plywood manufacturing operations and processes. Because of the many variables these figures are not directly comparable.

Yield calculations vary depending on countries, species, final product configuration, size and moisture content, nominal as contrasted with actual size, and different scales for calculating volumes in logs for processing. Log size, crook, and taper are other factors that cause differences in scaling log volumes. Percentages of log volume converted into lumber are calculated differently in Ghana, Malaysia, Brazil, and other tropical exporting countries than in the United States. North American recoveries are usually reported in board feet per cubic foot. They may even be given in less precise terms such as board foot per cord. For better comparison of North American statistics with cubic volumes as calculated with the metric system of measurement in most other countries, it must be known whether yields are based on green or finished thickness, what typical log diameters are, and the number of board feet per cubic foot.

Yields may be influenced by species use and growth conditions. In the case of rubberwood the current plantation management methods have not considered log quality and most of the wood is small diameter and of irregular shape. Where inappropriate tapping methods have been used the value of the first log is normally reduced. What is normally the most valuable part of the tree may have to be discarded because of too low yield in processing to justify transportation to the mill site. The existing rubberwood using industries were often originally built to make use of large logs. This, together with poor log quality largely explains why rubberwood sawmilling suffers from low recovery rates.

In a study of recovery factors based on cubic scale as well as three different board foot scales, it was found that the cubic recovery percent based on rough green lumber varies little for logs of a given size with the assumptions made for the analysis (Snellgrove, 1982).

Three or more different scaling systems with variations of each are used for log scaling in the United States. They are International, Scribner and Doyle. In tropical exporting countries, the Brereton scale, among others, is used.

Sawing characteristics and lumber yields from *Anogeisus leiocarpus* (Kane) and *Khaya senegalensis* (Khaya) was studied using the Wood Mizer, which uses fairly thin horizontal bandsaws. The study showed that lumber yields from Kane and Khaya are very high. The mean lumber yield of Kane and Khaya were 59% and 61% respectively for the logs selected for this study. The average dbh for Kane was 50 cm and 60 cm for Khaya. Tree heights in each species were 20m (Ayarkwa, 1997).

A combination hardwood thinning and selection harvest in north central Minnesota generated a mix of veneer logs, high and low-grade sawlogs, and below-grade red oak logs representative of pallet and firewood quality material. The sample logs had an average small-end diameter-inside-bark and length of 9.5 and 101 inches, respectively. The below-grade logs were processed into 4/4 dimension and pallet parts. Total yield, expressed in cubic feet of dimension and pallet parts output per cubic feet of log input, was 31%. Sixty-one percent of the total product output from the sample logs was in clear, defect-free green-dimensioned parts in lengths of 12 to 43 inches and widths of 1-3/4, 2-3/4, and 3-1/2 inches. Pallet parts of 42- and 48-inch lengths and a width of 3-1/2 inches, accounted for the remaining 39% of product output. Total product yield for dimension and pallet parts was 197 and 125 board feet per cord respectively (Bratkovich, 2000).

Not sawing to unnecessarily large dimensions above the desired finished size is a way to significantly increase yield. In one study, the lumber recovery factor (LRF) improvement from eliminating longer than needed length was estimated at 2.5 percent. Reducing the green target set for lumber cross sectional size could result in a potential improvement in LRF of 6.6 percent (Carino, 1986).

Flosull Madeiras of Capivari do Sul in Rio Grande do Sul, a eucalyptus lumber producer since 1982, like most eucalyptus sawmills in South America, grew in stages over the years as the owners added equipment to accommodate an increasing log supply. Currently 3 lines convert about 7000 cubic meters of logs per month (1.55 million board feet) to 2700 cubic meters of lumber (1.15 million board feet). This corresponds to a recovery factor of 38.6% (Flynn, 1999).

In an ITTO project in Ghana it was found that the yield of main and by-products from four wood species ranged from 44 to 50%. The mean recovery rates were 44.1% rough green lumber, 4.3% by-products, 6.2% sawdust and 45.4% solid residues (such as boards for packaging, skids, stickers, second grade lumber, slabs, offcuts, edgings, etc. The total yield for wawa (43.7%) was significantly lower than the other three species (49.3 to 50.5%). The low recovery rate for wawa was due to the lower grades of logs used. They had heart rot and felling defects, and also longer storage periods in the mill (Forestry Research Institute of Ghana, 1992).

Malaysia's annual sawtimber production is more than six and a half million cubic meters (the raw material consumption being in the region of 12 million cubic meters). Recovery in the industry is about 54.5% on the average with Peninsular Malaysia showing a recovery rate of 55.6%, Sabah with 52.9% while Sarawak sawmillers have a recovery rate of 45.7%. About 77% of the saw timber is produced in Peninsular Malaysia, 17% in Sabah and about 6% in Sarawak. The sawmilling industry has long been established but there has not been much re-investment and modernization within the industry. As a result mills are relatively small by international standards. There is a low degree of automation and the methods used for sawn timber handling are designed for labor-intensive operation. Quality and consistency of output are necessarily affected while the precision-cut raw materials required by the molding and furniture industry can not always be met. Wastage is therefore quite high throughout the industry (Ghazili, 1990).

In Indonesia industrial sawmilling residues are about 50 percent. Residues are made up as follows: log ends 25.0%, sawdust 15.0%, others 10.0% (Meulenhoff, 1986).

In Sabah, logs of Sawmill Quality and Millable Quality produced lumber with mean recovery rates of 30 and 23% respectively. The recovery rates were not significantly affected by taper ratio and log diameter. With respect to lumber quality, the major output was Prime (Grade 1), Standard (Grade 3), Serviceable (Grade 5) and Utility (Grade 6). Common defects included sloping grain, stains, shakes, unpermitted sapwood occurrence, and unsound knots. The unsatisfactory yield and quality need to be weighted with the inferior quality of the logs. Also, the gross recovery rate will possibly be increased if the logs are broken down with the aid of scanners for the appropriate first cut. The first saw cut is important in determining the location of subsequent cuts for maximizing the volume of lumber. Although the study could not visualize the actual composition of the stand, it did reveal the minimum yield and quality of the lumber to be expected from a mature, 70-year-old plantation in Sabah (Tze, 1999).

Because of problems with rubberwood including small diameter, irregular shape, and lack of care during tapping the trees for sap, yields of lumber from this species have been low. One study showed yields of 15-35% (UNCTAD, 1993).

Conversion Efficiencies in Veneer and Plywood Production: One area that is fruitful for improving yields in both rotary-cut and sliced veneers is in bucking veneer logs to length. Crosscutting volume losses amounted to 8.0 percent in a mill in Ghana and 3.2 percent in a United Kingdom plywood mill. The skill employed during the crosscutting process was seen to affect the amount by which the log raw material could be upgraded. Up grading during log-to-bolt conversion can represent an important addition to raw material quality and ultimately to veneer yields.

Pretreatment of the logs can also affect raw material upgrading. In order to facilitate peeling to plywood veneer, it is often necessary to pre-treat by heating and soaking some timbers while others, such as mahogany, can be peeled cold. Where pretreatment is required, the manufacturer has the choice to crosscut the plywood log into bolts prior to treatment or to pre-treat the whole log and then crosscut. From observations made during this study the indications are that it may be advantageous to pre-treat all tropical hardwoods in the log form and then to crosscut to minimize degrade during the crosscutting process (Adams, 1976).

The heating of logs, bolts, and flitches to be cut into high-quality rotary or sliced veneer requires a knowledge of the temperatures appropriate for various species and conditions, and of the factors that control the attainment of these temperature during the heating process. Good equipment and good control of the heating process are essential. Under the guidelines given in this paper, optimum temperature levels for different woods and different conditions can be determined, and time schedules can be calculated for heating in steam or water (Fleischer, 1953).

In Ghana, the total recovery figures for sliced veneer varied from 23 to 35% for asanfena, while that of makore was about 39%. The wide variation in yield of asanfena was due to the variation in log/billets diameters. About 21% of log input volume was lost during the clipping of dry sliced veneer. Losses due to drying of the veneer were about 6%. Based on the two species investigated, about 32.3% of sliced veneer for export and 3.5% of local grade veneer were recovered in addition to some 7.2% of flitch boards (which are marketed locally as by-products or used in the manufacture of pallets). The solid residues include 15.2% of flitching waste (which is solid residue of slabs, offcuts, edgings, etc.) 15.9% of veneer sheets and veneer pieces, and 20.7% if veneer clippings. The flitching wastes are sold as firewood or used at the mill to fire the boiler, while the veneer sheets or pieces of veneer sheets are incinerated. An invisible loss of about 6.2% representing drying and/or shrinkage is also estimated. The yield of wet rotary veneer ranged from 52 to 77% with a mean yield of about 60%. The quality and grade of the logs greatly influenced the yield. Rounding off residues amounted to about 17%, wet clippings about 8%, and residual peeler core about 15%. Residual peeler cores of mixed redwood species of 30 cm diameter were sawn into lumber for export and the local market (Forestry Research Institute of Ghana (1992).

In Malaysia, the plywood industry is most developed in Peninsular Malaysia, which produces almost 90% of the total output for the country. There are however clear growth trends in Sabah where production increased from 43,000 cubic meters in 1985 to 160,000 cubic meters by 1988. Development in Sarawak was initially slow but with the establishment of a few large modern plants, it is was envisaged that in five years Sarawak would figure as a major supplier of plywood close to the Peninsula's capacity. In terms of recovery rates, the average intake capacity of Malaysian mills is 57,000 cubic meters per annum and the output produced is about 25,700 cubic meters giving a recovery of about 45%. However there are several new mills in Sabah and Sarawak twice as large or more than those in Peninsular Malaysia, which should have enhanced significantly the rate of recovery. Ghana recorded Africa's highest rate of growth at an average of six percent a year since 1983. Many Malaysian sawmills are wanting in efficiency and technique. Further downstream, skill in production, design, marketing and market research, R&D, etc. was very much desired (Ghazali, 1990).

Indonesia's plywood industry is largely based on meranti, which has excellent properties, and on other mixed light tropical hardwoods. Indonesia also produces sliced veneer. Main species are teak and ebony. Most of the sliced veneer production is sold on the local market. Industrial residues from plywood manufacture are about 55 percent. The plywood industry residuals are made up as follows: log ends 11.0%, cores 13.0%, green veneer 13.0%, dry veneer 12.0%, trimmings 4.5%, dust (from sanders) 1.5%. These wood residues from the mills, nationwide, are not yet utilized, except for the production of blockboard cores and as boiler fuel in the plywood industry (Meulenhoff, 1986).

3. Technologies to Reduce and Use Waste in the Lumber Industry

Applications of technologies may be applied to attain quality control in lumber production. This can be manifested in the way various operations are conducted. Included are felling, debarking, bucking, sawing, edging and trimming, sorting, and drying. Improvements may be made through computerization, optimized sawing, curve-sawing, variable feed rate of saws, high strain band saws, and minimal saw kerfs (Spelter, unpublished).

Heavy circular saws have been popular among smaller producers because they require little maintenance; such saws can often be used without the services of highly skilled saw filers. But, these saws also waste lumber, producing kerf from 9/32 inch to as much as 16/32 inch in contrast to the <8/32 inch with bandsaws. In response to the increasing availability of smaller timber, a third kind of saw appeared around the 1960s the Chip-N-Saw. Sawmills that use this machine do not quite achieve the recovery standards of conventional mills, but compensate by increased throughput of a lower cost resource with less handling. Today over 200 mills in North America use the Chip-N-Saw. Improvements to improve log recovery have included better scanners to measure log size and shape, computer control for optimum log breakdown based on best opening face (BOF) concept; saws with thinner blades; longer wearing teeth; better guides to reduce kerf and sawing variation; and more closely controlled drying using improved moisture sensing and removal to reduce energy use and lumber degrade. A modeling analysis yielded the following results: For small sawmills with current levels of technology, kerf of 0.280 inch was assumed, reflecting the use of heavy circular saws. Dressing allowance was assumed at 0.119 inch. Large mills with current technology typically achieve head saw kerf of ~0.200 inch, resaw kerf of ~0.175 inch, and dressing allowance of 0.114 inch. With current best technologies, it is believed that head saw and resaw kerfs of 0.120 inch can be attained. The use of thin rim circular saw blades for resawing cants for pencil slats has resulted in kerf as low as 0.051 inch. For future technology levels kerf is projected to fall to 0.110 inch, but because of the replacement of planing by touch sanding for board finishing and greater control over sawing variation, dressing allowance is projected to fall to 0.063 inch. It was predicted that large sawmills in the South of the U.s. would achieve current best technology levels by 2000. Future technologies using exotic features such as x-ray scanning for defects were also expected to surface around 2000. New structural wood products such as wood I-beams and laminated veneer lumber have their main advantage that they can be manufactured from smaller lower grade timber and yet achieve superior strength, because defects are spread out instead of being concentrated at a point, such as at a knot (Spelter, 1988).

In the U,S,, manufacturing efficiency tends to increase with increasing sawmill size unless the mills are very large. Very large operations use wider resaw kerfs and produce thicker lumber than do sawmills of intermediate size. Large sawmills also process longer logs than do small sawmills, although long sawlogs are not processed at very large sawmills (Steele, 1991).

According to FAO, large mills have outputs of about 100,000 m^3 /year. Medium mills have outputs of 100,000 to 200,000 m^3 /year, and small mills have outputs less than 100,000 m^3/year (FAO, 1979). In Brazil researchers analyzed sawmilling in the State of Acre. Percentage distribution according to size was up to 1000 m^3 55 %, from 1001 t0 2000 m^3 30 %, above 2000 m^3 15%. The main sawmill equipment was classified as follows: vertical band saw 82.26 %, horizontal band saw 11.29 %, circular saw 6.45 %. Main production difficulties for different mills were lack of qualified personnel (59.68%); lack of replacement parts for sawmill equipment (40.32%); administrative deficiency where there is poor inventory control of raw materials and products (27.42%); badly laid-out equipment (20.97%); and, hard to process species (19.35%).

In the United States, computerized log breakdown has contributed to increased recovery in sawmilling since the early 1970s. Many other sawmill operations also benefit from applied computer technology, but from the survey in tropical countries, there appears to be a log in applying computerized monitoring and control. In the U.S., the Best Opening Face (BOF) technique has been applied to determine how the first saw cut on a log should be made to get maximum lumber yield.

BOF Sawing Simulation Analysis can be used to assess the current level of lumber conversion efficiency and to improve management control in dimension sawmills. It has wide use in planning models, analyzing marketing and product mix decisions, and analyzing many types of lumber manufacturing operations. Sawing simulation models can be used to aid in the design of new sawmill layouts. Performance specifications can also be determined. Perhaps the greatest benefit from BOF is to predict maximum lumber recovery. This information can help pinpoint reasons for not achieving that recovery. Also it can provide justification for necessary changes. Sawing simulation models can be a component of automated control systems. While primarily designed for control of primary breakdown, they are often used at edging, trimming, and log bucking machine centers (Forest Products Laboratory, 1990).

BOF has been integrated log analysis program called IMPROVE. It is designed to help mill owners/operators collect, organize, and store information about logs. It can be important for buying or selling logs, determining inventory, and conducting efficiency studies. Log Analysis creates data files that can be read by BOF Sawing Simulation to simulate lumber recovery from actual log input. Running Log Analysis in preparation for the BOF sawing simulation requires collecting log length and both small and large end diameter information (Forest Products Laboratory, January 2, 1990).

BOF is most useful when using live sawing techniques, but other improved scanners are being used to measure log size and shape to help in sawing for maximum yields of higher grades of lumber. According to FAO (FAO, 1990), scanning and optimization at the primary headrig and the secondary breakdown centers (edging, trimming, resawing, cant breakdown) are becoming standard.

Computer controlled bucking systems should reduce problems with sweep and crook. Other problems are log length, over length, and debarking. As an example of over length, assume a mill sells lumber in even feet (8-10-12-14-16). If a log were to be cut 12 feet, 9-1/2 inches, and the log should have been cut 12 feet, 5 inches, there would be 4-1/2 inches over length. This lowers the recovery factor, consumes expensive processing time needlessly, and may, in some cases, reduce the number of logs that may be cut from a stem until the minimum log diameter suitable for sawing is reached (Love, 1984).

Some parameters of an optimized bucking system are 1)debark before bucking, unless scanner can accurately measure under bark log diameter, 2)diameter and sweep scanning be accurate to at least 0.4 cm, 3)length be accurate to 2 cm, 4)logs do not bounce, slide, or roll while being scanned. 5)nominal two-foot spacing be used for transverse bucking systems, 6)hardware be capable of operating in adverse mill conditions, 7)self-diagnostic capability be built in for the computer and scanning systems, 8)lumber output for log segments be determined accurately and classified by diameter, sweep, taper, and length, 9)butt ends be manually squared before scanning or be optimally squared by the scanning system, 10)lumber prices and operating costs be specified accurately, and 11)log trim allowance be reduced to near the minimum required (Middleton, 1989).

Different types of scanners are more effective than others. Results show that there is a yield increase of ca. 0.5 percentage points when replacing a 1-axis shadow scanner with a 2-axis shadow scanner. There is a further potential yield increase in introducing a 3-d scanner or an X-ray scanner; however, in order to get a substantial improvement using these scanners one has to control the orientation in sawing. The difference in yield of the 3-d scanner between random and optimized orientation is ca. 2 percentage points when measuring on bark and ca. 4 percentage points when measuring under bark (Skatter, 1998).

Curve sawing is a new technique that is applied in North America to gain greater yield from logs having some crook. The technology may be too advanced for wide application in tropical countries. However it was being applied very simply through hand feeding logs at the Papan Jaya Sdn. Bhd. Sawmill in Kuala Lumpur, Malaysia

Curve sawing is especially important in sawing small diameter logs. Smaller diameter logs may be of more concern in North America than in tropical countries, but the need for processing small logs is becoming greater worldwide. According to FAO (FAO, 1999) mills specializing in manufacturing narrow dimension lumber from small diameter stems are adopting curve sawing.

Curve sawing increased recovery 16,8,and 4 percent for three diameter classes in ascending order, respectively. The declining trend suggests that there is little advantage in curve sawing logs with sort diameters greater than 10 inches. Furthermore, curve sawing 10-inch cants with circular saws was found to be impractical from a saw maintenance point of view (Middleton, 1989).

How logs are debarked may be important for yield of chips of higher value as well as for facilitating scanning and eliminating rocks and debris that could dull saws. In Ghana and also at some places in Malaysia logs are debarked manually. In Brazil logs may not be debarked. Manual debarking may be more effective than hydraulic or mechanical debarking, and it may be cost effective in Africa where there is an abundant labor supply, but this would not work where labor is less available because of the local economic conditions.

According to FAO (FAO, 1979) residue utilization in China is hindered by no debarking at many mills and log debarking may be necessary for sale of chips for pulp (FAO, 1981).

Improvement in saws with thinner blades, longer wearing teeth, and better guides to reduce kerf and sawing variation and better maintenance of saws is recognized as beneficial in tropical countries. But there is room for improvement. For lighter sawing applications some operations are using machines such as the Wood-Mizer which have narrower and thinner saws. But, there are other difficulties. For mills sawing different species, the set of the saw which is most appropriate for one species might not be as efficient for cutting other species.

According to a fairly recent study (Loehnertz, 1996), in many sawing problems are related to maintenance. Saws usually do have durable stellite teeth. Among maintenance problems are saws being used when dull, gullet burn while sharpening, incorrect and uneven tension, uneven crown, burrs left in gullet when sharpening, faulty wheel bearings, saw too thick for wheel diameters, and band mill vibration. These problems result partially from a lack of skilled personnel in the shop and management.

Principal problems of the wood processing industry in Brazil include the highly selective nature of forest exploitation, a scarcity of qualified personnel at all levels, and obsolete equipment and inadequate maintenance infrastructure.

In most, if not all, tropical countries high species density and silica content pose problems for sawing. Stellite tipped teeth are the rule in Malaysia. The clearance angle is apparently kept high to reduce feed force and prolong the life of the tooth and blade. Most saw sharpening machines are not equipped with cams for changing tooth profiles, which might partially explain the predominant use of the flat-bottom shape. Many experts agree that this shape is not the ideal tooth profile for cutting medium to high density species, but it has proved in many countries to be capable of meeting all basic requirements. Unless the sawmill industry is prepared to sort logs according to density groups and/or abrasiveness of species, there appears no need to introduce another tooth shape. Although almost all sawmills have facilities for band saw maintenance, the typical saw filer does not know the profile, tooth height, angles, swage, or other parameters about the saw. Throughout Ghana, Brazil, and Malaysia the most commonly reported sawmilling problems included poor maintenance, lack of trained personnel, obsolete equipment, and inadequate saw tooth geometry and wear resistance.

Better sawing equipment and maintenance can always help in increasing the recovery factor. Other approaches involve better control of secondary processes such as drying and planning and molding and utilization of waste from cutting lumber in other applications.

Important ways of using smaller pieces and lower grades of of lumber include manufacture of finger-jointed lumber, blockboard, packaging and dunnage material, and pallets. In some cases, residue wood can be chipped and used in paper manufacture. Wood in various forms may be used as fuel in the sawmill or sold for other applications such as boiler fuel and application in brick or lime kilns or cement manufacturing.

In a study of sawmills in Sabah (Chaiapechara, 1988), those sawing for the local trade had little need for a planer. Small mills opted not to make this investment, but there may have been planing services at lumberyards to cater to demand. But adding planers could help attain more value-added and better quality in products (Kryzanowski, 1999).

Short logs can often be used in the manufacture of pallets and packaging and hardwood dimension (clear panels used in the manufacture of furniture or other objects).

In Sabah two weeks of air-drying was found to be standard practice. Few mills (only 5 of 41) had dry kilns. Two mills used the kilns only for drying veneer (Chaiapechara, 1988). Often, fueling the dry kiln provides an important outlet for residue wood.

With the current production levels in Malaysia rubberwood sawmilling generates about 2.5 million m^3 of residues of which part is used for fuel for lumber drying or by local households, and part (about 0.9 million m^3) for production of reconstituted panels (UNCTAD, 1993).

In Southern Brazil wood residue is used as fuel in brick kilns and lime kilns. In Sabah wood waste was also used in brick kilns (Chaiapechara, 1988).

According to FAO (FAO, 1981) Dry bark may be used for fuel. Wet bark may be piled and dried for fuel. Sawdust may be a valuable fuel for domestic or industrial fuel if it is not too wet. Some species produce sawdust suitable for agricultural mulch or animal bedding. If the sawdust cannot be sold as fuel, it may be possible to use it as fuel in the mill operations. Slabs, edgings, trim ends, and broken logs are a potential source of raw materials for small secondary or home industries. Alternatively, they can be chipped and sold for pulp mill furnish (log debarking may be necessary).

Larger pieces of wood waste often can be marketed for fuelwood, and high density hardwood species are good for manufacture of charcoal (FAO, 1990).

The manufacture of finger jointed studs from short lengths salvaged from stacked boards and slabs, which would have been chipped in the past, is becoming increasingly common (FAO, 1999).

4. Technologies to Reduce and Use Waste in the Veneer and Plywood Industry

For the veneer and plywood industries drying is an important part of the manufacturing process. It is in this part of the process and in the roundup of the bolt, and the size of the core that is left in rotary peeling of veneer that better technologies can be of most benefit.

The veneer and plywood industries have some ot the same opportunities for using wastes as the sawmilling industry. Cores from rotary peeling may be a source of lumber for pallets and packaging. Or cores may be chipped and used for other purposes including fuel.

Veneers may be used over blockboard cores or to cover finger joints.

In Ghana the total recovery figures for sliced veneer varied from 23 to 35% for Asanfena, while that of makore was about 39%. The wide variation in yield of asanfena was due to the variation in log/billets diameters. About 21% of log input volume was lost during the clipping of dry sliced veneer. Losses due to drying of the veneer were about 6%. Based on the two species investigated, about 32.3% of sliced veneer for export and 3.5% of local grade veneer are recovered in addition to some 7.2% of flitch boards (which are marketed locally as by-products or used in the manufacture of pallets). The solid residues include 15.2% of flitching waste (which is solid residue of slabs, offcuts, edgings, etc.) 15.9% of veneer sheets and veneer pieces, and 20.7% if veneer clippings. The flitching wastes are sold as firewood or used at the mill to fire the boiler, while the veneer sheets or pieces of veneer sheets are burned. An invisible loss of about 6.2% representing drying and/or shrinkage is also estimated. The yield of wet rotary veneer ranged from 52 to 77% with a mean yield of about 60%. The quality and grade of the logs greatly influenced the yield. Rounding off residues amounted to about 17%, wet clippings about 8%, and residual peeler core about 15%. Residual peeler cores of mixed redwood species of diameter 30 cm were sawn into lumber for export and the local market (Forestry Research Institute of Ghana, 1992).

In Brazil, sawmills with 100 veneer and/or plywood mills, constituted the primary wood processors in the Amazon region. They were concentrated in a few cities of Para (44 veneer mills and 9 plywood plants), Mato Grosso (34 veneer mills and 2 plywood plants), Rondonia (10 veneer mills), Amazonas (5 veneer mills and 5 plywood plants), and Amapa (one plywood plant). These mills often pointed out log storage, peeling, drying, and gluing difficulties, as deterrents to the increase of species processed for veneer and plywood production. Most veneer mills produce material that is shipped for plywood production at affiliated companies in the South and Southeast of Brazil. Among veneer mills only very few produced sliced veneer. This was mainly from Mogno (*Swietenia macrophylla*), Cerejeira (*Amburana cearensis*), Freijo (*Cordia goeldiana*), and Muiracatiara (*Astronium lecointei*) (Sobral, 1984).

In Malaysia, log quality is of particular importance for plywood production. Rubberwood use for this product is a recent development offering good expansion possibilities. In plywood the availability of suitable logs in sufficient volume will be the key constraint when the technological problems have been overcome. Productivity improvement in logging and industrial processing offer the most significant opportunities to improve profitability. Low recovery rates can also be interpreted as a sign of low wood prices that do not encourage producers to improve their efficiency (UNCTAD, 1993).

In the mid 1980s, 40 plants producing plywood, veneer, and blockboard were located in Peninsular Malaysia. The rate of growth of the industry was not as rapid as the sawtimber industry. Nearly 50% of the 1984 production total of 516,000 cubic meters was produced in the states of Jahore and Pahang. More that 60% of the plywood production was exported. Plywood was shipped mainly to Asian markets with Singapore accounting for the largest percentage (68%) of the export total. Three plywood plants annually consumed 100,000 cubic meters of logs to produce about 30,000 cubic meters of plywood, of which 15,000 cubic meters were exported. A forest industries development plan was aimed at diverting 40% of domestic log production into the sawtimber industry and 15% of log production to the plywood sector by 1990. Veneer plants, which were less expensive to construct and operate, might have been promoted instead of plywood plants (Krutilla, 1987).

In Indonesia, The plywood industry residuals are made up as follows: log ends 11.0%, cores 13.0%, green veneer 13.0%, dry veneer 12.0%,t rimmings 4.5%, dust (from sanders) 1.5%. Wood residues from the mills, nationwide,are not yet utilized, except for the production of blockboard cores and as boiler fuel in the plywood industry (Meulenhoff, 1986).

In the U.S. faced with competition from OSB in sheathing, plywood producers are adding value and manufacturing more efficiently. Survivors in the plywood industry are converting a significant proportion of their production to laminated veneer lumber-type veneers and value-added plywood. Although plywood production in the U.S has dropped significantly since 1995, sanded plywood production has been holding steady. Many plywood producers have identified niche markets such as boat builders, furniture manufacturers, truck trailer companies and other users. The traditional separation of the plywood business into hardwood and softwood segments will blur as product, raw material, and customer demands overlap. Coe Manufacturing has developed a new conversion process. The process begins by peeling small blocks on an extraordinary 4-foot lathe. The Coe high-speed lathe will peel blocks an initial diameter of 4 inches or less to a 1-inch core. Larger-diameter peelers (7 inches and more) can go to an 8-foot lathe. Veneer from the 4-foot lathe is end-glued into sheets up to 80 feet long. Random width material can also be glued into sheets of the desired width. The package of innovations includes the "Perfect Joint" process as part of the LVL assembly line and the down stream multi-opening hot press (Baldwin, 1999).

Technology developments in laminated veneer lumber include increasing use of ultrasonic veneer graders so that a substantial quantity of the veneer supply is routinely tested for possible use of laminated veneer lumber, rather than only for plywood. this development has contributed to a 75 percent increase in production of laminated veneer lumber and a threefold increase in I-joists in the United States from 1990 to 1996 (FAO, 1999).

The Forest Products Laboratory (Forest Products Laboratory, 1990) has developed a Veneer Analysis Routine (Veneer Manufacturing Program) to facilitate greater recovery from logs utilizing log information collected by Log Analysis in the FPL IMPROVE computer program..

PlyTech is a program designed to help Borden chemical Inc. plywood customers improve their processes and product quality by using continual improvement tools. PlyTech provides the platform for monitoring current and historical trends of critical process variables. PlyTech also offers users the ability to access data more easily for generating reports and analyses. PlyTech producers must register with Borden Chemical staff, Columbus, OH to use PlyTech. Using Internet Explorer 4.01, any authorized user can access the program through the Internet (Anonymous, 1999).

Modern technology will have a significant effect on the economics of plywood production, especially in developed countries. The increase in the use of small diameter logs, a significant cheaper source than the one traditionally used, will contribute to the reduction of production costs, as wood is the largest component of costs (Spelter and Sleet, 1989). Availability of forest resources does not mean availability of logs for veneer and plywood. Although technology has developed very fast during the last decade, and smaller logs are now used for veneer production. Generally speaking veneer logs must be of superior quality. Recent technology developments in plywood production include: charging - automatic log centering for improved veneer recovery; peeling - powered back up roll, powered nosebar, peripheral drive lathe, hydraulic knife positioner, and spindle-less lathe; clipping - rotary clipper; drying - automatic control and redryer (radio frequency/vacuum); gluing - foam extrusion and high-mositure gluing; pressing - compression controls and panel watering. There is sometimes conflict between labor costs and technology improvement. There might be some situations where increasing technology sophistication in plywood production might have a negative effect on costs. Labor costs might be increased as foreign experts and technicians with much higher wages are needed to run the mill. this does not mean that wages must be kept low in developing countries (Tomaselli, 1990).

5. Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling

Some influencing factors, both positive and negative, which are, generally, institutional and not direct part of plant operation are listed in Table 3.

<u>Obsolescence, breakdown of equipment, and shortage of spares:</u> There are still mills that are operating with basic equipment dating from shortly after World War II. These older mills are subject to more frequent breakdowns, may be subject to greater structural deficiencies from wear and tear, and have more difficulty in obtaining spare parts when they are needed. Tropical countries may also have to contend with spare parts inventories at locations which are far from productions sites.

Christiansen found that some 40 traditional small, circular sawmills survived in Latin America under very bad economic conditions, almost without external support. Sawmill installations and machinery were between 10 and 40 years old. Problems included shortage of spare parts, high waste factor, and poor quality (Christiansen, 1987).

Mills must be brought up to date so that they have precision cutting tools and operate at speeds consistent with high quality product output (Ministry of Primary Industries, Malaysia, 1992).

<u>Timber cutting regulations, land use planning, and enforcement:</u> In Ghana, a study used detailed stock, yield and cost data in a small optimal control theory model. Different policy options to promote low impact logging through the use of economic incentives were evaluated.

There is no doubt that in Ghana conversion of forest land to farming or plantation activities is the main cause of forest destruction. Proper land-use planning and enforcement is thus one of the foremost conditions if the forest resource is to be protected. Ghana has strict cutting regulations, but how far they are observed is difficult to evaluate. A major bottleneck is the severe lack of capacity and resources within the Forestry Department (Bach, 1999). There is some thought in Ghana that the forest and timber resources can only sustain an annual cut of one million cubic meters, but the capacity of the export-oriented wood industry is 3.7 million cubic meters (ITTO, 16 th - 29 th February 2000).

Statistics released in Ghana indicated that the total volume of logs produced in 1999 was 1,102,203 cubic meters (including 1% illegally produced logs). This is 10% above the annual allowable cut determined of 1.0 million cubic meters (ITTO, 1st – 16th April 2000).

In Ghana fifty Forest Management Units have been created to boost the sustainable management of the country's permanent forest estate. Each Forest Management Unit is approximately 500 square kilometers and is within one Forest District. In addition to the creation of the units, the off-reserve forest areas are also being consolidated into management units under a Timber Utilization Contract to facilitate rational harvesting (ITTO, 16th – 31st May 2000).

Stringent enforcement and application of forest felling plans in Malaysia, to ensure sustainability of resource, was to restrict the output of logs at a level some 30% less than what Peninsular Malaysia and Sabah used to enjoy. With similar moves being afoot in Sarawak there was no raw material abundance, although long term adequacy of raw material for the industry was deemed to remain secure (Ministry of Primary Industries, Malaysia, 1992).

The Government of Indonesia revealed that the demand for raw materials in the timber industry has reached 63.5 million cubic meters per annum, while the allowable log production amounts to only about 35 million cubic meters. Shortages have resulted in illegal logging and log thefts. Due to the declining log supply the Government is encouraging the industry to harvest under-utilized species as well as encouraging the use of small diameter logs. At the same time the authority is also encouraging the industry to maximize the usage of raw materials and retooling of the production facilities to improve efficiency. Some 50 timber companies have stopped logging due to security problems and growing conflicts with local communities according to the Association of Indonesian Forest Concessionaires. Apparently local communities in affected areas claimed ownership to the areas and have been threatening workers. The affected forest concessions are mainly in Irian Jaya, Kalimantan and Sulawesi (ITTO, 16th – 31st March 2000).

Controlling personnel performance: Brown (Brown, 1982a) mentions personnel performance as the second key area in his paper on Manufacturing Lumber from Small Logs. Performance can be broken down into four parts: job knowledge, supervisory decisions, recovery decisions and grade decisions. Training can be the key to personnel performance, and this is a prime topic in a book by Brown (Brown 1982b)

Cooperative ownership of logging and sawmill operations: Cooperative arrangements_could help smaller sawmills in achieving some of the benefits of larger integrated operations in implementing technology and marketing.

Certain forest-based processing activities lend themselves well to some form of collective or cooperative organization. Cooperative ownership of logging and sawmilling operations by small, rural furniture manufacturers can greatly assist in solving the raw material supply problem and facilitate the provision of working capital finance (Brunton, 1987).

Solberg suggested an alternative for sawing softwood in Tanzania which consisted of five semi-mobile mills. These five sawmills would have a common central unit for sorting, drying, trimming, dipping, impregnation, for sales of sawn wood, for administration, and for repairs and maintenance of the logging and sawing equipment (Solberg, 1986).

Taxes and subsidies: Taxes and subsidies are means through which Governments are able to boost sawmilling capabilities and opportunities for employment and economic development.

In the state of Acre, Brazil there was a proposal to decrease taxes to provide support for modernizing wood industries (da Gama e Silva, 1992).

In the Amazon basin of Brazil Subsidies coupled with tax breaks allowed Brazilian firms to reduce their income tax payments by 1/2 if the savings were directed to industrial investments. However recently many of the incentives have been eliminated (Ferzt, 1997).

In Indonesia the export of logs was encumbered with a tax of 200%, which favored export of high value and value-added products, especially plywood. But this tax wss to be eliminated. In place of it a resource use tax of 10% was to be imposed. All further export control factors such as export quotas were to be eliminated in 3 years. Wood concessionaires could export all wood as long as they sold at least 5% on the home market (Graf, 1998).

Local semi-processed timber product exporters object to being singled out for paying Indonesia's timber export cess and point to other sub sectors as furniture, MDF, and the timber industries in Sabah and Sarawak that should share the load. The cess is used by the Government to further develop the entire industry (ITTO, 16th to 31st March 2000).

National, regional, or local harvesting codes: Considerable progress has been made in recent years in the introduction of environmentally sound forest harvesting practices in many parts of the world. Nonetheless, much remains to be done. There is a continuing need to refine harvesting systems and techniques so that they become fully compatible with the objectives of sustainable forest management, allowing them to contribute in an important way to the economic and social aims of sustainable development. An FAO model code of forest harvesting practice is one response to this need. Its primary objective is to promote forest harvesting practices that improve standards of utilization and reduce environmental impacts, thereby contributing to the conservation of forests through their wise use. The information provided in this model code of forest harvesting practice has been compiled with the intent of highlighting the wide range of environmentally sound harvesting practices that are available to forest managers, especially those requiring only a modest level of investment in training and technology. This will permit policy-makers to develop national, regional or local codes of practice, which will best serve the particular needs of government agencies, the private sector, non-governmental organizations and other constituents (Dykstra, 1996).

In 1992 Ghana (FAO Advisory Committee on Paper and Wood Products, 1997) published a "Handbook of Harvesting Rules for Sustainable Management of Tropical High forest in Ghana."

Prohibition of log exports: Ghana had a prohibition of exports in log form of 18 primary species (ECE/FAO Agriculture and Timber Division, 1989).

Reduced impact timber harvesting: In Indonesia conventional and reduced impact timber harvesting operations were observed and compared. The research results indicate that conventional timber harvesting with the TPTI (Tebang Pilih Tanam Indonesia) system in the tropical natural forest in Indonesia caused heavier damage on soil and residual stands when compared with a reduced impact harvesting system. The application costs of reduced impact timber harvesting are not greater than conventional timber harvesting in either short or long periods because the wood damage value caused by conventional timber harvesting is twice as great as that caused by reduced impact timber harvesting; also, reduced timber harvesting will enhance future forest productivity and reduce the costs associated with potentially adverse side-effects of timber harvesting (Elias, 1998).

In a study in the Republic of the Congo it was found that damages to the residual stand occur during felling, skid trail construction and log skidding. The study observed crown damages, bark damages and uprooted or broken trees. The average damage frequency was 17.7 damaged trees per felled tree. Expressed in terms of damages per recovered log volume, this is approximately 3 damaged trees per cubic meter removed. Damage to residual Okoume trees was 3.3% with the majority of damaged stems in the higher DBH classes. The total number of felling damages of all trees (93) is 17.3 per hectare. Skidding damages occur with an average frequency of 11.5 trees per hectare. In total, the number of felling and skidding damaged trees per hectare was 29. The number of damages per felled tree was 30 and the number of damages per cubic meter of log volume removed was 5. The soil disturbance survey revealed a total disturbed area of 8.4% of the annual harvest area (FAO, 1997a).

Another study documented each phase of an environmentally sound forest harvesting system as applied by Precious Woods Ltd and compared its efficiency and environmental impacts with those of the traditional systems generally used in the Amazon region. The following results were provided: 1) Efficiency. Felling: A productivity of 19.76 cubic meter/h workplace time was found in the environmentally sound forest harvesting system, whereas the felling-productivity in the traditional logging system was 17.92 cubic meter/h workplace time. The productivity of timber extraction was difficult to compare since there were two extraction activities in the environmentally sound forest harvesting system: first, the pre-skidding phase with a productivity of 31.04 cubic meter/h workplace time and then the skidding phase with a productivity of 65.53 cubic meter/h workplace time. By contrast, the skidding operation was the only timber extraction activity in the traditional logging system. This skidding productivity was 24.90 cubic meter/h workplace time. 2) Cost. Comparable. 3) Environmental impact. Severe harvesting damage to potential crop trees was found to be more than twice as high with the traditional logging system (51.5%) as compared to the environmentally sound forest harvesting system with 22.2%. With the environmentally sound forest harvesting system an average area of about 4.5% per cutting unit is affected by roads and other forest infrastructure, whereas in the traditional logging system the corresponding value amounts to about 20%. The disturbance of canopy by tree felling was 10.8% of the area for the environmentally sound forest harvesting system. By contrast, the traditional logging system resulted in created canopy openings of 24.7%. Investigation of timber losses revealed a potential for improvement in the environmentally sound forest harvesting system, where the total in timber losses came to 3.9% of the utilizable stem volume. The total timber losses for the traditional logging system were more than twice as high at 8.5% (FAO, 1997b).

A study in the province of Salzburg. Austria documented each phase of environmentally sound road construction by excavator and advanced blasting technique as applied in the road projects under review and compared its environmental impacts with those of the traditional road construction by bulldozers (Winkler, 1998).

A study in Bhutan documented each phase of both environmentally sound road constructions by excavator and traditional road construction by bulldozer and compared environmental impacts of both construction techniques. Another objective was to provide information on "long-distance cable crane logging" which appears that it will continue to be the most common harvesting system applied throughout Bhutan in the near future. The results of this case study showed that environmentally sound road construction is superior. The short-term economic benefits from use of bulldozers in forest road construction in mountainous terrain are likely in the longer run to create environmental damage on a considerable scale as side slopes increase. The traditional harvesting system in Bhutan, strip-wise clear-felling with subsequent long-distance cable logging, can be modified towards more environmentally sound harvesting practice. The adverse environmental impacts such as loss of biodiversity, creation of monocultures or forest with a poor species composition as well as erosion can be reduced. This solution makes use of the available skills and equipment in the country, contributes to the livelihood of the people and improves the overall development in rural areas (Winkler, 1999).

Impact of no debarking on residue utilization: In China residue utilization is hampered because of no debarking at many mills (FAO, 1979). The problem was also evident in Kerala, India (Muraleedharan, 1989).

Plantations: There is a trend for utilization of trees from “farmed forests.” Already this constitutes 32 percent of the total volume used (FAO, 1998).

A paper by Rago (Rago, 1999) discusses the importance of forest plantations as an element of forest sustainability and examines their roles within the global environmental context and their contribution toward achieving sustainable development in the most ecologically efficient manner.

Infrastructure: Brazil is cited as having poor infrastructures such as ports, roads, and energy supply (FAO Advisory Committee on Paper and Wood Products, 1998).

Roads have economic advantages, but endanger the environment. They are necessary for forest access and the transport of wood and non-wood products towards national and international markets. They also appear to facilitate agriculture and hunting by opening up the forests hence leading indirectly to deforestation and the destruction of wildlife. ITTO has a publication that assembles all the opinions, ideas and proposals from representatives of all concerned parties: political decision makers, scientists, professionals, and ecologists (ITTO, 1999). See also publications by Winkler cited under Reduced impact timber harvesting above.

Control of insect infestations: In a situation in brazil it was recommended that logs be sampled before entering a sawmill that had been troubled with *Scolytidae*, and that logs be stored for less than 30 days, especially during August/September and March/May, the periods of peak scolytid flight. Not enough is being done to prevent *Xylofagus* attacks in Mozambique (Moamba, 1990).

Increasing demand for lesser-used species: Lesser-used species which are also known by terms such as under-utilized species, secondary species, minor species, and less-known species have long been a concern for improving tropical timber utilization and tropical forest management. But, progress is being made. In the Amazon area observations showed utilization of about 8 species in 1982, but on a recent visit about 50 species were being used.

The tropical rain forest of Peninsular Malaysia is one of the most complex ecosystems in the world. It has been estimated that 890 of the 2,500 tree species reach harvestable sizes of at least 45 cm diameter at breast height (dbh). Of these 890 species, a total of 408 have been introduced at one time or another to the international markets under the Malaysia Grading Rules (Forestry Department of Peninsular Malaysia).

The Government of Indonesia is encouraging the use of under-utilized species (ITTO, 16th – 31st March 2000). Lesser-used species are expected to find more markets in Brazil (ITTO, 1st – 16th April 2000).

In Cote d'Ivoire, commercially known species were being depleted while potentially usable species were left unharvested (Melaku, 1990).

Utilization of lesser-known species are research priorities in Malaysia (Ministry of Primary Industries, Malaysia) and Nigeria (Sanwo, 1990).

Stocks of preferred commercial tropical species were dwindling and increasing efforts were required to intensify the use of lesser known species. There are many reasons that caused hundreds of Amazonian species to remain less known. Most of them lie beyond the lack of knowledge on the species technical properties. There are hundreds of tropical species in the world that have been subjected to extensive studies covering their physical and mechanical properties; nevertheless, most of them fail to reach the markets. A paper developed some information on these so-called lesser-known species of the Brazilian Amazonian Forest, and presented some possible strategies for changing current consumption patterns (Sobral, 1984a).

It has not been possible to group the Amazon species into end-use classes, and this has made it difficult for them to compete with species from the Far East (Whitmore, 1990).

Lack of information on some species is adding to the problem of low yields at sawmills in Mozambique (Moamba, 1990).

In Africa the decline in the availability of principal timber species has forced logging companies and timber industries to seriously consider some secondary species. Fromager, *Ceiba pentandra*; Koto (*Pterygota macrocarpa*); Iaiandza, (*Albizzia ferruginea*) are exploited in only a few African countries. The bulk of secondary species is not made up of lesser known species, but of species which are well known for specific characteristics such as small diameter, internal stress, lack of stability, difficult seasoning, pinholes, stain, poor durability, etc., which result in higher processing costs (Parent, 1990).

Integrated forest products manufacturing: A paper presents a model of an integrated wood processing complex based on the concept of sustainable forest management for application in the Amazon region. The proposed integrated wood processing complex applies to a site area of 66,168 ha. It includes of 6 sawmills with a total sawn wood capacity of 120 m^3 per day, together with molding and pre-cut wood components sections, 1 small product unit, 1 briquette/charcoal unit, 1 wood cement board unit, kiln dryers, and a thermal-electric generating plant (Iwwakiri, 1992).

Newer sawmills located in the provinces of Johore, Pahang, and Kalantan in Malaysia have been larger, integrated complexes with the capability of processing smaller diameter (below 40 cm) logs (Krutilla, 1987).

Training: As sawmills are modernized and expanded, the addition of new equipment requires more skilled operators, and training becomes even more important than with the use of simpler equipment and older processes. Because a new sawmill in Canada uses technically advanced equipment, job candidates first had to complete appropriate job training. A total of 25 Indian minority candidates took part in job training for 17 mill positions, and all successfully completed the instruction. When Nabakatuk Forest Products purchases a piece of equipment to make the operation more efficient, they want to try to ensure that jobs which may be eliminated are replaced in another area of the operation (Kryzanowski, 1999).

Ethiopian participants in an African workshop in 1989 (Melaku, 1990) felt a need for upgrading the skills of sawmilling operators, saw doctors, and furniture manufacturers through on-job training and seminars.

Lack of knowledge, skill, and training is one of a number of problems in improving conversion technologies in the sawmills of Kerala, India (Muraleadharan, 1989)

Saw maintenance: In the sawmilling industry saws are critical to efficiency in the efficiency, accuracy, and quality of product output. Therefore saw maintenance is of extremely high priority to success and profitability of a sawmilling operation. Saw maintenance problems arei in part due to lack of skilled personnel in the saw doctoring shops and improper supervision. Lack of proper equipment for saw sharpening can also be a factor.

6. Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Veneer and Plywood Manufacture

Some influencing factors, both positive and negative, which are, generally, institutional and not direct part of plant operation are listed in Table 4.

Timber cutting regulations, land use planning, and enforcement: These factors as they apply to veneer and plywood manufacture are the same as described in the section headed with this title under “Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling” (above).

Prohibition of log exports: These factors as they apply to veneer and plywood manufacture are the same as described in the section headed with this title under “Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling” (above).

Reduced impact timber harvesting: These factors as they apply to veneer and plywood manufacture are the same as described in the section headed with this title under “Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling” (above).

Shift from plywood to structural flakeboard production: In the United States there has been a marked increase in structural flakeboard production (OSB), with no increase in structural (unsanded softwood) plywood production. In tropical countries similar effects could occur for unsanded plywood production in countries such as Brazil. Other countries such as Malaysia are feeling the effects of MDF being used in place of some plywood for core material. Blockboard also faces competition from other board products.

A drop of prices on the international market (1992 – 1998) has forced a revision of the Brazilian timber industry (FAO, 1998).

Plantations: This factor as it applies to veneer and plywood manufacture is the same as described in the section headed with this title under “Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling” (above). However, shorter rotation faster growing trees in plantations may be of smaller diameter than existing forest stands. Smaller diameter trees are more easily converted to lumber than to veneer.

Infrastructure: ABIMCI, the Brazilian Plywood Association, considered the 1997 economic crisis the worst ever faced. One of the factor saffecting Brazilian commerce is the so-called Brazil cost or the cost of Brazilian bureaucracy and poor existing infrastructures such as ports, roads, and energy production (FAO, 1998). Other factors affecting infrastructure are as listed under this title in "Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling" (above).

National, regional, or local harvesting codes: These factors as they apply to veneer and plywood manufacture are the same as described in the section headed with this title under "Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling" (above).

Taxes and subsidies: These factors as they apply to veneer and plywood manufacture are the same as described in the section headed with this title under "Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling" (above).

Increasing demand for lesser-used species: In the Amazon, mills pointed out log storage, peeling, drying, and gluing difficulties as deterrents to the increase of species processed for veneer and plywood production (Sobral, 1984b). Other factors affecting infrastructure are as listed under this title in "Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Sawmilling" (above).

Integrated forest products manufacturing: Often, plywood and veneer mills from production of a variety of products in addition to veneer and plywood or a combination of veneer and plywood. This improves the residue utilization factor. Thus, pallet lumber or raw material for blockboard may be manufactured from plywood peeler cores. A total of 40 plants producing plywood, veneer, and blockboard were located in Peninsular Malaysia according to Krutilla (Krutilla, 1987).

Obsolescence, breakdown of equipment, and shortage of spares: In Ghana problems in production from 1973-1988 arose from factors that included obsolescence, breakdown of equipment and shortage of spare equipment and parts. The lumber, plywood, and veneer mills were operating at about 53% of their installed capacities (Anonymous, 1990).

Mills must be brought up to date so that they have precision cutting tools and operate at speeds consistent with high quality product output (Ministry of Primary Industries, Malaysia, 1992).

7. Advanced Technologies and Practices in Developed Countries Which May Not be as Prevalent in Sawmills in Developing Countries

Some advanced technologies and practices in developed countries which may not be as prevalent in sawmills in developing countries are listed in Table 5.

8. Advanced Technologies and Practices in Developed Countries Which May Not be as Prevalent in Veneer and Plywood Mills in Developing Countries

Some advanced technologies and practices in developed countries which may not be as prevalent in veneer and plywood mills in developing countries are listed in Table 6.

9. Survey

The survey portion of the study was conducted in two parts. In the first part questionnaires were designed for distribution by postal services and email to individual producers and associations in Ghana, Malaysia, and Brazil. In mid-July about 10 forms were sent to potential respondents in Africa, about 120 to potential respondents in Malaysia, and about 5 to potential respondents in Brazil. This portion of the survey was not successful, because only one completed form was received from Ghana, one from Brazil, and none from Malaysia. The response from Ghana was only received by FAX on the day this is being written (September 15, 2000). The response from Brazil was received previously.

Copies of survey forms and a transmittal letter are attached on the following pages.

Tropical Timber Pre-Project Study

One Gifford Pinchot Drive
Madison, WI 53705-2398, U.S.A.
Phone: (1) 608-231-9353
Fax: (1) 608-231-9508

August 23, 2000

Dr. Jeziel Adam de Oliveira
Executive Superintendent
ABIMCI
Brazilian Association of Mechanically Processed Wood Industries
Brazil

Dear Dr. Oliveira:

At the Twenty-fourth session of the Committee of Forest Industry of the International Tropical Timber Organization (ITTO), it was decided to undertake a pre-project study to support the development of draft guidelines on increasing utilization efficiency and reduction of losses and waste in the tropical timber production chain. As an initial step, the ITTO has contracted consultants associated as volunteers with the U.S. Forest Products Laboratory to undertake a comprehensive review on previous work related to guidelines on increasing timber utilization efficiency with a focus on sawmilling and plywood manufacturing processes and products in tropical countries.

A part of the study is to analyze producers' efficiency and to compile and assess information and data on policies, measures, and technologies which contribute to finding answers to objectives of the study. We hope that ITTO involvement with investments and sharing of knowledge can lead to improved utilization and make the forest resource go farther at a sustained level of harvest. Utilization of the resource more effectively will also result in increased employment for workers and higher profitability for lumber and plywood producers.

To develop more meaningful information for analysis of overall conditions, we would greatly appreciate your cooperation in completing the enclosed inquiry form. We will, of course, keep individual replies confidential, but summarize responses to provide a meaningful review of conditions industry wide in three tropical countries. These countries are Brazil, Ghana, and Malaysia.

We are hoping to get responses from associations on their views of the industry, in general, and from individual mills on the situation that applies to them.

Please return your response to John I. Zerbe at USDA Forest Products Lab, One Gifford Pinchot Drive, Madison, WI 53705-2398, U.S.A. Your cooperation will certainly be appreciated.

Sincerely,

John R. Erickson, Consultant

John I. Zerbe, Consultant

ITTO Pre-project – *Wood Utilization Efficiency and Reduction of Losses and Waste Throughout the Tropical Timber Production Chain*

Survey Questions for Sawmills

13. What is the annual output of sawn timber, mouldings and millwork in cubic meters?

17. Are products manufactured mainly for the local market or export?

1. Name of association/manufacturer	**2. Region/Country:**

3. Main Products:

14. What is the estimated yield factor in cubic meters of product output in relation to cubic meters of raw material input?

18. What is the principal means for shipping products to market?

4. Main species processed:

15. Is lumber marketed sawn rough or planed? If planing is done, with what type or types of planing equipment?

5. Types of headsaw:	**6. Types of de-barkers:**
7. Systems for trimming and re-sawing:	**8. Types of edger:**

9. Is technical assistance available from qualified people from universities, equipment manufacturers, or consultants?

10. Are there sources of training for special skills such as for the plant manager, the sawfiler, etc.?

11. What percentage of your log supply, if any, originates from plantations as opposed to continuous forest growth?

12. How are logs transported to the mill?

Date:

16. Is lumber marketed green or air- or kiln-dried? Are kilns for drying located on site?

19. What is the targeted end use or disposal objective for residual sawdust, bark, and residual wood from sawmilling?
20. Do you also manufacture other special products such as plywood, I-joists or laminated veneer lumber?

21. Problems encountered:

22. Comments:

ITTO Pre-project – *Wood Utilization Efficiency and Reduction of Losses and Waste Throughout the Tropical Timber Production Chain*

Survey Questions for Veneer and Plywood Manufacturers

10. What is the annual output of veneers and/or plywood in cubic meters?

1. Name of association/manufacturer:	**2. Region/Country:**

3. Main Products:

11. What is the estimated yield factor in cubic meters of product output in relation to cubic meters of raw material input?

4. Main species processed:

5. Type of veneer (sliced or rotary cut):

6. Is technical assistance available from qualified people from universities, equipment manufacturers, or consultants?

7. Are there sources of training for special skills such as for the plant manager, the lathe or slicer operator, or the dryer operator?

8. What percentage of log supply, if any, originates from plantations as opposed to continuous forest growth?

9. Are logs conditioned before they are cut?

Date:

12. Are products manufactured mainly for the local market or export?

14. Do your members also manufacture other special products such as I-joists or laminated veneer lumber?

13. Do your members use bar-coding for inventory and marketing the product?
15. What is the targeted end use or disposal objective for residual bark and wood from veneer cutting and plywood lay-up?
16. What is the principal means for shipping products to market?

Results: The main products of the Brazilian association that responded to the survey are plywood and veneer. The location is in Southern Brazil. The main species processed by the association members are pine, eucalyptus and tropical woods. Both sliced and rotary veneers are cut. Technical assistance is available to the association members. There is training available to the producers from sources such as Manufacturers Federal Associations; however, it is oriented toward furniture manufacturers. About 50% of the log supply originates in plantations.

Question 9 on the survey form may have been confusing. We were interested in knowing whether veneer bolts are pretreated, but the respondent sort of answered that question, but also mentioned sustainable management before cutting down the trees. The response to bolt pretreatment was that logs may be conditioned before actual processing by means such as having the bark eliminated.

Yield factors were stated as follows: from log to veneer – about 55%, from log to plywood – about 40%, from veneer to plywood – about 73%. Association members rarely use barcoding. Members do not manufacture special products such as LVL. Residue wood is used to generate energy, to sell, or it is unused. In Southern and Southeastern Brazil residues are mainly used to generate electricity or they are sold. In Northern Brazil they are used mainly to generate electricity or they are unused. Means of shipping to market are by road domestically or by water internationally.

On the question of problems encountered, they requested that we be more specific. The respondent had no additional comments.

The response from Ghana was from a sawmill in the Western region. The main products are sawn timber, veneer and moldings. The company will soon be in production of parquet, furniture components, finger jointed products and glued laminated products. Main species processed are mahogany, sapele, odum, makore, wawa, ayan, asanfina, akassa, nianoon, chenchen, edinam, candollie, koto, ofram, walnut, mansonia, emery, hyedua, utile, Russia, dahoma. And danta. Technical assistance is available. Types of headsaw was given as Mem, Schulte, Brenta. Logs are not debarked. Processing equipment was given as Brenta resaws, Paul edger, Brenta edger, and Ogan multi resaws. Apparently tey also have a C.Woermann edger. Technical assistance is available to the company. There are sources of training. None of the log supply comes from plantations. Logs are transported to the mill by truck and train.

The annual output of timbers, moldings, and millwork is about 15,000 m^3. Planing equipment includes various molders, a finger jointer, parquet line planer, thickness planer, and thickness and spindle molders. Lumber is kiln dried and a small quantity is air-dried. Products are made mainly for export, and minimally for the local market. Products are shipped to market by water. They are in the process of installing a boiler to provide process steam. They do manufacture special products such as plywood, etc.

The main problem is lack of raw material. Under comments, they stated their intention to produce more value-added products in the future.

The second part of the survey consisted of site visits to sawmills and plywood manufacturing plants in Ghana, Malaysia, and Brazil. The site visits were conducted by John Zerbe, and his report follows.

10. Summary of Site Visits

Observations during the site visits to the three tropical countries bore out many points that appeared in the literature survey. A surprise in the visit to Ghana was the hand peeling of bark. This is probably a satisfactory procedure, considering the availability of labor. But, the Ghana mills did not seem to use the labor as effectively as in Malaysia or Brazil. Triangolo in Curitiba appeared to have a very industrious and productive labor force. At Papan Jaya Sdn. Bhd. Sawmill the labor force also seemed to be dedicated and productive.

One experience that emphasizes literature observation is the shortage of timber in Ghana in comparison to the production capacity. Here there is a tremendous need to improve efficiency and reduce waste. In Brazil too, many mills have shut down because of timber procurement. Here environmental regulations may be a contributing factor, but as Johan Zweede from his long experience in the Amazon area pointed out there is a great need for both low impact logging and better recovery in sawn wood manufacture. With the size of cores from peeling veneer that I saw the same should hold true for plywood manufacture. Malaysian mills seemed to have fewer problems with timber supply, although they may have to deal with smaller logs.

Plantations seem to be a good approach to a sustainable timber supply in Southern Brazil, but this approach was not evident elsewhere. Recovery factors were usually stated to be around 50%, but without knowing more about accuracy in measuring input and output and having a good material balance the stated figures are questionable.

I see a need for gaining more efficiency with much wider application of computerized control. Here the tropical countries seem significantly farther behind standard practice in the U.S. In the mills that I visited there was fairly good use of wood residues to provide in-house process heat. There could be some improvement in efficiency of wood burning, and wider use of energy from wood to generate electricity.

I was surprised and elated with the good receptions and cooperation of the plant managers and their staffs. I also appreciated all of the help which I received from the people who were my sources of transportation and language translators in all of the locations which I visited.

11. Conclusions

The results emphasize the desirability of applying advanced technologies to improve the production efficiency and reduce waste in tropical countries, We hope that support can be provided in helping the mills attain better product yields and meet increasing demands with sustainable forest production. The producers want to make improvements in order to accomplish more with the available resource.

There needs to be a better approach to surveying the current state of technology with questionnaires. Perhaps simpler forms could be developed. Perhaps it would also be desirable to make follow-up calls by telephone after forms have been sent. Perhaps questions on production quantities are thought to be too prying by some recipients.

In the United States the work of the U.S. Forest Products Laboratory has embodied these principles consistent with good forest management for the last 90 years. Utilization efficiency has grown steadily. But, with the gains in utilization efficiency, there have also been increases in opposing forces. Over the years harvests of saw logs have gone to including logs of lesser minimum diameters, and the overall quality of the harvested timber has decreased. Today in the U.S. a high priority management problem is small diameter utilization. In tropical countries these are parallel problems to those of the U.S. Perhaps the major problems in tropical countries are the utilization of secondary species. In the U.S. as in tropical countries practices in saw milling and plywood manufacture together with the use of products from these processes in secondary and tertiary processing are major determinants in gaining acceptable utilization levels.

As noted throughout the report an important sequel to sustainable forest management is the gearing of utilization practices to gain the maximum volume and value of products from the harvested resources in line with sustainable and best use as well as other environmental considerations. Some of these concerns should be conservation of energy from fossil fuel usage, sequestration of maximum amounts of carbon, recycling and re-use of the resource, and protection of soil, air, and water from increased pollution. Fundamental to all of these objectives are utilization practices that provide maximum efficiencies in product output and minimal waste of the raw material.

The following sections provide the major conclusions of the report.

<u>Factors Influencing Efficiency and Reducing Waste in the Production of Lumber</u> may be outlined as follows:

1. Computerization of Bucking, Log Breakdown, and Defect Sensing Operations
2. Statistical Process Control
3. Obsolescence
4. Type of Headsaw and Saws for Secondary Operations Including Edging and Trimming
5. Saw Configuration and Maintenance
6. Supervision and Training
7. Sawing Procedure (Live sawing, cant sawing, curve sawing)
8. Value Adding on Site (Drying, Molding)
9. Collateral Operations (Finger jointing, Chipping, Specialty product manufacture, Fuel use)
10. Sale of Blocks and Shorts to Other Users such as furniture manufacturers
11. Inventory Control
12. Debarking
13. Marketing Intermediate Lengths of Sawn Products

Computerization of bucking, log breakdown, and defect sensing operations are not commonly used in developing countries; but, they are essential to improving product yield. Other applications of computers include controlling dry kiln and molder operations. One of the most apparent shortcomings in sawmills in developing countries in comparison to practices in developed countries is the lack in application of computer technology to enhance recovery.

Software that can be used in these computer applications is readily available, and, in some cases, it is available free of charge. The U.S. Forest Products Laboratory developed computerized log breakdown technologies in the 1970s. Computerized scanning of boards to optimize recovery of clear cuttings has been studied at several laboratories. One is the Forestry Sciences Laboratory at Princeton, West Virginia, U.S.A. A 1992 report by Sun Joseph Chang of the National Agricultural Library of the U.S.A., "External and Internal Defect Detection to Optimize Cutting of Hardwood Logs and Lumber, " provides a comprehensive review of potential solutions to this problem. A recent installation of an "Optimizer" at Cikel in Belem, Para, Brazil saves significantly on waste and human labor. Through use of this machine yield of product was increased from 75 to 86 percent and labor requirements were reduced from 45 people to 9.

Statistical process control is a quality inspection technique. It incorporates procedures to successfully collect, analyze, and interpret lumber size variation. It is designed to be used with the Statistical Process Control-Lumber Size Analysis computer routine developed by the Forest Service of the U.S. Department of Agriculture. The primary objective of production center monitoring is to systematically evaluate and optimize the material passing through. Three key elements to production center monitoring are 1) condition of equipment, 2)maintenance monitoring, and 3) lumber size control.

Obsolescence is a hindrance to efficient sawmill operation. In Ghana mills built in the late 1940s and the 1950s stymie efficiency. These older mills are subject to more frequent breakdowns, may be subject to greater structural deficiencies from wear and tear, and have more difficulty in obtaining spare parts when they are needed. Tropical countries may also have to contend with spare parts inventories at locations, which are far from production sites. A study found some 40 traditional small, circular sawmills survived in Latin America under very bad economic conditions, almost without external support. Sawmill installations and machinery were between 10 and 40 years old. Problems included shortage of spare parts, high waste factor, and poor quality.

Mills must be brought up to date so that they have precision cutting tools and operate at speeds consistent with high quality product.

Types of headsaws and saws for secondary operations including edging and trimming are important to obtaining sawmill efficiency. Although circular headsaws are used, and are more easily maintained than band saws they generally saw wider kerfs to create more sawdust. When a sawmill in Ghana purchased a new edger with a thinner kerf saw, efficiency rose by 30 percent.

Saw configuration and maintenance complement saw selection to enable most efficiency in the sawing operation. Improved metal alloys such as stellite perform better with thinner cross sections. Many sawing problems are related to maintenance. Among these problems are saws being used when dull, gullet burn while sharpening, incorrect and uneven tension, uneven crown, burrs left in gullet when sharpening, faulty wheel bearings, saw too thick for wheel diameters, and band mill vibration. These problems result partially from a lack of skilled personnel in the shop and management.

In most, if not all, tropical countries high species density and silica content pose problems for sawing. The clearance angle is apparently kept high to reduce feed force and prolong the life of the tooth and blade. Most saw sharpening machines are not equipped with cams for changing tooth profiles, which might partially explain the predominant use of the flat-bottom shape. Many experts agree that this shape is not the ideal tooth profile for cutting medium to high-density species, but it has proved in many countries to be capable of meeting all basic requirements. Unless the sawmill industry is prepared to sort logs according to density groups and/or abrasiveness of species, there appears no need to introduce another tooth shape.

Although almost all sawmills have facilities for band saw maintenance, the typical saw filer does not know the profile, tooth height, angles, swage, or other parameters about the saw. Most commonly reported saw milling problems throughout developing countries include poor maintenance, lack of trained personnel, obsolete equipment, and inadequate saw tooth geometry and wear resistance.

Supervision and training must be enhanced if sawmills are to be successful in producing quality products at high efficiency. Many maintenance problems at sawmills result partially from a scarcity of skilled personnel at all levels. In a previous study of sawing technology in five tropical countries one of the most commonly reported problems was lack of trained personnel. There appears to be a need for more attention to regional training centers for sawmill personnel.

An excellent training facility is the Timber Industry Training Center operated in conjunction with the Forest Research institute, Rotorua, New Zealand. An earlier training facility for saw milling said to be operated in the Amazon basin in the 1950s by FAO points to a possibility and desirability for renewal or reinstatement today. Such an effort might be an area for cooperation between FAO and ITTO.

Sawing procedures (live sawing, cant sawing, curve sawing) can influence product yield significantly. With smaller logs and logs with crook and sweep being more common, curve sawing and end dogging may result in better recovery factors. To produce defect-free dimension lumber, a cant sawing routine is common; but, live sawing may be preferable. This appears to be the case in sawing smaller diameter and lower grade logs.

A study investigated the advantages of live sawing over conventional grade sawing of red oak factory logs with an emphasis on dimension yield rather than lumber yield. Goal was to gain the maximum dimension yield by feeding un-edged, live-sawn boards into the rough mill (rough mill simulators), these boards were analyzed in the un-edged as well as the edged condition to allow yield and value comparisons with normally edged grade sawn boards. Consistent results suggest that log grade and log value are relatively poor predictors of lumber value and dimension yield. Live sawing was superior in all scenarios.

Value adding on site (drying and molding) produces greater efficiency and less wastage in addition to higher revenue, since less material and contained moisture must be shipped and there is less chance for de-grade during shipping.

Collateral operations (finger jointing, blockboard, specialty product manufacture, chipping, fuel use) are value adding solutions to elimination of waste and the need for waste disposal through incineration or land-filling without value recovery. If residues are not used in these ways on-site they can sometimes be sold or given away for similar purposes.

The manufacture of finger-jointed studs from short lengths salvaged from stacked boards and slabs, which would have been chipped in the past, is becoming increasingly common. Other structural members and moldings are also finger jointed. In some cases structural finger jointed members may only be certified for vertical or compressive loads, but sometimes, particularly with machine stress rating (MSR), they may also be suited for horizontal or bending loading. Blockboard and other uses in the furniture industry may be an outlet for shorts. Other specialty items include such items as umbrella handles, fence posts predrilled for electric fencing, and vegetable stakes. Chipping can produce material for such uses as paper, mulch, playground ground cover, or fuel.

Depending on costs for alternative sources of energy, uses of residues for fuel may be of lower economic value; however, most plants should probably be using residues for space heating and/or process energy, and using residues for fuel for on-site power generation is often a good possibility. Wood fuels, in special cases, may be used for energy in brick and lime kilns, or for fuel in cement manufacture.

Sale of blocks and shorts to other users such as furniture manufacturers may be an alternative opportunity to processing such residues at the sawmill manufacturing site.

Inventory control is a factor that could be improved to the advantage of many tropical country sawmills. Often bar-coding would be a big assist to record keeping of inventories of input materials, and product output through the production and distribution chain, but bar-coding is seldom utilized. Communication between producers and customers might be improved through Electronic Data Interchange. It would be necessary to affix barcodes on every piece of lumber and to maintain a self-replenishment stock of lumber at the reload site of the customer. In return a long-term agreement involving the delivery of large volumes of wood would be expected.

Debarking at mills sometimes is not practiced when it could lead to better uses of wood chips for such purposes as papermaking. How logs are debarked may be important for yield of chips of higher value as well as for facilitating scanning and eliminating rocks and debris that could dull saws.

Marketing intermediate lengths of sawn products is a possibility that should be investigated. ITTO should consider encouraging lumber purchasers to import lumber in a greater variety of length classes. For instance for purchasers of lumber in lengths in multiples of two feet such as 10, 12, 14, and 16 feet, there could be reduction of wastes for producers if they could ship lengths of 7 feet, 8 feet, 9 feet, 10 feet, and 11 feet instead of only 8 feet and 10 feet.

Factors Influencing Efficiency and Reducing Waste in the Production of Plywood

1. Computerized Control
2. Obsolescence
3. Collateral Operations (Laminating, I-joists, MDF, Printing, Molding)
4. Inventory Control
5. Control of Peeler Core Diameter
6. Supervision and Training
7. Pretreatment
8. Niche Markets
9. Bucking

As in the lumber industry in developing countries, with plywood there are also some primary practices and deficiencies in taking needed actions that affect production efficiency and waste reduction adversely. For manufacturing plywood some of these factors are the same as with lumber. Or they may be in the same general category but have different implications and different orders of priority. For plywood there are some factors that are unique.

Sometimes ways of improving both lumber and plywood manufacture are interdependent. For instance veneer may be used to overlay utilization of lumber in blockboard or finger jointed products. In a unique circumstance wastes from lumber and plywood are combined to make a product that, in some cases, competes with other lumber and plywood products.

In Sarawak two MDF plants use large amounts of both lumber and plywood manufacturing residues. Daiken Corp of Bintulu, Sarawak has a capacity of 96.000 m^2/yr and Sampling Fibreboard lines I and II of Miri, Sarawak have a combined capacity of 100,000 m^2/yr. With lamination and overlays MDF board provides an ideal basic material in various kinds of secondary wood processing industries, such as housing including panels for interior use, furniture, and doors. The demand for thin MDF has a strong potential for use as an alternative to plywood. A growing use is as a substrate for circuit board manufacture, which is a growing industry in Asia. High density MDF (HDF) has a potential for growth. Perhaps it could be used as a core material for three-layer engineered parquet flooring.

The two Sarawak plants, started in 1996 and 1997, process mixed tropical hardwood waste. The waste is made up entirely of peeler log cores, veneer rejects, and sawmill off-cuts. The utilization of mixed species may be an approach that could help in utilizing lesser used species. But, some species are also less desirable for MDF manufacture. While rubberwood has many excellent characteristics for use in MDF, an inherent drawback is the latex that exudes after harvesting and coagulates at the log ends.

Computerized control is important to plywood and veneer manufacture as well as lumber. The Forest Products Laboratory has developed a Veneer Analysis Routine (Veneer Manufacturing Program) to facilitate greater recovery from logs utilizing log information collected by Log Analysis in the FPL IMPROVE computer program.

PlyTech is a program designed to help Borden chemical Inc. plywood customers improve their processes and product quality by using continual improvement tools. PlyTech provides the platform for monitoring current and historical trends of critical process variables. PlyTech also offers users the ability to access data more easily for generating reports and analyses. PlyTech producers must register with Borden Chemical staff, Columbus, OH to use PlyTech. Using Internet Explorer 4.01, any authorized user can access the program through the Internet.

In Canada, Levesque Plywood of Hearst, Ontario has mechanized its production with computer technology as much as possible.

Obsolescence in veneer and plywood manufacturing equipment is hindering efficiency and waste reduction considering the new and improved machinery that is available today.
Coe Manufacturing has developed a whole new conversion process to make peeling veneer more efficient.

Collateral operations (laminating, I-joists, MDF, printing, molding) besides producing additional profit centers, and making veneer and plywood plants more competitive, also facilitate increasing efficiency and reducing waste. Technology developments in laminated veneer lumber include increasing use of ultrasonic veneer graders so that a substantial quantity of the veneer supply is routinely tested for possible use of laminated veneer lumber, rather than only for plywood. This development has contributed to a 75 percent increase in production of laminated veneer lumber and a threefold increase in I-joists in the United States from 1990 to 1996.

Inventory control using the latest bar-coding techniques should be a boon to veneer and plywood industries as well as sawmills. This is especially true in the case of sliced veneers in which case it is important to keep track of flitch components through the chain of production and use.

Control of peeler core diameter and using peeler cores effectively in other products are important to production efficiency and reducing waste. At the U.S. Forest Products Laboratory, a powered back-up roll was designed and built for the purpose of providing auxiliary torque to a veneer bolt. The powered back-up roll can supply a substantial percentage of the required torque. This reduces the likelihood of spin-out occurring and allows a reduction in the final core size when used in conjunction with smaller chucks.

The new process developed by Coe Manufacturing begins by peeling small blocks on an extraordinary 4-foot lathe. The high-speed lathe will peel blocks an initial diameter of 4 inches or less to a 1-inch core. Larger-diameter peelers (7 inches and more) can go to an 8-foot lathe. Veneer from the 4-foot lathe is end-glued into sheets up to 80 feet long. Random width material can also be glued into sheets of the desired width. After the maximum amount of quality veneer has been peeled and relatively small diameter cores remain, they may be effectively used in such products as pallets, blockboard, pulp chips, and fuel.

Pretreatment of logs or veneer bolts can make them more valuable. In order to facilitate peeling to plywood veneer, it is often necessary to pre-treat by heating and soaking some timbers while others, such as mahogany, can be peeled cold. Where pretreatment is required, the manufacturer has the choice to crosscut the plywood log into bolts prior to treatment or to pre-treat the whole log and then crosscut. One study indicated that it may be advantageous to pre-treat all tropical hardwoods in the log form and then to crosscut to minimize degrade during the crosscutting process.

Niche markets provide a means for plywood producers to add value and manufacture more efficiently in the face of competition from OSB. Survivors in the plywood industry are converting a significant proportion of their production to laminated veneer lumber-type veneers and value-added plywood. Although plywood production in the U.S has dropped significantly since 1995, sanded plywood production has been holding steady. Many plywood producers have identified niche markets such as boat builders, furniture manufacturers, truck trailer companies and other users. The traditional separation of the plywood business into hardwood and softwood segments will blur as product, raw material, and customer demands overlap.

Bucking logs accurately and eliminating unneeded length can save significant amounts of timber. According to a study, crosscutting volume losses amounted to 8.0 percent in a mill in Ghana but only 3.2 percent in a United Kingdom plywood mill. The skill employed during the crosscutting process was seen to affect the amount by which the log raw material could be upgraded.

Incentives for Mills to Increase Efficiency and Reduce Waste. To enhance profitability in addition to having conscientious concern for protecting the environment and conservation of the resource, mill owners are deeply interested in becoming more efficient. Conservation is particularly pressing in Ghana where shortages of principle species are a predominating problem. Usually the greatest deterrent to upgrading facilities and implementing improvements in procedures, controls, and training is a lack of funding. Mill owners might be more amenable to taking out loans, and funding agencies might be more prone to make loans if assistance and software programs were available to show how investments could be paid back in a reasonable time.

Another approach would be to subsidize investments in greater productivity through development projects to provide job opportunities and community stability. Another possibility would be investment credits for reducing carbon emissions. Nigel Asquith writing on, “The Kyoto Protocol, ITTO and Tropical Forests,” in Volume 10, Number 3 of Tropical Forest Update states that there are three ways of producing the forest carbon commodity. These are 1) planting trees to remove carbon from the atmosphere; 2) maintain carbon stocks and prolong carbon storage in biomass; and 3) conserving and protecting forests.

One project in Malaysia cited by Mr. Asquith is estimated to prevent the release of 80 tons of carbon per hectare in the first two years post harvest through reduced impact logging. Similarly, if recovery factors could be increased by 5%, fewer trees would need to be harvested to produce the same amount of products, and there would be less waste for disposal in the short term. The savings through improved product recovery could be as great as the savings from reduced impact logging.

Enrichment planting in the Malaysian planting project is expected to offset 100 tons of carbon per hectare per year over a 60-year rotation. If harvested trees were to be manufactured into products that had a service life of 60 years more carbon would be sequestered in the products than in the growing trees. This is because over a 60 year rotation maximum carbon storage would only be obtained when the growing tree reaches its final size. Also, after harvesting it may take some time for new growth to be established (regeneration). Conceivably, If all wood harvested after a 6-year rotation were to be converted into products for a service period of 60 years, 2.5 times as much carbon would be stored in the products as in the growing trees.

Another advantage to using wood is the advantage in reduced carbon emissions from fossil fuel used in processing. Wood requires less energy for processing, transportation, and use than other structural materials such as steel, aluminum, plastics, and concrete. Higher recovery factors in processing wood would heighten this advantage.

Sustainability and Higher Utilization Standards. Sustainability in tropical forests is manifested not only in the extent of the forests, but also in the forest makeup. In many cases desirable species are being depleted, while other lesser used species are more readily available. Net gains in processing efficiency and waste reduction will be reflected in the availability of more principal species.

12. Strategies and Actions for Draft Guidelines

The final section to this report provides possible strategies and actions for the development of guidelines on increasing the recovery at the mill site, certification of mill efficiency and recovery processes, development of criteria for target recovery factors, subsidizing the replacement of obsolete equipment, and other techniques to enhance the use of secondary species. Based on this study future work in this area should consider the following principles and recommended actions:

1) Just as there is certification for producing timber from forests that are managed for sustainability and adequate observation of environmental values, there should be developed criteria for certified production of saw milling and plywood products over the long term.

2) ITTO should develop criteria for target recovery factors for lumber, rotary-cut, and sliced veneer.

3) For lumber, criteria will be different depending on type of product, i.e., structural lumber, dimension for furniture, or factory and shop lumber. There should be procedures for calculating lumber recovery factors that can be applied uniformly. There should be different acceptance criteria for special situations such as manufacture of lumber from trees harvested from rubber plantations.

4) To determine performance and yield at representative sawmills there should be pilot mill studies sponsored by ITTO. Otherwise if existing yield data developed by plant personnel are relied upon, there will be inconsistencies depending on how different mills calculate their recovery factors. Very successful mill studies were conducted in the U.S. to determine lumber recovery factors in the 1970s. From the results of these studies, technologies were developed and applied that increased overall recovery factors significantly.

5) Similar studies to those for lumber should also be conducted to gain recovery factors for representative veneer and plywood manufacturing plants. Different criteria will apply to rotary-cut and sliced veneer, decorative and structural grades of plywood, and exterior, marine, and interior use grades of plywood. Studies should cover both volume and grade recovery.

6) To evaluate waste reduction, representative and cooperating mills should be studied to evaluate utilization of bark, chips, shorts, sawdust, edgings, slabs, round-up waste, trimmings and flitch boards for such purposes as end and edge glued material; finger jointed material; material for containers, dunnage, and pallets; blockboard; paper; and in-house or externally-used fuel as in the manufacture of bricks, lime, or Portland cement. Such utilization contrasts with incineration or burial (land filling) without benefit. When ash from waste utilization for fuel serves as fertilizer or other purposes such as admixture with Portland cement this should be considered as an added benefit.

7) ITTO should support, promote, and encourage policies, practices, measures, and technologies that influence utilization efficiencies and waste reduction in saw milling and veneer and plywood manufacturing industries. These are enumerated as follows:
    a. Repair, expand, or replace obsolete equipment to obtain up-to-date production capability.
    b. Enhance utilization and marketing of secondary species.
    c. Accommodate utilization of raw material that results from low-impact harvesting.
    d. Work with tropical country governments to determine if tax concessions such as accelerated depreciation and other subsidies such as low-interest loans that reward efficient utilization are possible and desirable.

e. Develop software to enable manufacturing plants to determine payback times for investments to enhance production efficiency and reduce waste
f. Explore possibilities for financing improvements through payments for reducing carbon emissions.
g. Optimize saw milling capabilities through broader application of computerization, use of thin kerf saws, hiring of competent or trainable workers, emphasizing training especially for such skills as saw doctoring, operating with minimal dressing and bucking allowances, implementing statistical process control (SPC) techniques, and using saws with long-wearing teeth that are properly set for species being cut.
h. In situations where conditions warrant, apply technologies such as Chip-N-Saw.
i. Where small diameter and misshaped logs are common, implement technologies such as curve sawing and end dogging.
j. Improve operations corollary to sawing including molding and drying.
k. Optimize veneer and plywood manufacture through use of up-to-date equipment; particularly veneer lathes that cut to minimal core diameter consistent with production of veneer with acceptable quality.
l. Optimize gluing of plywood; hot-pressing of some glues may not be needed although hot-pressing of interior glue lines appears to be common.
m. Use pretreatment of veneer logs by steaming or soaking where this results in improvement of yield and/or quality and is therefore cost effective.
n. Optimize corollary operations including drying of veneer and sanding of plywood; sanding may not be needed with structural grades of plywood.
o. Strengthen inventory control throughout the production and distribution chains with wider use of barcoding.
p. Implement residue utilization widely in saw milling and veneer and plywood manufacturing operations. Improve and expand technologies for utilizing veneer cores, finger jointing, and blockboard manufacture.
q. Combine residue utilization techniques such as finger-jointing with non-destructive testing (NDT) to select material for structural members for I-beams and laminated veneer lumber (LVL). Expansion of plywood production to manufacture special items such as these may be an effective means for combating loss of structural plywood markets to particleboard products.
r. Pursue avenues for marketing other specialty items such as fence posts and vegetable stakes.
s. For residues in excess or unsuitable for product use, which may include bark and sawdust, use the residues for fuel to the extent possible. Fuel for space heating and cooling, process energy, and electricity should be high priority. Open burning with pollutants escaping to the air should be avoided in all areas, including those where the practice is legal.
t. Consider encouraging lumber purchasers to import lumber in a greater variety of length classes.

13. Tables

Table 1. Literature References to Conversion Efficiencies and Technologies to Improve Conversion Efficiencies in Saw Milling

Cited Conversion Efficiency	Technology Applied to Improve Conversion	Reference
	Patch stellite tips manually	2,
59% and 61%	Wood-Mizer	5,
	Computerized lumber sorting	13, 97
31%	Utilizing below-grade logs and green dimensioning	14, 70, 74
Increasing lumber recovery factor by 6.6%	Monitoring and controlling sawing variation	15, 16, 19, 20, 29, 32, 113, 169
	Adding value through drying, planing, and structural grading	24, 28, 99, 103, 136, 138, 160
	Statistical Process Control	32, 62, 169
Increasing lumber recovery factor by 2.5%	Monitoring and controlling log over-length	20, 29
	Increased sales of chips, sawdust, and bark	20, 45
Conversion of 7000 m^3 to 2700 m^3 of lumber	Expansion to edge-glued panels and flooring to utilize more material	57
Mean recovery rates of 44.1% rough green lumber, 4.3% by-products, 6.2% sawdust and 45.4 % solid residues		63
	Computerized lumber scanning and cutting for grade and/or yield recovery	69, 90, 150. 162
Recovery in the Malaysian Timber Industry is about 54.5%		71
	Short log utilization	90,
	Decrease planing allowance	113
	Decreasing over sizing	113
	Supply chain management	124
In Indonesia, residues from saw mill production are about 50 percent		
	Sorting for moisture content	128
	Camera scanning for computer optimized bucking	128
Log recovery study		135
	Computerized log sorting	137, 141
	Small Log Utilization	141, 142, 146, 174
	Measuring output/input electronically	148
	Scaling small logs	151
In Sabah lumber recovery from different grades of teak logs was 30 and 23%		166
Recovery rates from rubberwood are 15-35%		167
	Curve sawing	170

Table 2. Literature References to Conversion Efficiencies and Technologies to Improve Conversion Efficiencies in Veneer and Plywood Manufacture

Cited Conversion Efficiency	Technology Applied to Improve Conversion	Reference
8% loss in Ghana and 3.2% in UK	Crosscutting and pretreating logs	1, 55
	Computer Monitoring of Process Variables	3,
Recovery for sliced veneers ws 23 to 35% for asanfena, but 39% for makore; On average, 7.2$% flitch boards resulted. Yield of wet rotary veneer ranged from 52 to 77%; the residual peeler core was about 15%		63
Recovery in the Malaysian Plywood Industry is about 45%		71
	Computerized pro-duction technology	96
	Heating veneer bolts with hot water, steam, or electricity	115
In Indonesia, residues from plywood production are about 55 percent		
	Small diameter log utilization	174
	Improved veneer drying	109,114,119,120, 121.122, 153,164

Table 3. Literature References to Policies, Practices, Measures, and Technologies which Influence Utilization Efficiency in Saw Milling

Policies and Practices that Influence Conversion	Reference
Obsolescence, breakdown of equipment, and shortage of spares	4, 25, 130
Timber cutting regulations, land-use planning, and enforcement	6, 51, 84, 85, 86, 89, 130
Controlling personnel performance	15, 16
Cooperative ownership of logging and sawmill operations	17, 154
Decrease taxes so wood industries can modernize	27, 53, 73, 85
National, regional, or local harvesting codes	33, 48, 51
Prohibition of log exports	35
Reduced impact timber harvesting	37, 43, 44, 51, 175. 176
Lowered residue utilization because of no debarking	40, 133
Plantations or “farmed forests”	46, 50, 143, 146
Infrastructure such as ports, roads, and energy supply	47, 80, 83, 175, 176
Control of insect infestations	54, 131
Increasing demand for lesser-known timber species	64, 78, 82, 85, 86, 126, 129, 131, 139, 146, 152, 153, 172
Integrated forest products manufacturing	93, 94
Job training on switching to less labor-intensive operation	98, 126,128, 133
Saw maintenance , saw tooth geometry, and wear resistance	111

Table 4. Literature References to policies, practices, measures, and technologies which influence utilization efficiency in Veneer and Plywood Manufacture

Policies and practices that influence conversion	Reference
Timber cutting regulations, land-use planning, and enforcement	6, 51, 85, 86, 87, 89, 130
Prohibition of log exports	35,
Reduced impact timber harvesting	37, 43,44, 51, 175, 176
Shift from plywood to structural flakeboard production	39, 46
Plantations or "farmed forests"	46, 50, 143, 146
Infrastructure such as ports, roads, and energy supply	47, 52
National, regional, or local harvesting codes	33, 48, 51
Subsidies and tax exemptions	27, 53, 73, 85
Increasing demand for lesser-known timber species	85, 86, 87, 92, 129, 131, 134, 139, 146, 152, 153, 172
Integrated forest products manufacturing	94
Obsolescence	4, 130

Table 5. Advanced Technologies and Practices in Developed Countries Which May Not Be as Prevalent in Sawmills in Developing countries

Country	Technology or Practice	Reference
U.S.	Live sawing instead of grade sawing for production of dimension for furniture	9, 105
U.S.	Systematic reengineering through modeling and use of barcodes	10,
France	Systematic tree modeling to predict log grade yield	12,
Australia	End-dogging head rig for small logs	30
Germany and U.S.	Reduced saw kerf width	31, 113
Germany	Fully automated sawmills	31
U.S.	Finger jointing studs (structural members)	51, 58
U.S. and others	Non-destructive testing	51, 95
U.S.	Sawing simulation models such as "Best Opening Face"	60, 61, 159
Canada	MSR finger-jointed lumber	95
Japan, Europe, and the U.S.	Direct processing systems for converting low grade timber resources into high value solid wood products	14, 70, 74, 106, 107

Table 6. Advanced Technologies and Practices in Developed Countries Which May Not Be as Prevalent in Veneer and Plywood Manufacturing Plants in Developing countries

Country	Technology or Practice	Reference
U.S.A.	Making higher value products such as LVL	8, 178
U.S.A.	Seek niche markets such as boats, furniture, and truck/trailers	8
U.S.A.	Combine special 4-ft lathe with 8-ft lathe production	8,
U.S.A.	Pretreatment through dielectric heating	11,
U.S.A. and others	Non-destructive testing	51
U.S.A.	Auxiliary torque back-up roll	66, 68

14. Bibliography

1. Adams, M.J. Effect of Crosscutting and Pretreatment on Plywood Log Upgrading. Forest Products Journal; November 1976; 26(11): 40-41.

Crosscutting volume losses amounted to 8.0 percent in a mill in Ghana and 3.2 percent in a United Kingdom plywood mill. The skill employed during the crosscutting process was seen to affect the amount by which the log raw material could be upgraded. Up grading during log-to-bolt conversion can represent an important addition to raw material quality and ultimately to veneer yields. Pretreatment of the logs can also affect raw material upgrading. In order to facilitate peeling to plywood veneer, it is often necessary to pre-treat by heating and soaking some timbers while others, such as mahogany, can be peeled cold. Where pretreatment is required, the manufacturer has the choice to crosscut the plywood log into bolts prior to treatment or to pre-treat the whole log and then crosscut. From observations made during this study the indications are that it may be advantageous to pre-treat all tropical hardwoods in the log form and then to crosscut to minimize degrade during the crosscutting process.

Keywords: Plywood, Veneer, Yield, Pretreatment, Quality

2. Andersen, Jens. Patch Stellite Tips Manually to Save Time and Money. Wood Technology; June 1999; 126(5): 42-42.

Manual tipping of saws is practical for patching machine-tipped saws that have had several teeth injured. Instructions are given.

Keywords: Sawblades

3. Anonymous. Program Monitors Variables to Improve Plywood Quality. Wood Technology; August 1999; 126(7): 28-29.

PlyTech is a program designed to help Borden chemical Inc. plywood customers improve their processes and product quality by using continual improvement tools. PlyTech provides the platform for monitoring current and historical trends of critical process variables. PlyTech also offers users the ability to access data more easily for generating reports and analyses. PlyTech producers must register with Borden Chemical staff, Columbus, OH to use PlyTech. Using Internet Explorer 4.01, any authorized user can access the program through the Internet.

Keywords: Computer control, Quality

4. Anonymous. Seminar on "The Promotion of Further Processing of Tropical Hardwood of the African Region," 13-16 February, Accra, Ghana. Status Report on Ghana Timber Industry. Yokohama, Japan: International Tropical Timber Organization; 1990; Document No. 9.

In Ghana over 1/4 million are employed in the timber industry, and the industry provides direct livelihood to about 2 million people (about 14% of the population) The number of sawmills was given as 100 and plywood mills as 9 with veneer milling as 13. State-owned enterprises are Mim Timber Company, Africa Timber and Plywood, Gliksten (WA), Takoradi Veneer and Lumber Co., Ltd. Ewhia Wood Products, Kumasi Furniture and Joinery Company, Wood Supply (Gh) Ltd., Bibiani Wood Complex and Western Timbers. Problems in production from 1973-1988 arose from factors that included obsolescence, breakdown of equipment and shortage of spare equipment and parts. The lumber, plywood, and veneer mills were operating at about 53% of their installed capacities.

Keywords: Plywood industry, Lumber industry, Employment, Production, Ghana, Africa

5. Ayarkwa,J. and Addae-Mensah, A.G. Utilization of Savannah Tree Species: Some Processing Characteristics of *Anogeisus leiocarpus* (Kane) and *Khaya senegalensis* (Khaya). Wood-News; 1997; 7(3): 6-11.

Sawing characteristics and lumber yields from *Anogeisus leiocarpus* (Kane) and *Khaya senegalensis* (Khaya) have been studied using the Woodmizer, which uses horizontal bandsaws. The study has

shown that lumber yields from Kane and Khaya are very high. The mean lumber yield of Kane and Khaya were 59% and 61% respectively for the logs selected for this study. The average dbh for Kane was 50 cm and 60 cm for Khaya. Tree heights in each species were 20m.

Keywords: Logging, Yield, Costs, Logging Damage, Tropical forestry

6. Bach, Christian Friis. Economic Incentives for Sustainable Management: A Small Optimal Control Model for Tropical Forestry. Ecological Economics; 1999; 30(2): 251-265.

The model was constructed within an integrated framework including both the biological and the economic implications of timber extraction. A direct subsidy to low-impact logging activities through area-dependent subsidies was found to be a method far more efficient than subsidizing prices of tropical timber. The model takes a novel approach in combining growth and stock in a tropical forest area with the cost and damage connected with timber extraction. Different policy options to promote low-impact logging through the use of economic incentives were evaluated. The model permits analyzing the interactions among stock, growth, timber extraction, logging damage, and operating costs in an integrated manner. There is no doubt that in Ghana conversion of forest land to farming or plantation activities is the main cause of forest destruction. Proper land-use planning and enforcement is thus one of the foremost conditions if the forest resource is to be protected. Ghana has strict cutting regulations, but how far they are observed is difficult to evaluate. A major bottleneck is the severe lack of capacity and resources within the Forestry Department. Monitoring and evaluation seems inadequate due to lack of technical staffing, equipment, and motivation. Furthermore, the activities prescribed in the logging manual published in 1992 are generally not followed or enforced. Directional felling is not used; skid trails and roads are not planned on the basis of a topographic map but more or less randomly constructed after the trees have been felled. Clearly, damage on the residual stand could be reduced if the logging manual were strictly followed and enforced.

Keywords: Logging, Timber extraction, Yield, Cost, Tropical forestry

7. Balanakura, Nik (Trade and the Environment Database). Malaysian Raw Wood Export Ban (MALAY). Internet: http://www.american.edu/projects/mandala/TED/MALAY.HTM.

The aim of the Federal Government is to increase exports of sawn wood instead of raw logs, to generate increased profit, and to reduce the need to export raw logs. A complex and uneasy alliance between two groups has been mainly responsible for the huge amounts of deforestation that Malaysia has suffered over the last several decades. The first group consists of Chinese business interests. The second is the state bureaucracy, mainly Malay. In December 1992 the Federal Government imposed a temporary freeze on the export of raw logs from Sabah.

Keywords: Trade, Export, Lumber, Malaysia

8. Baldwin, Richard F. Plywood's New Pioneers Meet Future's Challenges. Wood Technology; March 1999; 126(2): 43-45.

Faced with competition from OSB in sheathing, plywood producers are adding value and manufacturing more efficiently. Survivors in the plywood industry are converting a significant proportion of their production to laminated veneer lumber-type veneers and value-added plywood. Although plywood production in the U.S has dropped significantly since 1995, sanded plywood production has been holding steady. Many plywood producers have identified niche markets such as boat builders, furniture manufacturers, truck trailer companies and other users. The traditional separation of the plywood business into hardwood and softwood segments will blur as product, raw material, and customer demands overlap. Coe Manufacturing has developed a new conversion process. The process begins by peeling small blocks on an extraordinary 4-foot lathe. The Coe high-speed lathe will peel blocks an initial diameter of 4 inches or less to a 1-inch core. Larger-diameter peelers (7 inches and more) can go to an 8-foot lathe. Veneer from the 4-foot lathe is end-glued into sheets up to 80 feet long. Random width material can also be glued into sheets of the desired width. The package of innovations includes the "Perfect Joint" process as part of the LVL assembly line and the down stream multi-opening hot press.

Keywords: Plywood, LVL

9. Barnekov, Vladimir; Suchsland, Otto; Nedeltchev, Rossen. Live-Sawing Hardwood Logs for Furniture Dimension Production. Forest Products Journal; February 1998; 48(2): 34-39.

A study investigated the advantages of live sawing over conventional grade sawing of red oak factory logs with an emphasis on dimension yield rather than lumber yield. Goal was to gain the maximum dimension yield by feeding unedged, live-sawn boards into the rough mill (rough mill simulators), these boards were analyzed in the unedged as well as the edged condition to allow yield and value comparisons with normally edged grade sawn boards. Consistent results suggest that log grade and log value are relatively poor predictors of lumber value and dimension yield. Live sawing was superior in all scenarios.

Keywords: Sawing, Yield, Edging

10. Beauregard, Robert; Beaudoin, Michel; Ait-Kadi, Daoud; Mongeau, Jean-Pierre Mongeau. A Systematic Modeling Approach to Reengineering Sawmills: A Supplier's Perspective. Forest Products Journal; February 1997; 47(2): 38-46.

A systematic modeling approach is proposed as a tool to support reengineering sawmills to meet new business demands. Communication between producers and customers is through Electronic Data Interchange. It is necessary to affix barcodes on every piece of lumber and to maintain a self-replenishment stock of lumber at the reload site of the customer. In return a long-term agreement is expected involving the delivery of large volumes of wood.

Keywords: Barcoding

11. Bell, E. R. and Dunlap, M. E. Dielectric Heating of A Yellow Birch Log in Preparation for Cutting Veneer. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1944.

Keywords: Pretreatment

12. Blackman, Ted. The Mission: Saw Crooked Logs into High-quality Lumber. Wood Technology; March 1999; 126(2): 34-38.

Maritime pine logs in France are crooked, non-homogeneous in quality, and include several grades of wood. If a sawmill's optimization system does not take these differences into consideration, a significant part of the log's potential value is lost during processing. A new mill owned by Escobois, one of France's largest lumber producers, marks one of the first times that an automated, high production mill is using cutting-edge technology to solve the problem of high speed sawing for lumber quality by using statistical tree modeling. Real tree shape is used to simulate a model of grade distribution within each log. Software will use these data, along with price and product information, to create quality-based sawing patterns. Most pines have problems similar to maritime pine including radiata and southern yellow pine. As a rule, the warmer the climate, the greater the problem.

Keywords: Sawing, Log grades, Computer control, Pricing

13. Borer, Howard (North American Controls Inc.). Computerized Sorting Systems. Improving Productivity Through Microelectronics; November 23, 1983; Moncton, New Brunswick, Canada. Ottawa: Forintek Canada Corporation; 1984.

Computers from North American Controls Inc sort lumber based on four attributes, i.e. grade, thickness, width, and length. Some mills do not grade lumber in the sawmill. They use three grades as a species separation capability. The computer could separate cedar from spruce in that way. Some systems control an automatic end trimmer. In that case the operator would also enter near end and far end trim information.

Keywords: Lumber sorting, Computer control

14. Bratkovich, Stephen M.; Gephart, John S.; Peterson, Paul; Bartz, Robert H. Green Dimensioning Below-Grade Red Oak Logs: A Minnesota Case Study. Forest Products Journal; February 2000; 50(2): 60-68.

A combination hardwood thinning and selection harvest in north central Minnesota generated a mix of veneer logs, high- and low-grade sawlogs, and below-grade red oak logs representative of pallet and firewood quality material. The sample logs had an average small-end diameter-inside-bark and length of 9.5 and 101 inches, respectively. The below-grade logs were processed into 4/4 dimension and pallet parts. Total yield, expressed in cubic feet of dimension and pallet parts output per cubic feet of log input, was 31%. Sixty-one % of the total product output from the sample logs was in clear, defect-free green-dimensioned parts in lengths of 12 to 43 inches and widths of 1-3/4, 2-3/4, and 3-1/2 inches. Pallet parts of 42- and 48-inch lengths and a width of 3-1/2 inches, accounted for the remaining 39% of product output. Total product yield for dimension and pallet parts was 197 and 125 board feet per cord respectively. Green dimensioning has the potential to: 1) enhance resource utilization by using low-grade logs; and 2) reduce drying and transportation costs since only usable wood sections are dried and shipped.

Keywords: Logging, Thinnings, Yield, Lumber, Log grades

15. Brown, Terence D. Quality Control for Product Improvement from Small Logs. Proceedings: Manufacturing Lumber From Small Logs. Contribution No. 44. Seattle, Washington: College of Forest Resources, University of Washington; 1982.

The primary objective of production center monitoring is to systematically evaluate the physical or mechanical ability of the production center to optimize the value of the material passing through it. There are three key elements to production center monitoring. They are: 1) condition of equipment, 2) maintenance monitoring, and 3) lumber size control. If sawing variation is not more than 0.015 inch planing may be eliminated. This will allow green target size of around 1.57 inches for dimension lumber. The second key area, which should be included in evaluating each step of the lumber manufacturing process, is personnel performance. It can be broken down into four parts: job knowledge, supervisory decisions, recovery decisions, and grade decisions.

Keywords: Quality control, Small logs, Sawing variation

16. Brown, Terence D. Quality Control in Lumber Manufacturing. San Francisco, CA: Miller Freeman publications; 1982.

This book discusses steps to develop quality control programs in the production of lumber. Subjects include optimal log grading, equipment evaluation and performance, lumber tolerance targets and control, lumber quality evaluation techniques, and training.

Keywords: Quality control, Log grading, Sawing variation

17. Brunton, P.D. Financing Small-Scale Rural Manufacturing Enterprises. FAO Forestry Paper 79: Small-Scale Forest-Based Processing Enterprises. Rome: FAO; 1987.

Certain forest-based processing activities lend themselves well to some form of collective or cooperative organization. Cooperative ownership of logging and sawmilling operations by small, rural furniture manufacturers can greatly assist in solving the raw material supply problem and facilitate the provision of working capital finance.

Keywords:

18. Bryan, Eugene L. The Best Possible Sawmill - Guidebook for the High-Tech Journey Ahead. San Francisco, CA: Miller Freeman Books; 1996.

This book provides an organized thought and action process to improve sawmilling efficiency and profitability.

Keywords: Yield

19. Carino, Honorio F. Sawmill Conversion Efficiency Improvement Analysis; A New Perspective. Forest Products Journal; July/August 1986; 36(7/8): 9-16.

In a case study of a Southern pine dimension mill it was found that the mill could realize a profit increase of 9 percent if sawlog input is limited to logs with small-end diameters of 7 inches and larger. LRF (Lumber Recovery Factor) was increased from 6.39 to 6.51. In addition the mill could realize considerable increases in profit by eliminating unnecessary log overlength and by reducing the green target size on the lumber produced to conform to industry norms. The LRF improvement from eliminating overlength was estimated at 2.5 percent. Reducing the green target set could result in a potential improvement in LRF of 6.6 percent.

Keywords: LRF, Yield, Logs, Log size

20. Carino, Honorio F.; Lin, Wenjie; Muehlenfeld, Ken; Gober, Jim; Waldrop, Pat. Wood Products Mill Improvement: An Important Component of Rural Development. Forest Products Journal; June 1995; 45(6): 47-52.

A mill could realize significant increases in profit if production were increased either by reducing downtime or increasing materials flow through the system. Also, increased production could be realized by reducing the current product size allowances by 50 percent. Increased sales of by-products such as wood chips, sawdust, and bark would enable the mill to gain more profit. Specific recommendations on how these improvements could be achieved and estimates of the maximum rational investment needed were presented to the mill management. For 6/4-in boards, 4/4-in boards, and 4 by 6 in cants statistics are provided for board ft per log, board feet per cubic feet of log input, and output in percent of log input volume.

Keywords: Wood residue, By-products, Yield, LRF, Rural development

21. Cesa, Edward T.; Lempicki, Edward A.; Knotts, J.Howard (Forest Service, Northeastern Area State & Private Forestry). Recycling Municipal Trees: A guide for Marketing Sawlogs from Street Tree Removals in Municipalities. Morgantown WV: USDA, NE Area State & Private Forestry; June 1994; NA-TP-02-94.

Information is provided on technologies and marketing techniques for using trees removed from urban areas.

Keywords: Recycling, Urban trees

22. Chaiyapechara, Sathi, Forest Industries Planner (Food and Agriculture Organization of the United Nations). Development of Forest Sector Planning, Malaysia. Sawmilling Industry in Sabah. Sandakan: Sabah State Forestry Department; 1988.

Forty-one sawmills active in 1987/1988 were visited at random. Visits covered mills of all sizes. Visits were in 6 regions- Sandakan, Lahad Datu, Tawau, Kota Kinabalu, Keningau and Beaufort. A list of topics was used for consistency in interviews. Twenty-six percent of licensed mills were idle. Of 120 active mills only 101 mills were active 6 months or more. There was little change in 1986. Some old circular mills were still present on the West Coast of Sabah. Others switched to band saws, but were still characterized as small mills. Some mills that converted to band saws still retained circular saws for sawing exceptionally hard woods for local consumption. The newer mills on the East Coast and inland are in general large and better equipped. Two were highly sophisticated sawmills fully automatic with remote control. Sawmills established in the 1980s are large with modern bandsaws and automatic carriages and conveyance systems. Structurally speaking, mills in Sabah are very impressive compared with other mills in Southeast Asia. Assessing sawmill capacity is rather complicated as there is no available record of the installed capacity of each mill. Only 17% of the mills had a planer. Those sawing for the local trade had little need for one. Small mills opt not to make this investment, but there may be planing services at lumberyards to cater to demand. Only 12% of the sawmills have trimmer/edgers. Trimming is often done by a hand-held chainsaw, instead of trim saws. Only 24% of the mills had trim saws. Preservative dipping of species like white and yellow seraya, which are highly susceptible to fungus and insect attack, is common in sawmills that export. Two weeks of air-drying is standard practice. Few mills (only 5 of 41) have dry kilns. Two mills use the kilns only for drying veneer. Most mill waste was burned. Resawing mill waste for sale as packaging material and other uses had begun. Some waste is used for fuel in brick kilns. One mill used heat to warm air and speed air-drying with an electrically driven fan. In the East some waste is used in block board manufacture.

Keywords: Forest plans, Mill survey, Sawmills, Trade, Drying, Sawing, Malaysia

23. Choon, Lim Seng; Yusoff, Mohd. Nadzri. Tension Wood in the Stems and Branches of Rubberwood (*Hevea brasiliensis*). Journal of Tropical Forest Products; 1995; 1(2): 222-225.

Keywords: Tension wood, Rubberwood

24. Chrestin, Hauke and Maness, Thomas C. High-Value Recovery Manufacturing Techniques for Softwood Lumber. Program of 54th Annual Meeting of Forest Products Society; June 2000; South Lake Tahoe, Nevada. Madison, Wisconsin: Forest Products Society: 25-26.

Lumber-manufacturing technologies in British Columbia's sawmill industry that were originally developed to produce high volumes of commodity products at high speed are inflexible and prevent today's sawmills from producing custom-tailored, high-value lumber products that would give them a competitive edge in world markets. In the European sawmill industry, on the other hand, value is commonly added to lumber products through simple techniques such as drying, planing,and strength grading of structural lumber. The production strategy of many European mills is customer-oriented and product-driven; cutting-to-order is standard rather than an exception. By means of a qualitative survey, sawmills in Europe were interviewed about their raw-material supply, processing technologies, product mix, and marketing techniques. A two-page questionnaire translated into three different languages was mailed to approximately 1,600 statistically selected companies in Norway, Sweden, Finland, Germany, Austria, and Switzerland. Approximately 300 companies replied; about 70 percent of them returned a completed survey. Almost all of these mills began optimized for high-value wood products, sorting logs by diameter, species, and according to the intended end product use. Many mills were specialized in products and processing technologies based on log mix. The majority of the interviewed mills were cutting between 60 and 100 percent of their production to specific customer orders, and besides standard dimension lumber many of them also produced specialty products such as glulam and laminated window stock. Based on the survey, recommendations are being made to softwood-lumber producers in British Columbia and throughout Canada on how they can change their manufacturing strategies to achieve a value-uplift of their production output and how more jobs-per-tree-felled can be generated.

Keywords: Survey, Log sorting

25. Christiansen, P. Case Studies of Small-Scale Forest-Based Processing Enterprises in Latin America. FAO Forestry Paper 79: Small-Scale Forest-Based Processing Enterprises. Rome: FAO; 1987.

Some 40 traditional small, circular sawmills have survived under very bad economic conditions, almost without external support. Sawmill installations and machinery are between 10 and 40 years old. Problems are lack of logs, shortage of spare parts, product storage and marketing problems, and high waste factor and poor quality.

Keywords: Yield

26. Creamer, Casey. Sawmiller's Guide to Troubleshooting: The Northeastern Loggers' Association, Inc.; 1995.

This book covers general maintenance required in sawmills, including advices on inspection and trouble-shooting. Greatest attention is given to sawing and saw maintenance.

Keywords: Sawing

27. da Gama e Silva, Zenobio A.G.P.; Amarot, Marco Antonio; Braz, Evaldo Munoz (FUNTAC). Forest Sector of State of Acre-Brazil: a Descriptive Analysis. Rio Branco, Brazil.

For extractives from the state of Acre, rubber is the most important product. The wood industry is composed of a plywood mill, furniture factories and sawmills that are concentrated in the city of Rio Branco. The plywood mill produces medium to large sheets and exports almost all of its production. In 1992 60 sawmills were working in the State of Acre, (10 units located in Rio Branco) and had a monthly timber production of 2,963 m^3. Although the number of sawmills was constant for 1988-90 production decreased by 35%. There is much waste and poor quality in manufacture, and the labor force is unskilled. One political consideration is to decrease taxes in order to modernize the wood industries of Acre.

Keywords: Plywood, Extractives, Sawmills, Plywood industry, Furniture, Brazil

28. de Freitas, Amantino Ramos (IPT). Research Priorities in South America for Tropical Woods. Properties and Utilization of Tropical Woods; November 19-23, 1984; Manaus, Brazil: IUFRO; April 1985: Appendix I.

An initial list of priority research areas called for a) evaluation and better use of the forest resource, b) assessment and determination of wood properties, c) grading for strength and appearance, d) conversion techniques, e) wood-using industries and applications, and f) utilization of residues. As supply of traditional species gradually diminishes, new species of wood entering the market require greater care and more sophistification in processing. Urgent problems are high silica content that causes premature dulling of tools, high level of growth stresses that cause splitting and warping, high susceptibility to fungal and insect attack, added shrinkage ratio, collapse, and splitting in drying. These problems are compounded with inadequate conversion techniques such as poor sawing patterns, poor secondary transformation (machining), inadequate drying, and poor gluing and finishing techniques. It was recommended that industrial extension activities be strengthened, more appropriate equipment for sawing and drying be obtained, practices for quality assurance be developed. Recommendations for waste utilization centered on low--cost equipment for making panels such as wood-cement boards, direct-firing kilns for safe drying of tropical woods, and densification processes possibly followed by carbonization.

Keywords: Research, Tropical woods, Wood properties, Research needs

29. Denig, Joseph. Small Sawmill Handbook - Doing it Right and Making Money. San Francisco, CA: Miller Freeman Inc.; 1993.

The book provides a good background on log grades, log bucking for quality and value and lumber yield. In addition it discusses sawing practices to improve productivity, grade and value. Two chapters deal with sawmill equipment and layout. It concludes with secondary manufacturing and lumber drying.

Keywords: Yield, Sawmilling, Log grades

30. Detjen,R.K. An End Dogging Headrig for Small Logs. Ed Williston. Manufacturing Lumber from Small Logs; College of Forest Resources, University of Washington. Seattle, Washington; 1982; Contribution No. 44.

Australia has a standard stock width of 78 mm or about 3-1/8". They also have plantations of radiata pine, which are ready for harvest. McKee of Australia and McDonaugh together developed a twin EDLF system for timber industries in Oberon, New South Wales that can produce 3 1/8" cants. The user reports excellent accuracy at a production rate of up to eight logs per minute.

Keywords: End dogging, Small logs

31. Dietz, H. S. Gewerkstechniken zur Verbessurung der Ausbeute und des Arbeitsplatzes. Holz als Roh- und Werkstoff; 1977; 35(8): 283-287.

The kerf width of sawmill machinery was reduced, and its output was increased. In order to increase productivity further the down time of equipment had to be reduced. Automatic adjusting and feeding devices can increase output. In fully automated sawmills, workers can be transferred to areas where injuries are more readily avoided.

Keywords: Sawing, Yield, Automated sawmill, Maintenance

32. Dramm, John R. Statistical Process Control - Lumber Size Analysis (Procedures Guide). Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, State and Provide Forestry, Forest Products Laboratory; March 1994.

This guide describes the general procedures necessary to successfully collect, analyze, and interpret lumber size variation. It is designed to be used in conjunction with the Statistical Process Control - Lumber Size Analysis (SPC-LSA) computer routine developed by the USDA Forest Service. The reports produced by SPC-LSA help evaluate the sawing performance of breakdown systems by analyzing size variation in lumber.

Keywords: Sawing variation, Statistical process control

33. Dykstra, Dennis P. and Heinrich, Rudolf. FAO Model Code of Forest Harvesting Practice. Rome: Food and Agriculture Organization of the United Nations; 1996; ISBN: 92-5-103690-X.

Considerable progress has been made in recent years in the introduction of environmentally sound forest harvesting practices in many parts of the world. Nonetheless, much remains to be done. There is a continuing need to refine harvesting systems and techniques so that they become fully compatible with the objectives of sustainable forest management, allowing them to contribute in an important way to the economic and social aims of sustainable development. This document is one response to this need. Its primary objective is to promote forest harvesting practices that improve standards of utilization and reduce environmental impacts, thereby contributing to the conservation of forests through their wise use. The information provided in this model code of forest harvesting practice has been compiled with the intent of highlighting the wide range of environmentally sound harvesting practices that are available to forest managers, especially those requiring only a modest level of investment in training and technology. This will permit policy-makers to develop national, regional or local codes of practice, which will best serve the particular needs of government agencies, the private sector, non-governmental organizations and other constituents.

Keywords: Harvesting

34. Eastin, I.L.; Addae-Mensah,A.; de-Graft Yartey, J. Tropical Timber Boycotts: Strategic Implications For the Ghanaian Timber Industry. Unasylva; 1992; 43(3): 39-44.

In 1989 the timber industry produced more than 10 percent of the gross domestic product of Ghana. There were 169 sawmills operating in Ghana during 1990. The top four firms in 1990 produced 17.3 percent of total log production while the top ten firms accounted for 33.1 percent of production. In the sawmilling industry the top four firms manufactured 21.9 percent of total sawnwood production while the top ten firms produced 42.8 percent of sawnwood production.

Keywords: Timber industry, Sawmills, Ghana

35. ECE/FAO Agriculture and Timber Division, Geneva. Study of the Trade and Markets for Tropical Hardwoods in Europe. Geneva, Switzerland: United Nations Economic Commission for Europe; April 1989; ITTO Technical Series 4. 108 Pages.

Ghana has recently shown an improved export performance for logs despite the prohibition of exports in log form of 18 primary species. Only the Federal Republic of Germany is a consistent buyer and over the period Ghana provided nearly 17% of its log imports, reaching 119,000 m^3 between 1982 and 1986. Ghana has recently made an impressive recovery from a considerable economic recession in its forest-based industries with the aid of a US$ 100 million World Bank assistance program. Its sawnwood exports more than doubled during the period. Its most important customers among the seven selected European countries are the Federal Republic of Germany and the United Kingdom that together represented 77% of Ghana's export market in 1986. Malaysia is the primary source of sawn hardwood imports into Europe averaging more than 50% of the Asian total over the period but increasing its market share from 48 to 55% between 1982 and 1986. Exports from Malaysia emanate from both Western (Peninsula) Malaysia and Eastern (primarily Sarawak) Malaysia. In three of the seven selected European countries, the Netherlands, the Federal Republic of Germany and Belgium, Malaysia provides more than 50% of the total tropical sawn tropical hardwood imports. Significant increases in market share have been obtained in the Netherlands and Belgium during the period. In France, the United Kingdom and Italy, Malaysia contributes between 10 and 15% of total tropical sawn hardwood imports. Only Spain among the selected European nations is an insignificant importer of Malaysian sawnwood. European supplies from Latin America are to a predominant extent from Brazil that accounts for 86% of European imports from the region.

Keywords: Tropical woods, Malaysia, Ghana, Brazil, Export

36. El-OSTA, M.L.M (Alexandria, Egypt University). Research Activities on Wood Properties and Utilization in Egypt. African Workshop; November 19-25, 1989; Abidjan, Cote d'Ivoire: IUFRO; May, 1990: 105-110.

Egypt imports squared timber, logs, plywood and lumber. The country produces 28,800 m^3 per year of plywood from imported woods.

Keywords: Wood properties, Plywood lumber, Timber

37. Elias (Lecturer at Faculty of Forestry, Bogor University, Bogor, Indonesia). Forest Harvesting Case-Study 11: Reduced Impact Timber Harvesting in the Tropical Natural Forest in Indonesia. Rome: Food and Agriculture Organization of the United Nations; 1998.

The conventional and reduced impact timber harvesting operations were observed and compared. The research results indicate that conventional timber harvesting with the TPTI (Tebang Pilih Tanam Indonesia) system in the tropical natural forest in Indonesia caused heavier damage on soil and residual stands when compared with a reduced impact harvesting system. The application cost of reduced impact timber harvesting are not greater than conventional timber harvesting in either short or long periods because the wood damage value caused by conventional timber harvesting is twice as great as that caused by reduced impact timber harvesting; also, reduced timber harvesting will enhance future forest productivity and reduce the costs associated with potentially adverse side-effects of timber harvesting.

Keywords: Harvesting

38. Elmendorf, Armin. Wood Fibers From Veneer Waste. Forest Products Society 1949 Preprint; 1949.

A machine for producing strand-like fibers out of veneer waste is described. The fibers are cut at the rate of about 1 ton per hour. They can be felted by mechanical means and lend themselves to the manufacture of highly fire-resistant wall boards whose manufacturing cost will be far below that of plywood. Such boards in the 1/2-inch thickness are much stronger and stiffer than insulation boards of the same thickness.

Keywords: Veneer waste

39. Erickson, John R. Trends in Wood Utilization and Their Implications for the Future. In: New Forests for a Changing World: Proceedings of the 1983 SAF National Convention; October 16-20, 1983; Portland, OR. Washington, DC: Society of American Foresters; 1984: 57-64.

Timber use trends point to a continuing rise in consumption to meet future product needs. However, the final product mix is changing as a result of technological advances, increased energy prices, changes in the forest resource, and other factors. One of the most significant changes, unpredicted during the 1970's, is the rapid increase in firewood use in all areas of the country. A less noticeable change, but one that may have large impacts in future utilization patterns, is the shift from plywood to structural flakeboard production. Existing and planned research programs support current changes in wood use patterns and will accelerate the trends to use more hardwoods, logging residuals, and smaller trees from managed forests.

Keywords: Plywood industry, Waste utilization

40. FAO. FAO Forestry Paper 16: China: Integrated Wood Processing Industries. Rome: FAO; 1979.

Mills claim to be profitable, but there is need for improved utilization of residuals. Sawmills are grouped in three sizes. Large mills have outputs of about 100,000 cubic meter/year. Medium mills have outputs of 100,000 to 200,000 cubic meter/year, and small mills have outputs less than 100,000 cubic meter/year. Band saw, gang saw, and circular saw technologies are utilized. The trend is to favor multiple band sawmills. The Hsing Fang timber mill in Harbin was studied in detail. Plywood mills produce products of good quality and make rational use of species of special value such as Manchurian ash. Many Chinese plywood mills manufacture their own adhesives, but these are not of high quality. Residue utilization is hindered because of no debarking at many mills. Wood is obtained as offcuts, edgings, and slabs from sawmills in Guangzhou (Canton) and in the form of green hardwood chips, produced by using mobile chippers in forested areas.

Keywords: Sawmilling, Residue utilization, Plywood manufacture

41. FAO. FAO Forestry Paper 28: Small and Medium Sawmills in Developing Countries. Rome: FAO; 1981.

Basic considerations for a sawmill venture and methods of collecting data for analysis are discussed. Included are marketing, log supply, production, personnel, engineering and construction, costing and accounting. Then case studies with three different examples are described. Residue type and uses include bark, sawdust, slabs, edgings, broken logs and limbs. Dry bark may be used for fuel. Wet bark may be piled and dried for fuel. Sawdust may be a valuable fuel for domestic or industrial fuel if it is not too wet. Some species produce sawdust suitable for agricultural mulch or animal bedding. If the sawdust cannot be sold as fuel, it may be possible to use it as fuel in the mill operations. Slabs, edgings, trim ends, and broken logs are a potential source of raw materials for small secondary or home industries. Alternatively, they can be chipped and sold for pulp mill furnish (log debarking may be necessary).

Keywords: Sawmilling, Residue utilization

42. FAO. FAO Forestry Paper 69: Management of Forest Industries. Rome: FAO; 1986.

Collection of papers on forest industry management in Finland.

Keywords: Management

43. FAO. Forest Harvesting Case-Study 7: Forest Harvesting in Natural Forests of the Republic of the Congo. Rome: Food and Agriculture Organization of the United Nations; 1997.

The overall objective of the study is to contribute to the development of sustainable forest management in the tropics through the establishment of credible data on forest harvesting practices and harvesting impacts in tropical high forests. The study concentrated on inventory, harvesting performance, and harvesting impact. Damages to the residual stand occur during felling, skid trail construction and log skidding. The study observed crown damages, bark damages and uprooted or broken trees. The average damage frequency was 17.7 damaged trees per felled tree. Expressed in terms of damages per recovered log volume, this is approximately 3 damaged trees per cubic meter removed. Damage to residual Okoume trees was 3.3% with the majority of damaged stems in the higher DBH classes. The total number of felling damages of all trees (93) is 17.3 per hectare. Skidding damages occur with an average frequency of 11.5 trees per hectare. In total, the number of felling and skidding damaged trees per hectare was 29. The number of damages per felled tree was 30 and the number of damages per cubic meter of log volume removed was 5. The soil disturbance survey revealed a total disturbed area of 8.4% of the annual harvest area.

Keywords: Harvesting

44. FAO. Forest Harvesting Case-Study 8: Environmentally Sound Forest Harvesting - Testing the applicability of the FAO Model Code in the Amazon in Brazil. Rome: Food and Agriculture Organization of the United Nations; 1997.

The study documents each phase of the environmentally sound forest harvesting system as applied by Precious Woods Ltd and compares its efficiency and environmental impacts with those of the traditional systems generally used in the Amazon region. The following results were provided: 1) Efficiency. Felling: A productivity of 19.76 cubic meter/h workplace time was found in the environmentally sound forest harvesting system, whereas the felling-productivity in the traditional logging system was 17.92 cubic meter/h workplace time. The productivity of timber extraction is difficult to compare since there are two extraction activities in the environmentally sound forest harvesting system: first, the pre-skidding phase with a productivity of 31.04 cubic meter/h workplace time and then the skidding phase with a productivity of 65.53 cubic meter/h workplace time. By contrast, the skidding operation is the only timber extraction activity in the traditional logging system. This skidding productivity was 24.90 cubic meter/h workplace time. 2)Cost. Comparable. 3)Environmental impact. Severe harvesting damage to potential crop trees was found to be more than twice as high with the traditional logging system (51.5%) as compared to the environmentally sound forest harvesting system with 22.2%. With the environmentally sound forest harvesting system an average area of about 4.5% per cutting unit is affected by roads and other forest infrastructure, whereas in the traditional logging system the corresponding value amounts to about 20%. The disturbance of canopy by tree felling was 10.8% of the area for the environmentally sound forest harvesting system. By contrast, the traditional logging system resulted in created canopy openings of 24.7%. Investigation of timber losses revealed a potential for improvement in the environmentally sound forest harvesting system, where the total in timber losses came to 3.9% of the utilizable stem volume. The total timber losses for the traditional logging system were more than twice as high at 8.5%.

Keywords: Harvesting

45. FAO. Manual on Sawmill Operational Maintenance. Rome; 1990. (FAO Forestry Paper; 94).

Sawmill maintenance is not just a matter of repairing or maintaining machinery but also of organization and method whereby maximum production of sawn timber can be achieved to the financial gain of all involved. The financial viability of any sawmilling enterprise is largely dependent on the performance of its mechanical equipment, which, in turn is dependent on the knowledge and skill of the personnel responsible for its operation and maintenance. The main objective regarding waste disposal must always be to keep the volume of wood waste produced as small as possible. Larger pieces of wood waste often can be marketed for fuelwood, and high density hardwood species are good for manufacture of charcoal. Systematic regular disposal of waste must be organized whether manual, mechanical, or otherwise, and the cost involved must be carefully considered. For an efficient and viable operation it is necessary for sawmill management to have a planned annual production program by which the performance of the sawmill can be assessed over any period of time within the year. Machine breakdowns, changing saws and waiting for logs are common reasons for temporary stops in the daily operation of many sawmills.

Keywords: Sawmilling, Maintenance, Waste utilization

46. FAO. State of the Industry. Proceedings: FAO Advisory Committee on Paper and Wood Products,39 session; 23-24 April 1998; Rome, Italy.

Solid Wood (Sawnwood, plywood, particleboard and other fiber boards are included): The total usage of woods for these segments were 54 million cubic meters for a final production, estimated at 22 million cubic meters of products. There is a trend for continuous utilization of roundwood from "farmed forests" which currently is already 32 percent of the total volume used. Plywood (Plywood production data given from 1992 to 1998): Drop in prices on international market forces revision of the Brazilian timber industry. Brazil can change from an exporting country to an importing one. In 1994 there were around 400 plywood mills in Brazil. That was reduced to around 250 in 1997, and could reach only 70 in the near future. Sawn Lumber: Brazilian sawn lumber exports - 1995,US$379,816,218; 1996, US$344,745,905; 1997, US$410,999,756.

Keywords: Lumber, Plywood, Price

47. FAO Advisory Committee on Paper and Wood Products, Thirty-ninth Session. State of the Industry (Brazil). Rome: FAO; 1998.
Due to the lack of an efficient forest expansion policy, there is a risk of farmed wood deficit already in the next decade. ABIMCI, the Brazilian Plywood Association, considered the 1997 economic crisis the worst ever faced. This was especially due to the cancellation of orders from Korea, one of the major markets for Brazilian plywood, and the drop in prices of up to 40 percent of plywood produced by Indonesia and Malaysia, the two main competitors of Brazil for tropical plywood. The following points were made: Strong points - Availability of large forest areas; Markets with great potential for consumption; Perfect knowledge of silvicultural techniques in native tropical forests; Good know-how on industrial production. Weak points - High production costs, comparing with other producing countries; Lack of specific financing credit lines for mechanical wood processing; Quality cost control and selection of raw material; Brazil cost (cost of Brazilian bureaucracy and poor existing infrastructures, such as ports, roads, energy supply, and so on). Strangling points - Lack of a well-defined and structured industrial policy; Lack of a defined forest policy; High investment cost for intense capital activities; Low labor qualification for both forest and industrial operation; Marketing problems (long distance to consumers); Expensive logistics for exports; High social and fiscal costs; Environmental cost due to emotional focus on issue.

48. FAO Advisory Committee on Paper and Wood Products, Thirty-eighth Session. Update on Sustainable Forest Management and Certification. Rome: FAO; 1997.

Plantation forestry is relatively new in Ghana. Employment in the timber industry in Ghana has grown from 75,000 (household heads) in 1994 to 100,000 (household heads) in 1996. Ghana published a "Handbook of Harvesting Rules for Sustainable Management of Tropical High forest in Ghana" in 1992. Future wood supply of wood to industry is very precarious.

Keywords: Ghana, Tropical forestry

49. FAO Committee on Paper and Forest Products. Associacao Brasileira de Celulose e Papel (Bracelpa). Brazil(Economic Conditions in 1998 and Outlook for the Future). Rome: FAO; 1998.

Economic and environmental aspects of the paper and wood industry of Brazil are discussed.

Keywords: Brazil, Wood industry, Paper industry, Sawmill, Plywood

50. FAO Committee on Paper and Forest Products (Ghana Timber Millers Organization). Ghana. Banahene, Fosuaba A. Mensah. Forest Resources of Ghana. Rome; 1999.

Current and future wood supply and plantation development in Ghana are discussed.

Keywords: Ghana, Plantations

51. FAO Forestry Department. State of the World's Forests 1999. Rome: FAO; 2000.

The many causes of forest degradation include over harvesting of industrial wood and fuelwood. Efforts to improve the stewardship of forests designated for wood production include silvicultural improvements and the adoption of environmentally sound timber harvesting practices. Codes of practice and guidelines for forest harvesting have recently been drafted for tropical forests, most notably in the Asia and the Pacific region. FAO has projected that demand for industrial roundwood will increase by 1.7 percent annually between now and the year 2010, driven by both population increases and economic growth. While recent studies suggest that supplies are sufficient to meet this demand, the situation will vary among countries and will depend greatly in market conditions, government policies, technological improvements and human resource development. Production of industrial roundwood is expected to exceed consumption in all regions except Asia, which will continue to rely on imports to make up the difference. The increased demands are expected to be helped by increased production from plantations and from trees outside forests, particularly on agricultural land; new forest product technologies and gains in efficiency in wood processing; greater use of recovered paper and wood processing residues; and increased use of wood and fiber from "non-forest species" (e.g. rubber, oil palm) in forest industries. Growth in the production of tropical forest products has slowed over the past three to five years and export volumes of tropical logs, sawnwood, and wood-based panels have decreased. Reasons include increasing domestic consumption in important developing producer countries, reduced harvest levels because of both environmental concerns and export market conditions, a shift in exports from logs, and to a lesser extent sawnwood, towards higher valued products, and most recently marked reductions in demand in Asia, especially in Japan. The FAO supply and demand analysis model has not included improvements in harvesting practices that could increase log recovery and reduce logging residues. Many developing countries have substantial opportunity to increase their log and mill recovery rates. The increased production of reconstituted panels such as oriented strand board and medium density fiberboard and developments in the manufacturing of engineered wood products will continue to improve the efficiency of using raw material. Engineered wood products increase opportunities for using small-diameter logs of lower quality and lesser-used species. The use of microprocessors the production cycle can increase product quality and minimizes the amount of residues generated. Technology developments in laminated veneer lumber include increasing use of ultrasonic veneer graders so that a substantial quantity of the veneer supply is routinely tested for possible use of laminated veneer lumber, rather than only for plywood. this development has contributed to a 75 percent increase in production of laminated veneer lumber and a threefold increase in I-joists in the United States from 1990 to 1996. The increasing volume of small diameter material is driving some technological developments. Mills specializing in manufacturing narrow dimension lumber from small-diameter stems are adopting curve sawing. Scanning and optimization at the primary headrig and the secondary breakdown centers (edging, trimming, resawing, cant breakdown) are becoming standard. The manufacture of finger jointed studs from short lengths salvaged from stacked boards and slabs, which would have been chipped in the past, is becoming increasingly common. Not much is known about utilization of mill residues outside a few of the large developed countries. However it is suspected that large volumes of residues are left unused. As the Asia-Pacific Forestry Sector Outlook study has shown, better recovery using new technologies could make a significant contribution to wood supply.

Keywords: Logging, Silviculture, Government policies, Lumber, Plywood, Export, Logs

52. FAO Forest Harvesting Bulletin: Promoting Environmentally Sound Forest Practices Worldwide; May 1999; 9(1): 8p.

Roads continue to be a contentious issue in forest management. Various locations around the world have forest road construction moratoriums in place this year. The attributes of desirable forest roads have been collected from various parts of the world and modified into a single coherent list. This list represents the current view of advocates for sustainable forest management. Information in addition to forest roads and harvesting, and mountain logging, etc. in this bulletin also includes helicopter logging in Malaysia,

Keywords: Harvesting, Helicopter logging, Roads

53. Ferzt, Ruth; Franzheim, Sabrina (Trade and the Environment Database). Brazil Deforestation and Logging. Internet: http://www.american.edu/projects/mandala/TED/BRAZIL.HTM; 1997.

The main sources of deforestation in the Amazon Basin are agricultural production, cattle ranching, commercial logging, and gathering of fuelwood. Subsidies coupled with tax breaks allowed Brazilian firms to reduce their income tax payments by 1/2 if the savings were directed to industrial investments in the Amazon basin. However recently many of the incentives have been eliminated.

Keywords: Brazil, Deforestation, Logging, Fuelwood

54. Flechtmann, Carlos Alberto Hector; Gaspareto, Celso Luiz. Scolytidae Infestation in Paula Souza Sawmill (Botucatu, Sao Paulo State, Brazil) Log Deposits. Scientia Forestalis; June 1997; 51: 61-75.

In the sawmill accumulation of wood residues on piles and in the ground were the main breeding sites of Scolytidae. Neither sawmill surrounding area nor the eucalyptus forest were the source of scolytid infestation, but instead logs acquired from other forested areas. It was recommended that logs be sampled before entering the sawmill, and that logs be stored for less than 30 days, especially during August/September and March/May, the periods of peak scolytid flight.

Keywords: Sawmill, Insects, Damages

55. Fleischer, H. O. Heating Rates for Logs, Bolts, and Flitches to Be Cut Into Veneer. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; June 1959; No. 2149.

The heating of logs, bolts, and flitches to be cut into high-quality rotary or sliced veneer requires a knowledge of the temperatures appropriate for various species and conditions, and of the factors that control the attainment of these temperature during the heating process. Good equipment and good control of the heating process are essential. Under the guidelines given in this paper, optimum temperature levels for different woods and different conditions can be determined, and time schedules can be calculated for heating in steam or water.

Keywords: Pretreatment

56. Fleischer,H.O. and Lutz, John. The Veneer- and Plywood-Making Properties of Klinki Pine. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1953.

In many aspects klinki pine appears to be an excellent raw material for the manufacture of veneer and plywood. It appears to be available in quantity in the form of large clear logs, yielding a high percentage of defect-free wood. Various properties of klinki in veneer cutting and drying and plywood fabrication were given.

Keywords: Veneer, Plywood, Tropical forestry

57. Flynn, Bob. Brazilian Mill Benefits from "Dream" Growing Conditions. Wood Technology; July 1999; 126(6): 18-20.

Flosull Madeiras of Capivari do Sul in Rio Grande do Sul has been producing Eucalyptus lumber since 1982, and has recently expanded into the manufacture of edge-glued panels and flooring. The sawmill, like most eucalyptus sawmills in South America, grew in stages over the years as the owners added equipment to accommodate an increasing market demand and log supply. Currently 3 lines convert about 7000 cubic meters of logs per month (1.55 million board feet) to 2700 cubic meters of lumber (1.15 million board feet). All of the sawmill equipment is of European origin, including Schiffer bandsaws using winch carriages (one double band and two singles), and two Dambrosz resaws. The logs (3 and 4.5 meters in length) are not debarked before logging.

Keywords: Lumber, Sawmills, Brazil, Eucalyptus

58. Forest Research Institute Malaysia. Research Programs, 1991-1995. Kuala Lumpur, Malaysia: FRIM; June 1991.

Research to improve timber processing technology seeks to overcome inefficiencies due to a) low productivity owing to small capitalization and low level of technology, b) inconsistent quality of finished products due to poor or negligible quality control and poor product standards or specifications, and c) low recovery rates due to inadequate machine maintenance and inefficient practices in the processing operations. In a project on structural application of timber and timber products finger jointing techniques are being studied. Another project study area concerns guidelines for structural plywood manufacture and applications. In a project on improvement of industrial processing productivity there are studies in 1) improvement in the performance and accuracy of the bandsaw machine, 2) application of productivity improvement techniques, 3) sawing of small diameter logs, and 4) plywood manufacturing from small diameter logs.

Keywords: Malaysia, Lumber, Sawing, Finger jointing, Plywood

59. Forest Research Institute Malaysia; Malaysian Forestry Research and Development Board; Ministry of Primary Industries Malaysia. Design Stresses for Locally Produced Structural Plywood. Annual Report 1995.

A few years ago efforts were made to promote the manufacture and use of structural plywood in the local wood-based industry, In 1995, a handbook titled, "Standard Product Manual for the Production of Malaysian Basic Structural Grade Plywood," was prepared by FRIM and was subsequently accepted to be incorporated into the latest revision of MS 544 which pertains to the code of practice for the structural use of timber. A study on the strength properties of rubberwood plywood showed, preliminarily, that the strength was lower than that of plywood made from mixed species suggesting that rubberwood may not be suitable for structural plywood.

Keywords: Malaysia, Wood industry, Plywood, Rubberwood

60. Forest Products Laboratory, State and Private Forestry. Best Opening Face Sawing Simulation Analysis Routine: Computer User's Manual. Madison, WI: Forest Products Laboratory; October 1, 1990.

BOF Sawing Simulation Analysis can be used to assess the current level of lumber conversion efficiency and to improve management control in dimension sawmills. It has wide use in planning models, analyzing marketing and product mix decisions, and analyzing many types of lumber manufacturing operations. Sawing simulation models can be used to aid in the design of new sawmill layouts. Performance specifications can also be determined. Perhaps the greatest benefit from BOF is to predict maximum lumber recovery. This information can help pinpoint reasons for not achieving that recovery. Also it can provide justification for necessary changes. Sawing simulation models can be a component of automated control systems. While primarily designed for control of primary breakdown, they are often used at edging, trimming, and log bucking machine centers.

Keywords: Sawing, BOF, Yield, Lumber, Simulation

61. Forest Products Laboratory, State and Private Forestry. IMPROVE System Log Processing Program: Log Analysis Computer User's Manual. Madison, WI: Forest Products Laboratory; January 2, 1990.

This log analysis program is designed to help mill owners/operators collect, organize, and store information about logs. It can be important for buying or selling logs, determining inventory, and conducting efficiency studies. Log Analysis creates data files that can be read by BOF Sawing Simulation to simulate lumber recovery from actual log input. Running Log Analysis in preparation for the BOF sawing simulation requires collecting log length and both small and large end diameter information. Similarly the Veneer Analysis Routine (Veneer Manufacturing Program) utilizes log information collected by Log Analysis.

Keywords: IMPROVE, Computer simulation, BOF

62. Forest Products Laboratory, State and Private Forestry. Statistical Process Control-- Lumber Size Analysis: Computer User's Guide. Madison, WI: Forest Products Laboratory; February 1994.

This guide presents the instructions for running the Statistical Process Control- Lumber Size Analysis (SPC-LSA) computer routine. SPC-LSA is a tool that can be used for analyzing the performance of log breakdown systems for SPC methods, primarily using control charts. Control charts can help identify information that can lead to the source of problems. Ongoing lumber size control helps provide assurance that lumber is manufactured to customer specifications. The SPC-LSA computer routine consists of compiled Pascal programs. It is menu driven and provides clear, concise instructions and prompts. Computer output consists of various lumber size analysis reports. A tutorial showing how to execute the routine is included in the guide.

Keywords: Computer simulation, Sawing, Lumber

63. Forestry Research Institute of Ghana. Annual Report 1992. Kumasi, Ghana.

The report contains sections with reports on ITTO Project PD 74/90 on Assessment of Product Yield & Residues in Wood Processing Mills in Ghana. The yield of main and by-products from four wood species ranged from 44 to 50%. The mean recovery rates were 44.1% rough green lumber, 4.3% by-products, 6.2% sawdust and 45.4% solid residues (such as boards for packaging, skids, stickers, second grade lumber, slabs, offcuts, edgings, etc. The total yield for wawa (43.7%) was significantly lower than the other three species (49.3 to 50.5%). The low recovery rate for wawa was due to the lower grades of logs used. They had heart rot and felling defects, and also longer storage periods in the mill.

The total recovery figures for sliced veneer varies from 23 to 35% for Asanfena, while that of makore was about 39%. The wide variation in yield of asanfena was due to the variation in log/billets diameters. About 21% of log input volume was lost during the clipping of dry sliced veneer. Losses due to drying of the veneer were about 6%. Based on the two species investigated, about 32.3% of sliced veneer for export and 3.5% of local grade veneer are recovered in addition to some 7.2% of flitch boards (which are marketed locally as by-products or used in the manufacture of pallets). The solid residues include 15.2% of flitching waste (which is solid residue of slabs, offcuts, edgings, etc.) 15.9% of veneer sheets and veneer pieces, and 20.7% if veneer clippings. The flitching wastes are sold as firewood or used at the mill to fire the boiler, while the veneer sheets or pieces of veneer sheets are burned. An invisible loss of about 6.2% representing drying and/or shrinkage is also estimated. The yield of wet rotary veneer ranged from 52 to 77% with a mean yield of about 60%. The quality and grade of the logs greatly influenced the yield. Rounding off residues amounted to about 17%, wet clippings about 8%, and residual peeler core about 15%. Residual peeler cores of mixed redwood species of diameter 30 cm were sawn into lumber for export and the local market.

Keywords: Ghana, Yield

64. Forestry Department of Peninsular Malaysia. Current Status in Forestry Sector of Peninsular Malaysia. Jalan Sultan Salahuddin, 50660 KUALA LUMPUR: Forestry Department of Peninsular Malaysia.

General information: The tropical rain forest of Peninsular Malaysia is one of the most complex ecosystems in the world. It has been estimated that 890 of the 2,500 tree species reach harvestable sizes of at least 45 cm diameter at breast height (dbh). Of these 890 species, a total of 408 have been introduced at one time or another to the international markets under the Malaysia Grading Rules. The total export volume of timber and timber products in 1990 was 4.1 million cubic meters, valued at M$2.7 billion or 4.0% of Peninsular Malaysia's total gross export earnings. In 1990,the total forest revenue collected from the various status in Peninsular Malaysia was M$258.4 million based on a production of 12.8 million cubic meters of round logs including rubberwood logs and other forest products. The forestry sector also provided direct employment for about 76,762 persons in 1990. Apart from its socio-economic role, the forest also plays an important protective function such as the maintenance of environmental stability, minimization of damage to rivers and agricultural land by floods and erosion and the safeguarding of water supplies.

Forest Harvesting and Production: Although annually the total area of forest harvested has been scaled down from 366,000 ha during the period 1971-1975 as compared to only 219,600 ha during the period 1986-1990, a scaling down of 40%,the total volume of logs produced was maintained at around 8-12 million cubic meters per year. This has been made possible by increasing demand for the lesser-known timber species and the ability of sawmills and plywood/veneers mills to adapt their processing machines to smaller diameter logs.

Forest Industry: Sawmilling is the largest wood-based industry in Peninsular Malaysia. In 1990 there were 686 sawmills with an installed capacity of about 10.4 million cubic meters per annum based on one shift operation. The industry consumed about 9.4 million cubic meters of logs and produced about 6.2 million cubic meters of sawn timber of which 3.0 million cubic meters were exported. In 1990,there were a total of 43 plywood/veneer mills with an installed capacity of about 2.2 million cubic meter based on two shifts operation. Most of the mills were established in the late 60's and early 70's and are small by international standards. In 1990, the industry consumed about 1.96 million cubic meters of logs and produced 995,068 cubic meters of plywood of which 678,021 cubic meters were exported. The bulk of the plywood production was standard utility hardwood plywood with a small volume of film-faced and overlaid plywood.

Keywords: Tropical forestry, Malaysia, Sawmill, Export, Plywood

65. Foss, K.; Deherve, L. (FAO). Appropriate Development of Sawmilling Industry in Africa. Paper presented at the ITTO Seminar, "Promotion of Further Processing of Tropical Hardwood of the African Region, " Accra, Ghana; February 13-16, 1990.

Nigeria, Cote d'Ivoire, Ghana and Liberia have serious problems with their future raw material supplies. Central African Republic, Zaire and northern Congo are land-locked and far away from the markets. No new industries will be needed in most of these countries. Instead, efforts should be put into manpower development and upgrading existing plants in order to increase product volume and quality.

Keywords: Africa, Tropical hardwood, Ghana

66. Fronczak, Frank J. and Hunt, John F. Auxiliary Torque Back-Up Roll: United States Patent 4,381,023; Apr. 26, 1983.

A power back-up roll for a rotary veneer lathe comprises a drive roller for applying a rotational force to the outer periphery of a log axially mounted on the veneer lathe, a controllable drive source for driving the roller and a servo-control system for maintaining the static friction between the roller and the log. In a preferred embodiment of the invention, the servocontrol system includes a first DC-generator tachometer for monitoring the peripheral speed of the log, a second DC-generator tachometer for monitoring the peripheral speed of the roller; and a feedback loop, operatively associated with the controllable drive source as well as the first and second tachometers, for matching the peripheral speed of the roller to that of the log.

Keywords: Back-up roll

67. Fronczak, Frank J. Influence of Chuck Design on Spin-Out Torque in Softwood Veneer Peeling Blocks. Research Paper FPL 427; September 1982: 14p.

Five chuck configurations were used to determine maximum torque deliverable to peeling blocks of four species. Chucks with relatively slender spurs transmitted greater torque before spinning out than did chucks with relatively large circumferential surface profiles. Maximum torque increased with depth of spur penetration. Limiting factors were spur stiffness and strength. Properly designed chucks can deliver substantially increased torque, thus reducing spin-out rate at a minimal cost.

Keywords: Plywood, Chuck design

68. Fronczak, Frank J and Loehnertz, Stephen. Powered Back-up Roll - New Technology for Peeling Veneer. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; October 1982; Research Paper FPL 428.
A powered back-up roll was designed and built for the purpose of providing auxiliary torque to a veneer bolt. Initial testing indicates that a substantial percentage of the required torque can be supplied by the powered back-up roll. This reduces the likelihood of spin-out occurring and allows a reduction in the final core size when used in conjunction with smaller chucks.

Keywords: Back-up roll

69. Gatchell, Charles J.; Thomas, R. Edward; Walker, Elizabeth S. Some Implications of Remanufacturing Hardwood Lumber. Forest Products Journal; February 2000; 50(2): 79-89.

Research on several hundred well manufactured 1 and 2A Common red oak boards shows that better edging and trimming or division-based remanufacturing can produce boards of higher grade and value. Division-based manufacturing divides a board into as many as four smaller boards. The UGRS computer program grades digitized boards, examines their remanufacturing potential, remanufactures to the highest valued solutions greater than the original board values, and displays the size, defect location, and grade of new boards for UGRS analysis. An example analysis of the effects of such remanufacturing for a simple, gang-rip-first, rough mill cutting bill is included, Whether boards can be remanufactured profitably depends on the relative prices among the lumber grades and the costs assigned to remanufacturing. All software used in the research is available free.

Keywords: Lumber, Edging, Lumber grades, Cost

70. Gephart, John S.; Petersen, Harlan D.; Bratkovich, Stephen M. Green Dimensioning: A Review of Processing, Handling, Drying, and Marketing. Forest Products Journal; May 1995; 45(5): 69-73.

"Green Dimensioning" has the potential to enhance resource utilization by using low-grade logs and lumber, and mill residues. The green dimensioning process can also reduce drying and transportation costs because only usable pars are dried and shipped to the secondary manufacturer. This paper provides a review of the processing handling, drying, and marketing of green dimensioned parts.

Keywords: Dimension lumber, Drying

71. Ghazali, Dato' Baharuddin Hj. (Director-General, Malaysian Timber Industry Board). The Promotion of Further Processing and Export of Timber Products: Malaysian Experience. Paper presented at the ITTO Seminar, "The Promotion of Further Processing of Tropical Hardwood of the African Region," Accra, Ghana; February 13-16, 1990.

There are 916 sawmills in Malaysia of which 667 are in Peninsular Malaysia, 143 in Sabah and 106 in Sarawak. About 79% of the sawmills are in active operation. Malaysia's annual sawtimber production is more than six and a half million cubic meters (the raw material consumption being in the region of 12 million cubic meters). Recovery in the industry is about 54.5% on the average with Peninsular Malaysia showing a recovery rate of 55.6%, Sabah with 52.9% while Sarawak sawmillers have a recovery rate of 45.7%. About 77% of the saw timber is produced in Peninsular Malaysia, 17% in Sabah and about 6% in Sarawak. The sawmilling industry has long been established but there has not been much re-investment and modernization within the industry. As a result mills are relatively small by international standards. There is a low degree of automation and the methods used for sawn timber handling are designed for labor-intensive operation. Quality and consistency of output are necessarily affected while the precision-cut raw materials required by the molding and furniture industry can not always be met. Wastage is therefore quite high throughout the industry.

Growth of the plywood industry in the 1980's was modest and occurred mainly in Sabah and Sarawak. Malaysia's current total plywood production is 920,000 cubic meters, and it is presently the world's second largest exporter, following Indonesia. The plywood industry is most developed in Peninsular Malaysia, which produces almost 90% of the total output for the country. There are however clear growth trends in Sabah where production has increased from 43,000 cubic meters in 1985 to 160,000 cubic meters by 1988. Development in Sarawak has initially been slow but with the current establishment of a few large modern plants, it is envisaged that within the next five years Sarawak will figure as a major supplier of plywood close to the Peninsula's capacity. In terms of recovery rates, the average intake capacity of Malaysian mills is 57,000 cubic meters per annum and the output produced is about 25,700 cubic meters giving a recovery of about 45%. However there are several new mills in Sabah and Sarawak twice as large or more than those in Peninsular Malaysia, which upon completion will enhance significantly the rate of recovery. Many Malaysian sawmills are wanting in efficiency and technique. Further downstream, skill in production, design, marketing and market research, R&D, etc. is very much to be desired.

Keywords: Malaysia, Export, Sawmills, Lumber recovery, Yield, Plywood

72. Gorman, D.E.; Persaud, E.V. (ADI Limited). Improving Yield at the Headrig Through Computerization. Improving Productivity Through Microelectronics; November 23, 1983; Moncton, New Brunswick, Canada. Ottawa, Canada: Forintek Canada Corporation; 1984.

Computerization could help in sorting at the infeed deck and after the debarker, selection of cuts in the larger logs passing through a rotary saw, selection of cut at the double twin saw, selection of cut at the edger, and trimming to length of the finished stock. However in small log mills complete computerization may be too expensive. It was found that a hybrid system using computer and graphics with a strong input from key positions in the production line offered a relatively low cost and highly effective system.

Keywords: Sawing, Edging, Trimming, Costs

73. Graf, Roger. Indonesian: Lockerung der Restriktionen fuer Holzexporte. Tong Tana. Basel, Switzerland; July 1998: 4-5.

Retiring President Suharto carried out a series of reforms on March 1, 1998. Export of logs, boards, rattan and plywood is to be simplified. Now the export of logs is encumbered with a tax of 200%, which favors export of high value and value-added products, especially plywood. But this tax is to be eliminated. In place of it a resource use tax of 10% is to be imposed. All further export control factors such as export quotas will be eliminated in 3 years. Wood concessionaires can export all wood as long as they sell at least 5% on the home market.

Keywords: Tropical wood, Export, Tax, Plywood, Lumber

74. Hacker, Jan J.; Carlson, Bonnie J. Sawmill Production of Hardwood Dimension Parts, A Guide for Potential Manufacturers and Users. St. Paul, MN: Northeastern Area, State & Private Forestry; 1997.

Outlines manufacture of hardwood dimension as a means of adding product value. Approach to manufacture is through green dimensioning. Though rough hardwood dimension parts can be produced at the sawmill using this technique, it has been successfully implemented in the U.S. by only a handful of producers.

Keywords: Dimension lumber, Sawing

75. Harpole, George B. How to Estimate Break-Even Points for Sawmill Improvement Projects. Forest Products Journal; 1977; 27(4): 54-56.

The purpose of this work is to describe and illustrate how to estimate the profit contribution of a sawmill improvement project and to explain how this, in turn, can be used to estimate the break-even point of an investment. The key variables that sawmill improvement projects are most likely to affect are 1) the lumber recovery factor (the board feet of lumber recovered per cubic foot of log input), 2) the value of the lumber product mix, and 3) the volume of logs processed. Total profit contribution (TPC) can be expressed as a function of these three variables and the variable cost.

Sawing, Yield, Lumber recovery, Cost, Price

76. Harpole, George B. (Forest Products Laboratory). Payback as an Investment Criterion for Sawmill Improvement Projects. Madison, WI: Forest Products Laboratory; May 1983; General Technical Report FPL 34.

This paper indicates how payback ratios are calculated, how they can be used to rank alternative improvement projects, and how to calculate the benefit value of improvement projects.

Keywords: Sawing, Lumber, Cost, Price

77. Henley, John W.; Bulgrin, Erwin H.; Haskell, Henry H. and Woodfin, Richard O. Jr. Work Plan For Hardwood Veneer Log and Bolt Grade Development. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; November 1963.

This work plan for the development of hardwood veneer log and bolt grades requires the use of the Forest Products Laboratory hardwood veneer grades. These veneer grades have been tested in several veneer studies and are recommended by the U.S. Forest Products Laboratory as a standard for measuring veneer quality. The purpose of this working plan is to outline procedures for conducting research that will provide additive data necessary for developing adequate grading specifications for hardwood veneer logs and bolts. The plan is intended to be applicable for three hardwood veneer log and bolt product groups, namely: face veneer, veneer for standard hardwood plywood, and container veneer.

Keywords: Log grade, Veneer, Plywood

78. Hess, Robert W. Use of Tropical Woods in Veneer and Plywood. Forest Products Journal; December 1952; 2(5): 194-199.

In some very rapid-growing tropical trees, tension wood is prevalent. This adverse feature causes warpage, buckling, grain-tearing, and fuzziness from sanding. It is becoming increasingly common among our second-growth hardwoods. It is the same defect that is becoming increasingly common among our second-growth hardwoods. Undoubtedly, this material has caused some of the unsatisfactory results obtained in trials of new woods. If recognized, tension wood can often be avoided in the standing tree or in the log, or graded out of the cut wood.

Keywords: Tropical woods, Veneer, Plywood, Wood Properties, Sawing defects

79. Hoff, Kristen. Limitations of Lumber-Yield Nomograms for Predicting Lumber Requirements. Newtown Square, PA: USDA Forest Service, Northeastern Research Station; February 2000; General Technical Report NE-270.

Lumber yield nomograms developed during the last 30 years have limited use when predicting volume of rough lumber needed to fill a particular cutting bill. Inaccuracies occur when nomogram yields are applied to situations in which processing technologies differ from those used during data collection, and when a variety of lengths and widths are specified in the cutting bill. Inaccuracies can occur when predicting yields for more than two lengths, cutting for a single width, or predicting yields based on the longest length rather than on a specific cutting bill. Most importantly, nomograms respond poorly to changes in processing technologies or in the hardwood resource. The impact of each of these problems associated with predicting lumber requirement is discussed.

Keywords: Yield

80. Hoffman, Benjamin F. How to Improve Logging Profits. United States of America: The Northeastern Loggers' Association, Inc.; 1991.

This book covers aspects of setting up and operating a logging business. It discusses logging costs, costs for road and trails, and environmental issues.

Keywords: Logging costs

81. Hornick, John R.; Zerbe, John I.; Whitmore, Jacob L. Jari's Successes. Journal of Forestry; November 1984; 82(11): 663-667.

The sawmill has an annual production capacity of 36,000 cubic meters. Daily processing was 100 cubic meters of sawtimber plus 1800 green metric tons of chips for boiler fuel for the 55-megawatt power plant that powered the Jari manufacturing complex. Of two sawmill lines one has a 2.7-meter band mill. The other has a 1.8-meter diameter twin circular saw headrig.

Keywords: Tropical woods, Veneer, Plywood, Export, Lumber, Ghana

82. Instituto Brasileiro de Desenvolvimento Florestal. Identifacao e Agrupamento de Madeiras Tropicais Amazonicas (Identification and Grouping of Amazonian Tropical Timbers). 1985: 49 pages.

Report prepared by an IBDF-INPA-IPT team in which 323 tropical timber producers from 6 northern states of Brazil were visited and interviewed. This project investigated species and groups of species according to use, regional names and variations, characteristics, defects, industrial process flows within different regions, and marketing problems.

Keywords: Brazil, Tropical woods, Survey

83. International Tropical Timber Organization. Road Infrastructure in Tropical Forests - Road to Develop or Road to Destruction? Rome: Food and Agriculture Organization of the United Nations; 1999.

Tropical forests regulate the climate and contribute to the balance of natural elements such as air and water, both on regional and world-wide scale. In spite of an awareness campaign aimed at the general public, the annual deforestation rate is still high. The tropical forest cover has shrunk from 1910 million ha in 1980 to 1756 million ha in 1990, which makes up for an annual loss of 0.8 percent. Roads have economic advantages, but endanger the environment. They are necessary for forest access and the transport of wood and non-wood products towards national and international markets. They also appear to facilitate agriculture and hunting by opening up the forests hence leading indirectly to deforestation and the destruction of wildlife. This publication assembles all the opinions, ideas and proposals from representatives of all concerned parties: political decision makers, scientists, professionals, and ecologists.

Keywords: Tropical forestry, Roads

84. International Tropical Timber Organization. Tropical Timber Market Report; 16 - 29th February 2000: 20 Pages.

Some log, lumber, and plywood veneer species for export from Malaysia, including Sarawak, for which market data are provided are meranti, keruing, kapur, selangan batu, balau, merbau, rubberwood, seraya. sepetir, perupok, K. semangkok, melapi, agathis,and kempas. From Brazil market data are provided for mahogany, ipe, jatoba, guaruba, mescla (white virola), angelim pedra, mandioqueira, pine, and eucalyptus. From Ghana market data are given for wawa, ceiba, chenchen, K.ivorensis, sapele, makore, afzelia, ayan, albizzia, utile, otie, odum, dahoma, redwood, ofram, bombax, kyere, ogea, essa, and canarium. Malaysia is shipping some manufactured products such as parquet flooring and furniture parts. However, the Government has decided to impose a total ban on the export of finger jointed and or laminated rough-sawn rubberwood to help improve the supply of such semi processed timber in the domestic market. There is some thought in Ghana that the forest and timber resources can only sustain an annual cut of one million cubic meters, but the capacity of the export-oriented wood industry is 3.7 million cubic meters.

Keywords: Tropical woods, veneer, Plywood, Export, Lumber, Ghana

85. International Tropical Timber Organization. Tropical Timber Market Report; 16th to 31st March 2000.

The Government of Indonesia revealed that the demand for raw materials in the timber industry has reached 63.5 million cubic meters per annum, while the allowable log production amounts to only about 35 million cubic meters. Shortages have resulted in illegal logging and log thefts. Due to the declining log supply the Government is encouraging the industry to harvest under-utilized species as well as encouraging the use of small diameter logs. At the same time the authority is also encouraging the industry to maximize the usage of raw materials and retooling of the production facilities to improve efficiency. Some 50 timber companies have stopped logging due to security problems and growing conflicts with local communities according to the Association of Indonesian Forest Concessionaires. Apparently local communities in affected areas claimed ownership to the areas and have been threatening workers. The affected forest concessions are mainly in Irian Jaya, Kalimantan and Sulawesi. Additional Malaysian species mentioned were falfata, pine, ramin, and mahoni.

Additional Ghanaian species mentioned were cedrela, danta, edinam, emeri, ekki, guarea, flack ofram, niangon, kusia, apa, and koto. Local semi-processed timber product exporters object to being singled out for paying the country's timber export cess and point to other sub sectors as furniture, MDF, and the timber industries in Sabah and Sarawak that should share the load. The cess is used by the Government to further develop the entire industry.

Keywords: Tropical wood, Export, Government policies, Logging

86. International Tropical Timber Organization. Tropical Timber Market Report; 1st - 16th April 2000: 22 Pages.

The Brazilian plywood industry has a problem, because of increased pine plywood production capacity and reduced market demand. It is expected that the Brazilian economy will grow more than the 4% initially projected. Statistics just released in Ghana indicated that the total volume of logs produced in 1999 was 1,102,203 cubic meters (including 1% illegally produced logs). This is 10% above the annual allowable cut determined of 1.0 million cubic meters. Of the 66 species felled for the year Wawa (31%), Ceiba (19%), Ofram (5%) and Chenchen (5%) collectively accounted for 60% of the total production with 61 other species accounting for the rest. Tests aimed at developing a national forest management certification scheme were conducted. Lesser used species are expected to find more markets. Exports in the first quarter of 2000 may exceed the whole of 1999. It is a real possibility that the target of 25,000 cubic meters for the year will be exceeded. A growth in exports was seen for curls and peeled veneers, plywood and processed lumber (moldings, profile boards) and poles. The major trading countries in 1999 were Germany, Italy, UK, France, Saudi Arabia, USA, and Ireland.

Keywords: Tropical woods, Brazil, Forest management, Plywood, Lumber, Government policies

87. International Tropical Timber Organization. Tropical Timber Market Report; 16th-30th April 2000.

Last week in Brazil the National Forest Program was officially launched. Included in the main objectives is to support actions to enlarge national and international market for forest products. The president of Brazil has instructed that a detailed program should be ready by September 21, the national tree day. Forest cover in the Western Region of Ghana, one of the five main producing areas, faces the threat of depletion within 30 years if the rate of encroachment continues. Ghana's exports in March showed an increase in volume over March 1999, but a decrease in value because of the inclusion of more LUS.

Keywords: Export, Governmental policies, Tropical woods, Deforestation

88. International Tropical Timber Organization. Tropical Timber Market Report; 1st - 15th May 2000: 19 Pages.

In Malaysia Li Hen Industries Bud, a holding company with interests in the manufacture and export of wooden furniture, was recently listed on the second board of the Kuala Lumpur Stock Exchange.

Keywords: Export, Furniture, Tropical woods

89. International Tropical Timber Organization. Tropical Timber Market Report; 16th - 31st May 2000: 35 Pages.

During a workshop in Ghana it was announced that fifty Forest Management Units have been created to boost the sustainable management of the country's permanent forest estate. Each Forest Management Unit is approximately 500 square kilometers and is within one Forest District. In addition to the creation of the units, the off-reserve forest areas are also being consolidated into management units under a Timber Utilization Contract to facilitate rational harvesting.

Keywords: Forest management, Sustainability, Logging, Tropical woods

90. Ishengoma, R.C.; Ringo, W.N. (Sokoine University of Agriculture). Current Research Priorities in Tanzania. African Workshop; November 19-25, 1989; Abidgan, Cote d'Ivoire: International Union of Forestry Research Organizations; May, 1990.

Logging systems in use leave most of the wood in forests. Short logs, top logs and branches, which could be sawn for veneer or peeled for veneer, are not used. Young and old trees of undesirable species that fall during logging are also left behind. The problems are especially evident where pit sawing takes place in steep terrain. Specific research should establish possibilities of partially or fully sawing short logs in the forest using mobile sawmills or other types of machinery. From short logs it is possible to fabricate some products such as boxes, crates, brush and broom heads, tanks, parquetry, pallets, etc.

Keywords: Tropical woods, Logging, Sawing

91. IUFRO Working Party on Slicing and Veneer Cutting. Veneer Species of The World. Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, Madison, Wisconsin, USA: IUFRO; 1973.

This report is a compilation of available information on the various species suitable for the production of veneer and plywood. Most of the data presented in the report came from research conducted in government laboratories in a half dozen nations. Additional information was obtained from contracts with the veneer and plywood industry. Each country's species are divided into hardwoods and softwoods and are then listed alphabetically by botanical (Latin) name. Veneer properties and appearance and use of veneer are tabulated in the tables that correspond to the research organization that supplied the data. Supplementary information supplied by various research groups is given with the matching tables.

Keywords: Veneer, Plywood, Tropical woods

92. IUFRO Working Party on Slicing and Veneer Cutting. Veneer Species of the World. Madison, WI: IUFRO; 1976.
Several hundred species of trees that might be used for veneer are described in standardized form from data from ten of the world's wood research laboratories.

Keywords: Veneer

93. Iwakiri, Setsuao (UN Center for Regional Development). Developing a Model of Integrated Wood Processing Complex for Sustainable Forestry in the Amazon Region. Nagoya, Japan; June 1992. (UNCRD/EPMU Working Paper Series No. 92-1).

This paper presents a model of an integrated wood processing complex based on the concept of sustainable forest management for application in the Amazon region. The proposed integrated wood processing complex applies to a site area of 66,168 ha. It includes of 6 sawmills with a total sawn wood capacity of 120 m^3 per day, together with molding and pre-cut wood components sections, 1 small product unit, 1 briquette/charcoal unit, 1 wood cement board unit, kiln dryers, and a thermal-electric generating plant.

Keywords: Tropical woods, Sustainability, Forest management, Amazon, Sawing

94. Krutilla, Kerry. A Guide to Investment and Trade in the Forest Products Sectors of Southeast Asia: Indonesia, Malaysia, and the Philippines. Malaysia. Raleigh, NC: School of Forest Resources, North Carolina State University; 1987; Working Paper No. 32. 27-48. (The Forestry Private Enterprise Initiative).
Capacity expansion in the sawmilling industry occurred at steady rate between 1975 and 1984, with the number of mills increasing by 79% from 536 to 678. Newer sawmills have been located primarily in the States of Johore, Pahang, and Kalantan. These mills have been larger, integrated complexes with the capability of processing smaller diameter (below 40 cm) logs. Sawtimber production reached a peak of 5.7 million cubic meters in 1983, before dropping by a million cubic meters to 4.6 million in 1984. The Peninsular industry produces rough cut and finished air-dried and kiln-dried timber in several standard dimensions. The vast majority of the dry kilns are located in the Peninsular state of Pahang. A total of 40 plants producing plywood, veneer, and blockboard are located in Peninsular Malaysia. The rate of growth of the industry has not been as rapid as the sawtimber industry. The distribution of the plywood industry mirrors the sawtimber industry with nearly 50% of the 1984 production total of 516,000 cubic meters produced in the states of Jahore and Pahang. More that 60% of the plywood production is exported. Plywood is shipped mainly to Asian markets with Singapore accounting for the largest percentage (68%) of the export total. Sarawak’s sawmilling industry consists of around 100 very small (9 cubic meters per day) sawmills specialized to converting peat swamp ramin. Three plywood plants annually consume 100,000 cubic meters of logs to produce about 30,000 cubic meters of plywood, of which 15,000 cubic meters are exported. A forest industries development plan was aimed at diverting 40% of domestic log production into the sawtimber industry and 15% of log production to the plywood sector by 1990. Veneer plants, which are less expensive to construct and operate, may be promoted instead of plywood plants.

Keywords: Tropical woods, Sawmills, Plywood industry, Lumber, Drying, Veneer

95. Kryzanowski, Tony. Quebec Sawmill Uses Finger-jointed Wood Innovatively. Wood Technology; May 1999; 126(4): 18-21.

A large sawmill in northern Quebec, Les Chantiers de Chibougamau Ltee., is working with Forintek and Canada's National Lumber Grading Association to establish a Special Products Specification 4 (SPS4) standard. The new standard will allow sawmills to manufacture machine stress rated (MSR) finger-jointed products for horizontal and vertical structural uses. Now, sawmills can manufacture SPS3 lumber, which is for vertical use only. The sawmill in Chibougamau has already invested C$7 million in a high-production line to make SPS4 flanges for I-beam joists. The SPS4 line can produce flanges from 26-50 feet long. the exact assembly line process is being kept secret.

Keywords: Lumber, Finger jointing, Structural lumber

96. Kryzanowski, Tony. Buyout of Independent Plymill Speeds Modernization, Growth. Wood Technology; May 1999; 126(4): 38-40.

With a switch in ownership the Levesque Plywood plant in Hearst, Ontario is becoming more efficient. It is now operated by Columbia Forest Products of Portland, Oregon. Columbia operates 16 hardwood plywood mills in the U.S. and Canada. The Levesque division of Columbia has a plywood mill, a particleboard plant, and a melamine overlay plant in Hearst, and a hardwood plywood mill in St. Casimir, Quebec. In addition to purchasing more production line equipment the company has mechanized its production line as much as possible with computer technology. Levesque Plywood uses trembling aspen exclusively.

Keywords: Plywood

97. Kryzanowski, Tony. Independent Sawmillers Invest to Improve Lumber Recovery. Wood Technology; June 1999; 126(5): 44-47.

Owners of a sawmill in Opasatika, Ontario have invested about C$7 million to improve recovery by at least 15%. The first phase in upgrading was to incorporate a reserve system into the single log line to eliminate downtime. Phase two was to purchase of a mechanized sorter. Phase three involved a major upgrade to the infeed system. During phase four the company will invest in advanced computer scanning technology to optimize wood recovery.

Keywords: Sawmills, Computer control

98. Kryzanowski, Tony. Industry-Indian Partnership Offers Training, Wood Products. Wood Technology; June 1999; 126(5): 34-37.

Because the sawmill uses technically advanced equipment, job candidates first had to complete appropriate job training. A total of 25 band members took part in job training for 17 mill positions, and all successfully completed the instruction. When Nabakatuk Forest Products purchases a piece of equipment to make the operation more efficient, they want to try to ensure that jobs which may be eliminated are replaced in another area of the operation.

Keywords: Sawmills, Training

99. Kryzanowski, Tony. Nova Scotia Sawmill: "Quality over Quantity". Wood Technology; March 1999; 126(2): 58-60.

The sawmill added a new planer to gain capability for surfacing all of its production. This helps attain a goal of more value-added and better quality. The company prefers to take more time in processing rather than lose wood. Emphasis is on more time in the dry kiln to limit warp and twist. Accuracy in sawing leads to greater efficiency in secondary processing.

Keywords: Sawing, Planing, Drying

100. Kuebler, Hans. Drying stresses in Veneer and Their Relief. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1961.

During drying, veneers free of checks caseharden just as does lumber. These veneer stresses and strains are easy to evaluate by measuring the bowing of slices cut parallel to the veneer surface. Compared with investigations on casehardening in lumber, experiments with small veneer sections have several essential advantages: The experiments are much faster to run, more accurate conditions can be applied, and considerably less material is needed. Under certain conditions maximum residual stresses in the dried veneers resulted with drying temperatures from 120 to 160 F, but even at -7 and 360 F, some residual stresses were observed. Slices cut from the surface of casehardened veneers bowed instantaneously; their curvature increased in succeeding hours and days. After some time, the slices flattened out, provided they were stored under warm and humid conditions. Boards resaved from casehardened thicker boards should behave similarly. It is to be expected that casehardening and stress relief in veneers have an effect on the properties of veneers and veneer products. By conditioning the veneers, their stresses were relieved in several minutes, provided the temperature was high enough. Dry wood required considerably more heat than moist wood.

Keywords: Drying, Veneer, Casehardening

101. Lim, K.O. (University Sains Malaysia). Malaysia's Bioenergy Utilization Scenario. Overend, R.P.; Chornet, E. Biomass: A Growth Opportunity in Green Energy and Value-Added Products; August 29-September 2, 1999; Oakland, CA. Kidlington, Oxford, UK: Elsevier Science, Ltd.; 1999; 1: 209-214; ISBN: 0 08 043019 8.

Large quantities of biowastes are generated from logging of forested areas. It is estimated that 15% of a felled tree is not removed from the logging site. For each cubic meter of sawlogs produced the amount of residual branches and leaves is about 0.176 m^3. Smaller trees in the path of felled trees are damaged, but this is minimized. For 1996 it was estimated that Malaysia produced 31 million m^3 of sawlogs. From studies at sawmills and plywood mills it is estimated that processing wastes are 0.181, 0.226, and 1.222 million dry tonnes of bark, sawdust, and fuelwood respectively. Barks if not removed at logging sites are burned, incinerated or allowed to decompose. In some mills sawdust is burned to produce energy, or it may be briquetted to make charcoal.

Keywords: Tropical woods, Bio-energy, Wood residues

102. Lim, S.C. Density and Some Anatomical Features of the Stem and Branch Woods of Rubber Trees. Journal of Tropical Forest Products; 1996; 2(1): 52-58.

Keywords: Wood properties, Rubberwood

103. Lim, S.C.; Choo, K.T.; Gan, K.S. The Effect of Tension Wood on the Drying Defects of Rubberwood. Journal of Tropical Forest Products; June 1999; 5(1): 102-103.

The production of rubberwood logs in Peninsular Malaysia in 1995 was estimated at 88,000 m^3 which represents just under 10% of the total log production of 9.03 m^3 in Peninsular Malaysia. But there are problems in using rubberwood. One of the main defects in sawn lumber is tension wood, The presence of tension wood makes the wood surface lustrous, wooly, and rough which can cause various finishing problems.

Keywords: Wood properties, Rubberwood

104. Lim, S.C.; Fujiwara, T. Wood Density Variation in Two Clones of Rubber Trees Planted at Three Different Spacings. Journal of Tropical Forest Products; 1997; 3(2): 151-157.

Keywords: Wood properties, Rubberwood

105. Lin, Wenjie; Kline, D. Earl; Araman, Philip A.; Wiedenbeck, Janice K. Design and Evaluation of Log-to-Dimension Manufacturing Systems Using System Simulation. Forest Products Journal; March 1995; 45(3): 37-44.

The results of this study show that the dimension production rates in mills configured for live sawing average 22 percent higher than those configured for five-part (cant) sawing. The part production rate in mills processing Factory Grade 2 logs averaged 41 Percent higher than those processing Factory Grade 3 logs. Other results show how different cutting-length specifications can impact production rate. The application of system simulation as a tool for identifying resource bottlenecks and improving overall mill efficiency is also illustrated.

Keywords: Sawing, Lumber , Yield

106. Lin, Wenjie; Kline, D. Earl; Araman, Philip A.; Wiedenbeck, Janice K. Dimension Yields from Factory Grade 2 and 3 Red Oak Logs. Forest Products Journal; September 1994; 44(9): 19-25.

Research results showed that overall scaling yield of rough green dimension parts ranges from 57.8 to 78.5 percent for Grade 2 red oak logs and from 52.3 to 76.7 percent for Grade 3 red oak logs. Economic recovery from Grade 3 logs was much better than from Grade 2 logs because of a much lower cost for grade 3 logs. The combination of live sawing and rip first can provide the highest value recovery. Results suggest that direct processing systems offer a very promising method for converting low-grade timber resources into high value solid wood products. The direct processing system has been used previously in Japan and Europe.

Keywords: Dimension lumber, Yield

107. Lin, Wenjie; Kline, D. Earl; Araman, Philip A.; Wiedenbeck, Janice K. Producing Hardwood Dimension Parts directly from Logs: An Economic Feasibility Study. Forest Products Journal; June 1995; 45(6): 38-46.

It was found that the direct processing system is much more profitable than current sawmills and dimension mills. The predicted return on sales (ROS) values of the direct processing mills are 7 to 12 percent higher than the average upper quartile ROS values achieved by the hardwood sawmill industry and by the hardwood dimension and flooring industry from 1983 to 1992. A sensitivity analysis showed that dimension part price, green cutting yield, and drying degrade and remanufacturing loss are the three most important factors affecting the economic feasibility and profitability of the direct processing systems. If the drying degrade and remanufacturing loss is too high, the proposed direct processing system may not be able to achieve its high profit potential.

Keywords: Dimension lumber, Sawing, Costs, Yield, Drying, Profitability

109. Loehnertz, Stephen P. A continuous press dryer for veneer. Forest Products Journal; September 1988; 38(9): 61-63.

The purpose of this research was to determine the feasibility of continuous press drying of veneer. An experimental dryer developed at the USDA Forest Service, Forest Products Laboratory (patent applied for) shows promising results. Compared to a laboratory roller dryer with longitudinal air flow, the experimental dryer dried 1/32-inch aspen veneer in 25 percent less time, with 67 percent less transverse shrinkage and volume loss, and the veneer was much flatter and smoother. Compared to a laboratory platen press, the experimental dryer dried veneer with 75 percent less thickness loss and 60 percent less volume loss.

Keywords: Drying, Veneer

110. Loehnertz, Steve. How to save face (veneer) with the Lab's MVP Dryer. Wood Based Panels North America; October 1988: 32-33.

The Forest Products Laboratory at Madison, Wisconsin, has attacked the difficulties associated with drying 'problem woods' by developing a dryer where the veneer stays flat in a continuous press.

Keywords: Drying, Veneer

111. Loehnertz, Stephen P.; Cooz, Iris Vazquez; Guerrero, Jorge. Hardwood Sawing Technology in Five Tropical Countries. Forest Products Journal; February 1996; 46(2): 51-56.

The authors studied hardwood sawing technology and problems experienced by sawmills in Ghana, Brazil, Venezuela, Indonesia, and Malaysia. Percentages of log volume converted into lumber are listed. These percentages are not directly comparable with yield figures from North American mills. North American recoveries are usually reported in board feet per cubic foot. For better comparison knowledge as to whether yields are based on green or finished thickness and what typical log diameters are in addition to board feet per cubic foot must be known. In Ghana harvesting and cutting of timber are heavily mechanized. Many sawing problems are related to maintenance. Among these problems are saws being used when dull, gullet burn while sharpening, incorrect and uneven tension, uneven crown, burrs left in gullet when sharpening, faulty wheel bearings, saw too thick for wheel diameters, and band mill vibration. These problems result partially from a lack of skilled personnel in the shop and management. Principal problems of the wood processing industry in Brazil include the highly selective nature of forest exploitation, a scarcity of qualified personnel at all levels, and obsolete equipment and inadequate maintenance infrastructure. In most, if not all, tropical countries high species density and silica content pose problems for sawing. Stellite tipped teeth are the rule in Malaysia. The clearance angle is apparently kept high to reduce feed force and prolong the life of the tooth and blade. Most saw sharpening machines are not equipped with cams for changing tooth profiles, which might partially explain the predominant use of the flat-bottom shape. Many experts agree that this shape is not the ideal tooth profile for cutting medium to high density species, but it has proved in many countries to be capable of meeting all basic requirements. Unless the sawmill industry is prepared to sort logs according to density groups and/or abrasiveness of species, there appears no need to introduce another tooth shape. Although almost all sawmills have facilities for band saw maintenance, the typical saw filer does not know the profile, tooth height, angles, swage, or other parameters about the saw. Throughout the countries the most commonly reported sawmilling problems included poor maintenance, lack of trained personnel, obsolete equipment, and inadequate saw tooth geometry and wear resistance.

Keywords: Tropical woods, Lumber, Sawing, Yield, Lumber recovery, Saws

112. Love, W.F. (Forintek Canada Corp.). Room for Improvement: A Discussion of Machine Center Inefficiencies Based Upon Sawmill Improvement Studies Performed by Forintek. Improving Productivity Through Electronics; November 23, 1983; Moncton, New Brunswick, Canada. Ottawa: Forintek Canada Corp.; 1984.

Computer controlled bucking systems should reduce problems with sweep and crook. Other problems are log length, over length, and debarking. As an example of over length, assume a mill sells lumber in even feet (8-10-12-14-16). If a log were to be cut 12 feet, 9-1/2 inches, and the log should have been cut 12 feet, 5 inches, there would be 4-1/2 inches over length. This lowers the recovery factor, consumes expensive processing time needlessly, and may, in some cases, reduce the number of logs that may be cut from a stem until the minimum log diameter suitable for sawing is reached. Ineffective debarking may result in too much bark on chips to make them salable, or too much fiber removed decreases the yield of the log. In a mill with more than one headrig it is also important to assign each log to the proper production line. Other important aspects in microelectronic processing are efficiency of the scanning system, efficiency of diameter sorts to sawing diagrams, sawing variation, target size and quality control monitoring.

Keywords: Computer control, Logs, Bucking, Debarking, Wood residue, Lumber, Yield

113. Lunstrum, Stanford J. Opportunity for Improved Lumber Recovery - A National Perspective. Proceeding: Manufacturing Lumber From Small Logs. Contribution No.44. Seattle, Washington: College of Forest Resources, University of Washington; 1982.

Increased lumber recovery is possible by decreasing saw kerf from 0.180 inch to 0.150 inch, decreasing planing allowance from 0.100 to 0.060 inch, decreasing sawing variation from 0.160 to 0.080 inch, and decreasing over sizing from 0.046 inch to 0.000 inch.

Keywords: Recovery

114. Lutz, John F. Drying Veneer in Progressive Conveyor-Type Dryers. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1958.

There are problems in veneer drying. Among these are stresses that develop in veneer of refractory species dried at high temperature, gluing problems with veneer dried at very high temperatures, and problems associated with drying veneer to a uniform moisture content at levels appreciably higher than 2 to 4 percent. One of the most common problems in veneer drying in a progressive dryer is the non-uniformity of the moisture content of the dry veneer. The higher the average moisture content to which the veneer is dried, the greater will be the final range of moisture content. Veneer can be conditioned by storing it in controlled humidity rooms, by stickering it in piles, and by reconditioning it in a kiln. However, none of these techniques provides the final answer to this problem of uniform drying. Any commercial manufacturer of veneer dryers who can build a dryer that will dry veneer to a uniform moisture content of 8 percent, or any research man who can devise a method for doing this, will make a significant contribution to the veneer and plywood industry.

Keywords: Drying, Veneer

115. Lutz, John. Heating Veneer Bolts to Improve Quality of Douglas-fir Plywood. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; March 1960; Report No. 2182.

The quality of Douglas-fir plywood is directly related to the quality of the veneer. Veneer quality, particularly its smoothness and tightness, can be improved by heating the bolts. This paper describes three methods of heating - hot water, steam, or electricity - and discusses the advantages and limitations of each.

Keywords: Veneer, Pretreatment

116. Maeglin, Robert R., Editor (Forest Products Laboratory); Boone, R. Sidney; Valdevino Jose Carlos; Gandolfi, Jr., Aldo; Gjovik, Lee R.; Han-Rosenblum, Mario; Harpole, George R.; Laundrie, James F.; Wolfe, Ronald; Zinkel, Duane F. Forest Products from Latin America: An Almanac of the State of the Knowledge and the State of the Art. Maeglin, Robert R., Machining. Madison, WI: Forest Products Laboratory; March 1981; FPL-GTR-67.

Sections on Sawmilling and Veneer and Plywood Manufacture.

Keywords: Tropical woods, Sawmilling, Veneer, Plywood

117. Maeglin, Robert R.; Boone, R. Sidney (Forest Products Laboratory). Forest Products from Latin America: Annotated Bibliography of World Literature on Research, Industry, and Resource of Latin America 1915 to 1989. Madison, WI: Forest Products Laboratory; August 1993; FPL-GTR-79. 120 Pages.

Sections on Sawmilling and Machining and Veneer and Plywood Manufacture.

Keywords: Sawmilling, Machining, Veneer, Plywood, Tropical woods

118. Maine Forest Service. 2000 Primary Processor Mill List. Augusta, ME: Maine Forest Service; March 2000.

Lists characteristics, products, and equipment at seasonal, hobby, and custom sawmills in Maine.

Keywords: sawing, Sawmills

119. McAlister, R.H. Hawaiian - Grown Woods for Face Veneer. Reprinted from PLYWOOD Magazine; Mid-January, 1962.

Silk-oak and shamel ash, grown in Hawaii, have undergone preliminary veneer cutting and drying tests at the Forest Products Laboratory in cooperation with the State of Hawaii. Experiments indicate that both species are suitable for face veneer.

Keywords: Veneer, Tropical woods

120. McAllister, R.H. A Study of The Veneer Cutting and Drying Properties of Yagrumo Hembra. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1960.

This study was made at the Forest Products Laboratory to gain information on the suitability of yagrumo hembra (*Cecropia peltata* L.) for rotary-cut veneer. Yagrumo hembra is a tropical tree, which occurs in Puerto Rico, Cuba, Central America, and as far south as Brazil. In large parts of its range it occurs in almost pure stands. This preliminary work on the veneer cutting and drying properties of yagrumo hembra indicates that, although excellent veneer may be cut from this species, it would have limited use due to the prevalence of tension wood, wet streaks, and the wide range in density including some extremely low-density material. Yagrumo hembra would have limited use for core and cross band material due to its extreme compressibility under heat and pressure.

Keywords: Veneer, Drying, Tropical woods

121. McAllister, R.H. A Study of The Veneer Cutting and Drying Properties of Shamel Ash. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1961.

This exploratory work on the veneer cutting and drying properties of shamel ash indicates that excellent face veneer may be cut from this species if material free from beetle attack can be supplied. Shamel ash veneer is light colored, attractive, and apparently easy to glue.

Keywords: Veneer, Drying, Tropical woods

122. McAllister, R. H. and Olson, W. Z. A Study of The Veneer Cutting and Drying Properties of Hawaiian-Grown Silk-Oak (*Grevillea robusta*, A. Cunn). Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1961.

Silk-oak grown in Hawaii can be made into decorative plywood panels by using quarter-sliced face veneer. The veneer cuts and dries well. It is moderately difficult to glue, but can be glued satisfactorily by using special gluing techniques. The low widthwise shrinkage of quarter-sliced veneer and the pleasing appearance of sanded panels indicate that the wood will compare favorably with other face veneer species. Rotary-cut silk-oak has less figure than quarter-sliced veneer but does appear suitable as a face veneer.

Keywords: Veneer, Drying, Tropical woods

123. McAllister, R. H. A Study of The Veneer-Cutting Properties of Plantation-Grown Teak. Madison, Wisconsin: Forest Products Laboratory, USDA Forest Service; 1962.

The preliminary work on the veneer-cutting properties of plantation-grown teak indicates that excellent veneer may be cut from this wood. The limiting feature of plantation-grown teak appears to be the relatively wide band of sapwood, which does not show the typical teak color. This preliminary work has also shown the feasibility of using small sample blocks to determine the best cutting conditions for rotary-cut veneer.

Keywords: Veneer, Drying, Tropical woods

124. McDougall. Into the New Millennium: Technology Sparks a Revolution. Wood Technology; April 1999; 126(3): 54-56.

Supply chain management systems help decision makers assess the impact of each decision across the entire supply chain of events and activities that take raw material (trees), turn the material into a product, and deliver it to a customer. Such visibility is gained by deploying supply chain management systems throughout an operation. Examples are as follows: Production - Log allocation among mills, Log selection, Fiber allocation, Recipe choice, Cutting pattern choices, Shift planning, Kiln scheduling, Capital equipment/investment.

Keywords: Wood residue, Fuel

125. McKeever, David B. How Woody Residuals are Recycled in the United States. BioCycle; December 1999; 40(12): 33-42.

Provides details on wood waste generated; recovered, combusted, or not usable; and available for recovery in the U.S. in 1998.

Keywords: Wood residues

126. Melaku, Abegaz. Objectives and Programs of the Wood Utilization Research Center. African Workshop; November 19-25, 1989; Abidjan, Cote d'Ivoire: IUFRO; May, 1990.

Commercially known species are being depleted while potentially usable species are left unharvested. Objectives of the Wood Utilization and Research Center are to 1) promote the economic viability of lesser known species, 2) introduce completely unknown species to the wood processing industry, 3) assist planning and establishment of sawmills and advise on the handling of tools and saw doctoring, and 4) promote the utilization of wood panel products like particle board and fiber board, cement particleboard, and wood wool cement slabs, plywood, and block board. There is some work on the study of mechanical processing that includes sawing and planing properties of solid lumber and veneer slicing and peeling properties. The Ethiopian forest industry has some problems with logging and sawmilling. Work is needed on improving logging extraction methods and log standardization and grading. Sawmilling needs improved methods of sawing, lumber standardization and grading, and upgrading the skill of sawmilling operators, saw doctors, and furniture manufacturers through on-job training and seminars.

Keywords: Tropical woods, Research, Veneer, Particleboard, Sawing, Logging, Lumber

127. Meulenhoff, L.W.M. Recent Developments in Sawmill and Plywood Industries in Indonesia. FAO Forestry Paper 68: Appropriate Forest Industries. Rome: FAO; 1986.

The bulk of the commercial forests of Indonesia, on which the wood-based industry relies for its raw material supply, are lowland tropical rain forests and hill tropical rain forests. In the past three years sawn wood species exported from Indonesia were ramin (43.4%),meranti (20.6%),keruing (4.0%),agathis (1.0%),kapur (0.8%),pulai (0.5%). Other species accounted for 28.3% of the total export volumes.

Indonesia is becoming one of the world's largest plywood producers. By the end of December 1984 there were 96 mills in production with a total capacity of 4.7 million cubic meters/year. On the average 60 to 70 percent of the production is exported. Indonesia's plywood industry is largely based on meranti, which has excellent properties, and on other mixed light tropical hardwoods. Indonesia also produces sliced veneer. Main species are teak and ebony. Most of the sliced veneer production is sold on the local market. Logging residues are estimated to be about 30-40 percent of the logs felled. Industrial residues are, respectively, about 50 percent from sawmilling and about 55 percent from plywood mills. The sawmilling residues are made up as follows: log ends 25.0%,sawdust 15.0%,others 10.0%. The plywood industry residuals are made up as follows: log ends 11.0%,cores 13.0%,green veneer 13.0%,dry veneer 12.0%,trimmings 4.5%,dust (from sanders) 1.5%. These wood residues from the mills, nationwide,are not yet utilized, except for the production of blockboard cores and as boiler fuel in the plywood industry.

Keywords: Export, Plywood, Tropical woods, Veneer, Wood residues

128. Middleton, G.R. FRDA Report 102. Advances in Sawmill Technology. British Columbia, Canada: Forintek Canada Corp.; December, 1989; FRDA Report 102.

This is a compilation of reports on advances that can make sawmilling more efficient. Advances include sorting for moisture content, camera scanners for computer optimized bucking systems, training and education, curve sawing, cant optimization, and log rotation. Sorting for moisture reduces planer down time in addition to saving energy in dry kilns.

Some parameters of an optimized bucking system are 1)debark before bucking, unless scanner can accurately measure under bark log diameter, 2)diameter and sweep scanning be accurate to at least 0.4 cm, 3)length be accurate to 2 cm, 4)logs do not bounce, slide, or roll while being scanned. 5)nominal two-foot spacing be used for transverse bucking systems, 6)hardware be capable of operating in adverse mill conditions, 7)self-diagnostic capability be built in for the computer and scanning systems, 8)lumber output for log segments be determined accurately and classified by diameter, sweep, taper, and length, 9)butt ends be manually squared before scanning or be optimally squared by the scanning system, 10)lumber prices and operating costs be specified accurately, and 11)log trim allowance be reduced to near the minimum required.

Curve sawing increased recovery 16,8,and 4 percent for three diameter classes in ascending order, respectively. The declining trend suggests that there is little advantage in curve sawing logs with sort diameters greater than 10 inches. Furthermore, curve sawing 10-inch cants with circular saws was found to be impractical from a saw maintenance of view. An optimizer selected the best cant width for each log. As with curve sawing, cant optimization improved recovery of lumber and value substantially.

A simulation study found that lumber and value recoveries decrease steadily with increasing rotation error. If the rotation error was within 15 degrees from the hands down position, less than 1% loss in lumber or value recovery was estimated. If the rotation error was 90 degrees, almost 9% of the value was lost.

Keywords: Curve sawing, Rotation, Bucking, Yield

129. Ministry of Primary Industries, Malaysia. Forestry in Malaysia.

Utilization research in Malaysia encompasses development of appropriate technology for economic use of logging wastes, greater use of lesser known species, smaller diameter logs, and reduction of costs during harvesting operations. Another effort involves efficient utilization of fast grown plantation species.

Keywords: Tropical woods, Wood residue, Costs, Logging, Plantations

130. Ministry of Primary Industries, Malaysia. Industry at its Peak: How Sustainable? Maskayu; December 1992: 1-3.

Stringent enforcement and application of forest felling plans, to ensure sustainability of resource, will restrict the output of logs at a level some 30% less than what Peninsular Malaysia and Sabah used to enjoy. With similar moves afoot in Sarawak there is no raw material abundance, although long term adequacy of raw material for the industry remains secure. The days of abundant labor force are numbered. Too many mills are left with unwieldy, outdated machinery more suited for labor-intensive work. These mills are slow and have lost their effectiveness. Such mills need to modernize or divest. There is no choice, but to give way to mills using precision cutting tools and fast automated equipment. To ensure continued viability the industry needs a second wave of growth.

Keywords: Tropical woods, Logging, Sustainability, Sawmills, Automated sawmills

131. Moamba, Carlos Ernesto (Moputo, Mozambique Forestry Research Center). General Information about Mozambique Wood Industry and Activities of the Technology Department of CEF/FHC. African Workshop; Abidjan, Cote d'Ivoire: IUFRO; May, 1990: 117-133.

Fifty-nine units produce sawn wood from native forest and 1 unit produces it from plantations. Two units produce plywood, and 2 units produce veneer. About 50% of factories are in Maputo. Units work under their capacities because of obsolete equipment and lack of constant and programmed maintenance, shortage of skilled people, unsatisfactory methods of extraction and transportation of logs, and security problems. Low volumetric yield of sawmills is due to inappropriate methods of breaking down logs, low quality of logs due to lack of proper treatment in the forest (especially in preventing xylophagus attacks), lack of standardization, overexploitation of some areas, and lack of information on some native species.

Keywords: Tropical woods, Sawing, Lumber, Plantations, Plywood, Veneer, Logging

132. Mohd. Ali, Abdul Razak; Chiew, Cheah Leong (FRIM). Strengthening of Forestry Research in Malaysia. Proceedings of the Meeting of Experts on Forestry Research; October 12-14, 1992; Rome. Rome: FAO; 1993; FAO Forestry Paper 110: 68-77.

FRIM will assess available new technologies in use in developed countries to determine the suitability for adoption locally. FRIM will also establish a comprehensive database on the forest and wood-based industries to facilitate the development of new markets and the strengthening of traditional markets.

Keywords: Malaysia, Lumber industry, Plywood industry, Markets

133. Muraleedharan, P.K.; Bhat, K.M. (Kerala Forest Research Institute). A Techno-Economic Study of Sawmilling Industry in Kerala. KFRI Research Report : 60 (Summary). Peechi, India; July 1989.

Sawmills having per annum production capacity of less than 1500 m^3 and above 1500 m^3 are grouped as small and medium size respectively. The commonly processed timber species varies from as soft as the wood of semul and cashew to as hard as the wood of mesua and coconut with wood density range (at 12% m.c.) being 365-1090 kg/m^3. Log ponds are only at mills beside rivers. In the rest of the mills logs are stored in log yards. Only a few of them possess facilities for protection of logs against end splitting and surface cracks. Log hauling is done either manually (often with mechanical aids) or with elephants and machines (chain blocks and lifting winches with monorail hoist). Debarking is generally not done. Log breakdown is fairly efficient, because the headrigs are horizontal or vertical band mills - no circular sawmills. Straightening or tensioning of the blade and tooth setting are done manually. Blade sharpening is done by grinding the gullet with grinding wheels. Often automatic grinders with 0.7 kW motors are used. In spring set teeth, the amount of setting is not controlled or measured. While swaging the tooth, side dressing is a rare feature. Stellite tipping is seldom used in processing timbers containing silica. Sawmilling did not make any headway in Kerala since the 1950s. Despite the alarming situation of declining raw material supply, no effort has been made to improve technology. One exception is the few government owned units where improvements include imported machines such as headrig saws and doctoring equipment. There is a problem of log geometry in deciding the sawing pattern in processing logs that have flutes, buttresses, hollow centers, and severe rots. Lack of knowledge/skill/training is another major problem in improving conversion technology.

Keywords: Sawmills, Tropical woods, Logging, Sawing, Maintenance

134. Ngok, Wong Choong. Malaysian Timbers for Plywood Manufacture. Kuala Lumpur: Malaysian Timber Industry Board; 1985; Malaysian Forest Service Timber Trade Leaflet No. 94. (Timber Trade Leaflets; 94).

In Malaysia plywood is manufactured from a limited number of face veneer species that are being depleted rapidly. There is need to use other species, although there are no legal restrictions on the species that are being used. Therefore there is much variability in quality and strength properties. In this publication, 57 species are evaluated for utility, structural, and decorative use.

Keywords: Tropical woods, Plywood, Veneer, Properties

135. Nir, Edward. Sawn Timber Recovery rates of Some PNG Species of Logs. Klinkii: the journal of the Forestry Society of the Papua New Guinea University of Technology; 1989; 4(1): 85-98.

Recovery rates can vary because of (a) log characteristics and (b) sawmilling efficiency. Because of difficulty in determining recovery rate of PNG timbers, logs of six species were sawn and the timber cut from each log was marked. Initially the logs were measured using the metric system Brereton scale. The formula and procedure for this measurement are given.

Keywords: Tropical woods, Lumber recovery, Yield

136. Office of Technology Assessment. Technologies to Sustain Tropical Forest Resources (Summary). Washington, DC: Office of Technology Assessment; March 1984; OTA-F-215.

For little known but potentially marketable lumber species, cost effective preservation and drying technologies are needed to improve use characteristics. Many types of wood are susceptible to attack by termites, other insects, or fungi under tropical conditions. Although wood preservatives are available, they generally are costly. Some less expensive techniques exist but their effectiveness has not been proven.

Keywords: Tropical woods, Lumber, Drying, Wood preservation, Costs

137. Oja, Johan; Grundberg, Stig,; Gronlund, Anders. Predicting the strength of sawn products by X-ray scanning of logs: A preliminary study. Wood and Fiber Science; April 2000; 12(2): 203-208; ISSN: 0735-6161.

Eight logs were scanned using computed tomography (CT). Four center boards were sawn from each log, and MOE and MOR were measured. Means from the four boards were calculated. The CT images were used for simulations of the industrial X-ray LogScanner, resulting in simulated measurements of knot volume and the green density of heartwood. Multivariate models were calibrated using Partial Least Squares (PLS) regression. The results indicate that the X-ray LogScanner can be used for the sorting of saw logs according to strength and stiffness.

Keywords: Properties, Computer scanning, Strength, Stiffness

138. Okoh, Isaac K.A. (College of Agriculture and Forestry, University of Liberia). Seminar on "The Future of Further Processing of Tropical Hardwood of the African Region," Accra, Ghana. Appropriate Technology for Seasoning and Standards for Export Quality Wood Products. Yokohama, Japan: International Tropical Timber Organization; 1990; Document No. 8.

The paper recommends dependence on renewable energy for drying timber in Africa. Conventional kilns are expensive to install and operate. It was recommended that they use wood residues for fuel. Solar drying was recommended, particularly, for the small and medium wood processing enterprises. Solar drying could be combined with dehumidification drying or with a wood energy system. Wood has been used in most African countries without proper treatment. Drying requires about 40 to 70 percent of the total energy consumed in processing sawn timber from log to the final product (Rosen, 1981).

Keywords: Tropical woods, Wood residues, Fuelwood, Drying, Solar drying

139. Parent, Bernard (Centre Technique Forestier Tropical). Seminar for "The Promotion of Further Processing of Tropical Hardwood of the African Region," Accra, Ghana. African Secondary Timbers: New Prospects for Their Processing and Marketing in Europe. Yokohama, Japan: International Tropical Timber Organization; 1990.

The decline in the availability of principal timber species has forced logging companies and timber industries to seriously consider some secondary species. Fromager, *Ceiba pentandra*; Koto (*Pterygota macrocarpa*); Iaiandza, (*Albizzia ferruginea*) are exploited in only a few African countries. The bulk of secondary species is not made up of lesser known species, but of species which are well known for specific characteristics such as small diameter, internal stress, lack of stability, difficult seasoning, pinholes, stain, poor durability, etc., which result in higher processing costs.

Keywords: Tropical woods, Logging, Sawing

141. Pease, David A. Sawmill Adds Value to Small-log Resource. Wood Technology; March 1999; 126(3): 22-28.

The $12 million Yakima Forest Products sawmill at White Swan, Washington (Yakima Indian Reservation), dedicated in the Fall of 1998, consists of a log sorter/merchandiser, HewSaw sawmill, dry kilns and planing mill. As this HewSaw model is a "batch-run" machine without shift-on-the-fly setworks, diameter sorting ahead of the mill is essential to efficient operation. The 30-bin sorter's configuration is seen frequently in European sawmills. YFP sorts for length and diameter with the division between diameter sorts generally less than 11 inch and as narrow as .30 inch. Components of the merchandiser/sorter were supplied by Softac Systems Ltd. and Flare International Sawmill Systems Ltd., both of Surrey, BC. Logs are scanned for length and diameter on a transverse deck that terminates at six shifting, 44-inch overhead chop saws. Bucked sections continue longitudinally between the left and right side ranks of drop-sort bins. Manufacturing elements are arranged in a U-shaped pattern to minimize handling between steps and to keep material flowing in the same direction. The HewSaw process produces dimension lumber up to 8 inches wide. Sawdust, chips, and hog fuel are transported to Boise Cascade Corp's Wallula, Washington pulp mill. Planer shavings are sold to Boise Cascade's particleboard plant in La Grande, Oregon.

Keywords: Sawmills, Sawing, Computer scanning, Logs, Dimension lumber, Wood residue

142. Pease, David A. Sawmill Efficiency Rises with Regular Upgrades. Wood Technology; June 1999; 126(5): 22-26.

Steady renovation of Crown Pacific's Gilchrist, OR sawmill has increased lumber production and fiber recovery while lowering manufacturing costs. The sawmill, which contains large- and small-log headrigs, produces ponderosa pine and lodgepole lumber. Logs range in diameter from 6-50 inches, with the largest volume within the 8-16 inch range. blocks measuring 9 inches and above at the small end are processed by the large-log side; others by the small-log side. The headrig was converted from quad to twin, and piece count through the mill was increased. Bandmills at both headrigs are preceded by TM^E slabbing heads equipped with Key Knife Inc. chipper knives. Edgers run thin kerf saws with Stellite alloy tips. Two computers are used, one for the edger function and one for the gang saw function.

Keywords: Sawmills, Costs, Sawing, Sawing, Lumber, Edging, Computer control

143. Rago C., Fernando (Corporation Chilena de la Madera). Considerations on the Role and Sustainability of Forest Plantations. Rome: FAO; April 1999.

This paper discusses the importance of forest plantations as an element of forest sustainability and examines their roles within the global environmental context and their contribution toward achieving sustainable development in the most ecologically efficient manner.

Keywords: Plantations, Sustainability

144. Rubberwood Research Committee. Malaysian Timbers - Rubberwood. Malaysia: Malaysia Timber Industry Board; 1988; Timber Trade Leaflet N. 58. 12 Pages.
Note: ISSN 0127-9254.

Keywords: Rubberwood

145. Salahuddin, Jalan Sultan (Forestry Department of Peninsular Malaysia). Current Status in Forestry Sector of Peninsular Malaysia. Kuala Lumpur.

This publication has statistics that are more current for Peninsular Malaysia than those reported by Krutilla. According to this publication, there were 686 sawmills in 1990 with an installed capacity of about 10.4 million m^3 per annum based on one shift operation. The industry consumed about 9.4 million m^3 of logs and produced about 6.2 m^3 of sawn timber of which 3.0 million m^3 were exported. In 1990, there were at total of 43 plywood/veneer mills with an installed capacity of about 2.2 m^3 based on two-shift operation. Most of the mills were established in the late 60s and early 70s and are small by international standard. In 1990, the industry consumed about 1.96 m^3 of logs and produced 995,068 m^3 of plywood of which 678,021 m^3 were exported. The establishment of new primary manufacturing facilities in Peninsular Malaysia is no longer encouraged.

Keywords: Tropical woods, Lumber, Plywood, Veneer, Export

146. Sanwo, S.K.; Dada, S.A. (University of Ibidan, Nigeria). Forest Products Research Needs in Nigeria. African Workshop; November 19-25, 1989; Abidjan, Cote d'Ivoire: IUFRO; May, 1990: 95-104.

The wood supply of Nigeria is grim. With an average population of 100 million and an annual per capita wood consumption rate of 0.15 m^3, the nation's wood resource would be exhausted by 2000.

Priority research areas include intensified study of lesser-used species, adaptation of equipment and technology to suit smaller-sized logs produced from faster growing plantations, utilization of forest residues and wood wastes, and understanding the influences of forest silvicultural practices on wood quality. Forest residues, sawmill residues (including sawdust), forest poles, tree tops, and branches have all been used as fuels in Nigeria, either directly or converted into wood briquettes, charcoals, or other forms of energy. The forest products industry in Nigeria consists of groups of establishments that produce wood, wood-based panels, and other products for the Nigerian market.

Keywords: Tropical woods, Plantations, Silviculture, Wood residue, Energy, Fuel

147. Sawmill Exchange. The Portable Sawmill Encyclopedia. Birmingham, Alabama: Birmingham Exchange; 1998.

Contains a comprehensive list of sawmill manufacturers and support equipment manufacturers, trade shows, and information sources. It provides a venue for buyers and purchasers of portable sawmills to contact one another. Manufacturers sell new portable sawmills. Sawmill Exchange sells used portable sawmills throughout the United States and Canada.

Keywords: Sawmill

148. Seguin, J., J.Seguin Consultants Inc. The Mechanical/Electrical Interface. Improving Productivity Through Microelectronics; November 23, 2000; Moncton, New Brunswick, Canada. Ottawa, Canada: Forintek Canada Corporation; 1984: 43-49.

It is important for a sawmiller to know accurately how much lumber he is getting from the volume of sawlogs going to the mill. To get this information very accurately one needs electronic equipment. Volume should be measured at the infeed to the headrig.

Keywords: Electronic equipment, Computer control, Sawing, Yield

149. Senamede, Beheton; Shehu, Ibrahim. TED Case Studies: Ghana Forest Loss. Internet: http://www.american.edu/projects/mandala/TED/GHANA.HTM; 1997.

Since 1981, the annual rate of deforestation in Ghana has been two percent/year of 750 hectares each year. Ghana's tropical forest area is now just 25 percent of its original size. Contrary to developed countries that utilize up to 95% of the harvested wood, only about 15% of each tree cut in Ghana is used commercially. Besides the direct timber trade, some furniture companies such as Scanstyle have opened offices in Ghana to circumvent regulations on timber export. Scanstyle exports finished furniture to the UK, Germany, Italy and Ireland. The depletion of the rainforest for the purpose of firewood, although a concern for many, has been insignificant compared to commercial logging. Environmentalists have claimed that some wood processing industries of developed economies are dumping their inefficient sawmilling and veneer milling equipment in developing economies such as Ghana. A ban on log exports was decreed in 1994.

Keywords: Tropical woods, Deforestation, Exports, Government policies, Ghana, Logging, Fuelwood

149a. Sikkema, Richard; Vroom, Mans (FORM Ecology Consultants (NL)).Trends in market demands for certified products; 10 July 2000.

This report deals with certification of timber for opening new markets in Guyana.There is a possibility that Guyana could lose existing markets due to demand forcertified wood. The report describes current market demandsand trends for certified products and correlates it with market supply.

150. Skatter, S.; Haiba, O.A.; Gjerdrum, P. Simulated Yield in a Sawmill Using Different Measurement Technologies. Holz als Roh- und Werkstoff; July 1998; 56(4): 267-274.

The results show that there is a yield increase of ca. 0.5 percentage points when replacing a 1-axis shadow scanner with a 2-axis shadow scanner. There is a further potential yield increase in introducing a 3-d scanner or an X-ray scanner; however, in order to get a substantial improvement using these scanners one has to control the orientation in sawing. The difference in yield of the 3-d scanner between random and optimized orientation is ca. 2 percentage points when measuring on bark and ca. 4 percentage points when measuring under bark.

Keywords: Computer simulation, Scanners

151. Snellgrove, Thomas A; Fahey, Thomas D. Scaling Small Logs for Volume. Proceeding: Manufacturing Lumber from Small Logs. Seattle, Washington: College of Forest Resources, University of Washington; 1982; Contribution No.44.

Analysis of recovery factors is done based on cubic scale as well as three different board foot scales. The cubic recovery percent based on rough green lumber varies little for logs of a given size with the assumptions made for the analysis.

Keywords: Recovery, Yield

152. Sobral, M. Filho. Forestry Development in Brazil: Amazonian Species Utilization Status and Strategy for Higher Utilization of Lesser Known Species: Brazilian Institute for Forestry Development, United Nations Development Programme, FAO; 1984; FO:DP/BRA/82/008. Field Document no. 33.

Stocks of preferred commercial tropical species are dwindling and increasing efforts are required to intensify the use of lesser known species. There are many reasons that cause hundreds of Amazonian species to remain less known. Most of them lie beyond the lack of knowledge on the species technical properties. There are hundreds of tropical species in the world that have been subjected to extensive studies covering their physical and mechanical properties; nevertheless, most of them fail to reach the markets. This paper developed some information on these so-called lesser-known species of the Brazilian Amazonian Forest, and presented some possible strategies for changing current consumption patterns.

Keywords: Tropical woods

153. Sobral, M. Filho (Forest Products Research Center of the National Institute for Amazonian Research). Amazonian Species Utilization Status and Strategy for Higher Utilization of Lesser Known Species. Forestry Development in Brazil: Brazilian Institute for Forestry Development; 1984.

From 1973 to 1980 the number of installed sawmills totaled 190 to 200 yearly, but between 1952 and 1973 there was an addition of only 9 to 10 new sawmills yearly. It is generally believed that the number of installed sawmills presently exceeds 2000 units. These mills coupled with about 100 veneer and/or plywood mills, constitute the primary wood processors in the region. The sawmills, of which 90 percent have an installed capacity below 10,000 m^3/year, are distributed all over the region, although the highest production shares come form the States of Para (over 50%), Rondonia and Mato Grosso. The veneer and plywood mills are mostly medium size mills, and, contrarily to the sawmills, they are concentrated in a few cities of Para (44 veneer mills and 9 plywood plants), Mato Grosso (34 veneer mills and 2 plywood plants), Rondonia (10 veneer mills), Amazonas (5 veneer mills and 5 plywood plants), and Amapa (one plywood plant). These mills often point out log storage peeling, drying, and gluing difficulties, as deterrents to the increase of species processed for veneer and plywood production. Most veneer mills produce material that is shipped for plywood production at affiliated companies in the South and Southeast of Brazil. Among veneer mills only very few produce sliced veneer. This is mainly from Mogno (*Swietenia macrophylla*), Cerejeira (*Amburana cearensis*), Freijo (*Cordia goeldiana*), and Muiracatiara (*Astronium lecointei*).

Keywords: Tropical woods, Sawmills, Veneer mills, Plywood mills

154. Solberg, Birger. Socio-economic Appraisal of Alternative Technologies for the Sawing of Softwood at SAO Hill Sawmill in Tanzania. FAO Forestry Paper 68: Appropriate Forest Industries. Rome: FAO; 1986.

Three alternative technologies - A, B, and C for producing sawn wood are compared. Alternatives A and B represent centrally located sawmills. Alternative C consists of five semi-mobile mills. These five sawmills will have a common central unit for sorting, drying, trimming, dipping, impregnation, for sales of sawn wood, for administration, and for repairs and maintenance of the logging and sawing equipment.

Keywords: Sawmilling, Cooperative

155. Spelter. Plywood Mill Economics. Plywood & Panel World; April-May 1988: 18-20.

Within the past decade, several new technologies have emerged that promise to significantly improve plywood manufacturing. These technologies are spreading rapidly and raising questions about the inherent economic implications on mills as more of the industry modernizes. In this paper, the economic effects of technological change on a plywood mill were analyzed in terms of impact on productivity, costs, and profits. The PLYMAP program, developed by the author, was simulated for three mill configurations that approximated technology available in the mid 1970s,mid 1980s,and late 1980s. These estimates indicated that, based on 1987 prices and costs, a modernized plywood sheathing mill could operate at costs at or near that of a waferboard mill. Plywood manufacturing costs are reduced by using smaller, less expensive timber, increasing labor productivity, and reducing adhesive costs.

Keywords: Plywood, Computer simulation

156. Spelter, Henry. An Examination of Knife Pitch Settings for Rotary Peeling. Panel World; July, 1991: 32-35.

Three knife pitch configurations are examined and compared to a reference pitch rail that was empirically found to yield good results. Of the three, the one based on constant length of rub matches the reference curve the best.

Keywords: Veneer

157. Spelter, Henry. Plywood Manufacturing Cost Trends, Excluding Wood, in Western U.S. Mills: 1975-1988. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; September 1989.

Plywood manufacturing costs have increased over the years with inflation. In recent years, new technologies that improve productivity and reduce costs have become available. Cost data published by the American Plywood Association (APA) show moderating rates of increase by 1983. New data from a sample of western U.S. mills show that nonwood manufacturing costs have decreased since the 1983 APA estimates. Costs for sanded-plywood mills declined by 12 to 17 percent between 1983 and 1988,while sheathing costs declined by 8 to 9 percent. Sheathing mills were not included in this analysis. Therefore, these results apply primarily to mills with mixed sanded and sheathing capabilities.

Keywords: Plywood industry, Costs

158. Spelter, Henry. Simulating Plywood Economics For Improved Decision Making. Plywood & Panel World; February - March 1989: 28-30.

Plywood manufacturing is a complex process with many interdependent activities. A change at one process center has immediate effects, but often additional effects at other centers must be considered to fully evaluate a change. U.S. Forest Products Laboratory at Madison, Wisconsin developed a mill simulation program called PLYMAP to provide a way to test effects of new technology on the rotary-peeled plywood industry. However, the system can readily be used to answer many process-related questions, ranging from the effect of changing the rate of material flows to the effect of installing new machinery. PLYMAP is a personal-computer-based FORTRAN program that guides the users through a menu of mill specifications. These specifications define the manufacturing and economic environment of a plywood mill. Based on these specifications, the program generates estimates of mill productivity, costs and revenues, taking into account many of the physical interactions within the plywood-making process that affect the economics of a particular plant. Documentation on the PLYMAP and another related program called VENVAL is available from the Forest Products Laboratory (FPL), U.S. Forest Service, One Gifford Pinchot Dr., Madison, WI 53705-2398. These programs can be run on any IBM-compatible personal computer. Help in installing and running the programs my be obtained by contacting FPL.

Keywords: Plywood, Computer simulation

159. Spelter, Henry (Forest Products Laboratory). Technological Changes in Solid Wood Products Manufacturing in North America and their Impact on Wood Recovery. Unpublished Report.

This report was the outcome of a study for the Forest Policy and Planning Division of the Food and Agriculture Organization, Rome, Italy. Quality control in lumber production may be manifested in the way various operations are conducted. These include felling, debarking, bucking, sawing, edging and trimming, sorting, and drying. Improvements may be made through computerization, optimized sawing, curve-sawing, variable feed rate of saws, high strain band saws, and minimal saw kerfs. Plywood logging also involves felling, debarking, and bucking. Emphasis in North America is on structural plywood, but other practices apply to decorative plywood. Rotary peeling involves scanning and reducing spinout. Improvements that are made in the way veneers are clipped and pressed may in making decorative as well as structural plywood.

Keywords: Quality control, Logging, Debarking Sawing, Edging, Trimming, Drying, Computer control, Plywood, Veneer

160. Spelter, Henry; Durbak, Irene; Skog, Kenneth; Howard, James; Ince, Peter (Forest Products Laboratory). Healthy Forests, Healthy World. The Impact of Technological Change on Projections of Costs and Recoveries in Wood Products Processing; October 16-19, 1988; Rochester, NY. Bethesda, MD: Society of American Foresters; 1988: 332-336.

In the coming decades the quality of timber entering mills will decline as indicated by average log diameter, size of growth rings, specific gravity, and knots. Yet average softwood lumber recovery, currently estimated at just over 40 percent of the cubic volume, is projected to rise to about 47 percent and higher in some regions. Likewise, softwood plywood recoveries are projected to rise from about 50 percent to over 55 percent.

Heavy circular saws have been popular among smaller producers because they require little maintenance; such saws can often be used without the services of highly skilled saw filers. But, these saws also waste lumber, producing kerf from 9/32 inch to as much as16/32 inch in contrast to the <8/32 inch with bandsaws. In response to the increasing availability of smaller timber, a third kind of saw appeared around the 1960s the Chip-N-Saw. Sawmills that use this machine do not quite achieve the recovery standards of conventional mills, but compensate by increased throughput of a lower cost resource with less handling. Today over 200 mills in North America use the Chip-N-Saw. Improvements to improve log recovery have included better scanners to measure log size and shape, computer control for optimum log breakdown based on best opening face (BOF) concept; saws with thinner blades; longer wearing teeth; better guides to reduce kerf and sawing variation; and more closely controlled drying using improved moisture sensing and removal to reduce energy use and lumber degrade. A modeling analysis yielded the following results: For small sawmills with current levels of technology, kerf of 0.280 inch was assumed, reflecting the use of heavy circular saws. Dressing allowance was assumed at 0.119 inch. Large mills with current technology typically achieve head saw kerf of ~0.200 inch, resaw kerf of ~0.175 inch, and dressing allowance of 0.114 inch. With current best technologies, we believe that head saw and resaw kerfs 0.120 inch can be attained. The use of thin rim circular saw blades for resawing cants for pencil slats has resulted in kerf as low as 0.051 inch (Szymani et al, 1987). For future technology levels kerf is projected to fall to 0.110 inch, but because of the replacement of planing by touch sanding for board finishing and greater control over sawing variation, dressing allowance is projected to fall to 0.063 inch. It was predicted that large sawmills in the South would achieve current best technology levels by 2000. Future technologies using exotic features such as x-ray scanning for defects were expected to surface around 2000. New structural wood products such as wood I-beams and laminated veneer lumber have their main advantage that they can be manufactured from smaller lower grade timber and yet achieve superior strength, because defects are spread out instead of being concentrated at a point, such as at a knot. Improvements in veneer peeling techniques permit peeling from smaller lumber. Some key improvements are hydraulic carriage drives that produce more uniform smoother veneer, high moisture content glues that permit greater throughput through veneer driers, traditionally the bottleneck in most plywood mills, and the use of peripherally (spindle-less) driven lathes that enable peeling to core diameters of as little as 1-7/8 inches. It was the opinion of the authors that the key feature of spindle-less lathes is the change in knife angles as the diameter declines. In general, veneer quality, in terms of surface roughness and depth of lathe checks, deteriorates as diameter of the bolt declines. One variable available to the lathe operator for counteracting this is knife angle. Plywood recoveries were projected to rise sharply to the year 2000.

Keywords: Sawmills, Plywood mills, Veneer, Computer control, Sawing

161. Spelter, Henry; Sleet, George. Potential Reductions in Plywood Manufacturing Costs Resulting from Improved Technology. Forest Products J.; Jan. 1989; 39(1): 8-15.

Recent technology improvements in plywood manufacturing processes are described. The potential impact of these improvements on manufacturing costs and output capacity of a plywood mill was examined by a series of computer simulations. Results indicated that, compared to a mill equipped with technologies characteristic of the mid-1970's,a modernized mill could process similar wood input into the same product output with about 14 percent lower variable costs. By replacing medium-diameter (14-in) bolts with small-diameter (9-in.) bolts, additional cost savings of 20 to 24 percent could be realized, depending on the technology applied. Also, annual output could increase by 13 to 28 percent without adding more lathes, dryers, or presses.

Keywords: Plywood, Costs

162. Staalner, Claus. Automated Vision Systems: They're Not Just "Alchemy". Wood Technology; March 1999; 126(2): 40-46.

Today's technology offers sound solutions for most defect and crosscutting applications, and works as well for ripping and edging operations. Scanning technology is highly complex and the potential outcome and performance of a vision system is relatively limitless.

Keywords: Dimension lumber, Edging

163. Steele, Philip H.; Wagner, Francis G.; Skog, Kenneth El. Regional Softwood Sawmill Processing Variables as Influenced by Productive Capacity. Madison, WI: Forest Products Laboratory; October 1991; FPL-RP-504.

Manufacturing efficiency tends to increase with increasing sawmill size unless the mills are very large. Very large operations use wider resaw kerfs and produce thicker lumber than do sawmills of intermediate size. large sawmills also process longer logs than do small sawmills, although long sawlogs are not processed at very large sawmills.

Keywords: Sawmills, Sawing

164. Tomaselli, Ivan (Curitiba, Brazil). Seminar on "The Promotion of Further Processing of Tropical Hardwood of the African Region," 13-16 February 1990, Accra, Ghana. Development of Plywood Industries. Yokohama, Japan: International Tropical Timber Organization; 1990; Document No. 5.

Modern technology will have a significant effect on the economics of plywood production, especially in developed countries. The increase in the use of small diameter logs, a significant cheaper source than the one traditionally used, will contribute to the reduction of production costs, as wood is the largest component of costs (Spelter and Sleet, 1989). Availability of forest resources does not mean availability of logs for veneer and plywood. Although technology has developed very fast during the last decade, and smaller logs are now used for veneer production. Generally speaking veneer logs must be of superior quality. Recent technology developments in plywood production include: charging - automatic log centering for improved veneer recovery; peeling - powered back up roll, powered nosebar, peripheral drive lathe, hydraulic knife positioner, and spindle-less lathe; clipping - rotary clipper; drying - automatic control and redryer (radio frequency/vacuum); gluing - foam extrusion and high-mositure gluing; pressing - compression controls and panel watering. There is sometimes conflict between labor costs and technology improvement. There might be some situations where increasing technology sophistication in plywood production might have a negative effect on costs. Labor costs might be increased as foreign experts and technicians with much higher wages are needed to run the mill. this does not mean that wages must be kept low in developing countries.

Keywords: Tropical woods, Plywood, Costs

165. Trockenbrodt, M.; Tze, W.T.Y. The Sawing and Planing Properties of Binuang (*Octomeles sumatrana*) and Sentang (*Azidirachta excelsa*) from Sabah, Malaysia. Journal of Tropical Forest Products; 1999; 5(2): 216-219.

Binuang is considered a potential plantation species, and a few plantation trials have been set up. Sentang has been increasingly promoted as a plantation species, and a few small plantations have been started. In cross cutting, axial cutting, and planing tests, defects arising from defective machine guiding systems, defective saw setting, uneven tooth rotation, etc. were not taken into consideration. The study showed that binuang and sentang were relatively easy to saw and plane. However, cross cutting of binuang gave some problems. Parallel to the density of the timbers, there is a decrease in quality from sentang to binuang and the sawing and planing properties of both species are inferior to those of red seraya. Overall quality varied some with saw projection and feed speed.

Keywords: Recovery, Yield, Quality

166. Tze, W.T.Y. Recovery and Quality of Lumber from Mature Teak (*Tectona grandis*) Planted in Sabah, Malaysia. Journal of Tropical Forest Products; December 1999; 5(2): 115-123.

Logs of Sawmill Quality and Millable Quality produced lumber with mean recovery rates of 30 and 23% respectively. The recovery rates were not significantly affected by taper ratio and log diameter. With respect to lumber quality, the major output was Prime (Grade 1), Standard (Grade 3), Serviceable (Grade 5) and Utility (Grade 6). Common defects included sloping grain, stains, shakes, unpermitted sapwood occurrence, and unsound knots. The unsatisfactory yield and quality need to be weighted with the inferior quality of the logs. Also, the gross recovery rate will possibly be increased if the logs are broken down with the aid of scanners for the appropriate first cut. The first saw cut is important in determining the location of subsequent cuts for maximizing the volume of lumber. Although the study could not visualize the actual composition of the stand, it did reveal the minimum yield and quality of the lumber to be expected from a mature, 70-year-old plantation in Sabah.

Keywords: Tropical wood, Logs, Plantations, Log grades, Yield, Quality, Scanners

167. UNCTAD/GATT. Workshop on Global Development of the Rubberwood Industry: International Trade Center UNCTAD/GATT; September 23-34, 1993.

There is a considerable opportunity to increase economic benefits from rubber tree growing by integrating latex and wood production. But there are problems with profitability in using rubberwood for timber. The main constraints in the development of rubberwood industries are related to raw material supply, low productivity, the existing structure of user industries, low level of profitability. Due to seasonal variation in log supply the capability utilization rate of the industry tends to remain low. The current plantation management methods have not considered log quality and most of the wood is small diameter and of irregular shape. Where inappropriate tapping methods have been used the value of the first log is normally reduced. What is normally the most valuable part of the tree may have to be discarded because of too low yield in processing to justify transportation to the mill site. The existing rubberwood using industries were often originally built to make use of large logs. This, together with poor log quality largely explains why rubberwood sawmilling suffers from low recovery rates (15-35%).With the current production levels rubberwood sawmilling generates about 2.5 million m^3 of residues of which part is used for fuel for lumber drying or by local households, and part (about 0.9 million m^3) for production of reconstituted panels. It is conservatively estimated that about 1.0 million m^3 could be further utilized for production of such panels provided that the raw material can be made available in relatively concentrated areas throughout the year.

Log quality is of particular importance for plywood production. Rubberwood use for this product is a recent development offering good expansion possibilities. In plywood the availability of suitable in sufficient volume will be the key constraint when the technological problems have been overcome. Productivity improvement in logging and industrial processing offer the most significant opportunities to improve profitability. Low recovery rates can also be interpreted as a sign of low wood prices that do not encourage producers to improve their efficiency.

If not processed/reprocessed immediately, rubberwood has to be treated after logging or primary processing as it is easily attacked by fungi and wood borers. Mobile sawmills are a viable option to make use of scattered plantations. Plywood production is still in its initial stages and sophisticated processing has to be applied which leads to special requirements for worker training and maintenance. The overriding requirement of rubberwood products is that sawn wood is kiln dried to 6-8%. Vacuum pressure treatment against stain and insect attack is necessary. A major factor inhibiting the trade in sawn lumber is the lack of any accepted grading system.

Keywords: Rubberwood, Sawmills, Drying, Wood residue, Plywood, Logging costs, Lumber

168. Valentim, Judson Ferrreira; Cavalcanti, Francisco B.; Sothers, Cynthia Anne; et al. The Acre Project: An ITTO Action to Promote Sustainable Management of Forests and Development in the Amazon. FUNTAC - Technology Foundation of the State of Acre.

Sawmilling in the State of Acre was analyzed. Percentage distribution according to size was up to 1000 m^3 55 %, from 1001 t0 2000 m^3 30 %, above 2000 m^3 15%. The main sawmill equipment was classified as follows: vertical band saw 82.26 %, horizontal band saw 11.29 %, circular saw 6.45 %. Main production difficulties for different mills were lack of qualified personnel (59.68%); lack of replacement parts for sawmill equipment (40.32%); administrative deficiency where there is poor inventoryncontrol of raw materials and products (27.42%); badly laid-out equipment (20.97%); and, hard to process species (19.35%).

Keywords: Tropical woods, Sawmills, Saws, Quality control

169. Vuorilento, Jaakko. Manual Lumber Measurements too Slow for Today's Sawmills. Wood Technology; June 1999; 126(5): 28-33.

The article discusses a new way of control measurement and the opportunities it offers to sawmills in the breakdown process. Boards were measured manually and with a new Seecon system. A manual 3-point measuring system never provides enough information for even a simple analysis. When manual measurements were done, big differences in dimensions were detected. The caliper had to be replaced because of its play and inaccuracy exceeded 0.5 mm. Seecon measures the thickness of a sawn piece every centimeter. Seacon measurement is a significant time saver.

Keywords: Computer control, Scanning

170. Wagner, Francis G.; Gorman, Thomas M.; Pratt, Keith L.; Keegan, Charles E. III (Univ. of Idaho and Univ. of Montana). Impact of Log Sweep on Warp, Grade, and Value of Structural Lumber Curve Sawn from Small Diameter Douglas-fir Logs; June 19-21, 2000; South Lake Tahoe, NV. Madison, WI: Forest Products Society.

Much of the saw timber harvested in Western North America today is small in diameter and includes sweep. It contains large amounts of juvenile wood as well.

Keywords: Curve sawing, Small logs

171. Wertman, Paul. Small-Scale Technology for Local Forest Development: An Annotated Bibliography: Forintek Canada Corp., Western Forest Products Laboratory; August 1979; Review Report No. RR1.

This bibliography deals with the general field of forestry, and specifically with sawmilling, transportation, barking, chipping, seasoning and preservation of wood. An introduction by the compiler discusses the various theories on small-scale technology and the relationship between technology and social change. The purpose of this annotated bibliography is to provide a supplementary source of knowledge for the resource development activities of the Department of Renewable Resources and Transportation Services of the Province of Manitoba. For historical and present day reasons, the direction of development of Manitoba's resources will tend to require small-scale industries, so it is desirable that the knowledge of small-scale technology in the published literature be compiled in a readily available form.

Keywords: Sawmilling, Roads, Debarking, Chipping, Seasoning, Preservation

172. Whitmore, T.C.; Silva, J.N.M. Brazil Rain Forest Timbers are Mostly Very Dense. Commonwealth Forestry Review; 1990; 69(1): 87-90.

The tropical timbers, which are extensively traded and utilized, are nearly all of medium and low density. They come mostly from Southeast Asia and the western Pacific islands. These Eastern timbers are suitable for peeled veneer, which is turned into plywood, and for furniture and light construction. The denser ones like kapur, keruing, and selangan batu are used for bridges, groynes, and piling. Eastern tropical rain forests are being depleted faster than those in Brazil, but since the Brazilian timbers tend to be so dense, they would not appear to be as suited for the international markets. Moreover it has not proved possible to group the timbers of the Amazonian forest into a few end-use classes for marketing. This makes it much more difficult to use these forests for timber production than the eastern ones.

Keywords: Tropical woods, Export, Plywood, Furniture, Lumber

173. Williston, Ed. The Computer Approach to Improved Lumber Recovery from Small Logs. Proceedings: Manufacturing Lumber From Small Logs. Contribution No.44. Seattle, Washington: College of Forest Resources, University of Washington; 1982.

Since these studies showed in general that the 16 feet or shorter logs with 3 inches or less of taper yielded best when sawn by one sawing method, and longer logs with more taper, by another sawing method. The results of this research can form the basis for selecting sawing systems in many existing mills if the log mix is known. Other factors besides computerized log breakdown that were considered were sawing variation, planing allowance, surface roughness, and, in the case of dry lumber, shrinkage.

Keywords: Sawing, Computer control, Yield,

174. Willits, Susan A.; Lowell, Eini C. and Christensen, Glenn A. Lumber and Veneer Yields From Small-Diameter Trees. Role of Wood Production in Ecosystem Management - Proceedings of the Sustainable Forestry Working Group at the IUFRO All Division 5 Conference; July 1997; Pullman, Washington. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; July 1997; Gen. Tech. Rep. FPL-GTR-100: 73-79.

Forest management activities since the start of the 20th century have created vast acreages of densely stocked small-diameter stands throughout the intermountain West. Current management goals include reducing the stocking of these stands to increase their resistance to insect and disease attacks, to reduce the risk of catastrophic wildfires, to create diverse mosaics of wildlife habitat, and to provide economic benefits to the public. One of the economic benefits of active management of these stands is to use the material being removed from the forest to produce wood products. To efficiently use the small-diameter material, information about the volume and quality of products that can be produced is necessary. A recent series of mill recovery studies was conducted on small-diameter Douglas-fir, western larch, lodgepole pine, ponderosa pine, and white fir trees from eastern Washington, northern Idaho, and southwestern Oregon. Results of the lumber study showed that the volume recovery is as high or higher than previously experienced from timber of this size. Lumber grade recovery was also good, with 50 percent of the lumber from the lodgepole pine sample and 65 percent of the Douglas-fir sample graded as Construction or better. Veneer volume recovery also compared favorably with previous studies with the exception of the ponderosa pine sample, which had fairly low recovery.

Keywords: Small diameter logs, Recovery

175. Winkler, Norbert. Forest Harvesting Case-Study 10: Environmentally Sound Road Construction in Mountainous Terrain - Applying advanced operating methods and tolls. Rome: FAO; 1998.

The study was carried out in semi-natural forests of the Alps in the province of Salzburg, Austria. The road projects were selected to demonstrate that "Environmentally Friendly Forest Engineering" considerably reduces the effect of damaging elements of forest road construction. The study documents each phase of environmentally sound road construction by excavator and advanced blasting technique as applied in the road projects under review and compares its environmental impacts with those of the traditional road construction by bulldozers.

Keywords: Roads

176. Winkler, Norbert. Forest Harvesting Case-Study 12: Environmentally Sound Forest Infrastructure Development and Harvesting in Bhutan. Rome: Food and Agriculture Organization of the United Nations; 1999.

The study documents each phase of both environmentally sound road constructions by excavator and traditional road construction by bulldozer and compares environmental impacts of both construction techniques. Another objective was to provide information on "long-distance cable crane logging" which appears that it will continue to be the most common harvesting system applied throughout Bhutan in the near future. The results of this case study show that environmentally sound road construction is superior to road construction in the traditional way by bulldozers from the environmental point of view. The short-term economic benefits from use of bulldozers in forest road construction in mountainous terrain are likely in the longer run to create environmental damage on a considerable scale as side slopes increase. The traditional harvesting system in Bhutan, strip-wise clear-felling with subsequent long-distance cable logging, can be modified towards more environmentally sound harvesting practice. The adverse environmental impacts such as loss of biodiversity, creation of monocultures or forest with a poor species composition as well as erosion can be reduced. This solution makes use of the available skills and equipment in the country, contributes to the livelihood of the people and improves the overall development in rural areas.

Keywords: Roads, Cable logging

177. Youngs, Robert L. Plywood Adhesive Bond Evaluation - Past, Present, and Future. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1965.

Keywords: Plywood

178. Youngquist, John A. New Technology for Veneer and Plywood. Madison, Wisconsin: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; September 1977.

This article explores the concepts and the potential of laminated veneer products and pose three questions - "Why consider laminated veneer products? What is behind the whole concept? What is it all about?".

Keywords: LVL

179. Yusoff, Mohd. Nor Mohd.; Hurie, H. The Manufacture of Oriented Strand Boards from Rubberwood. Journal of Tropical Forest Products; 1997; 3(1): 43-56.

Keywords: Rubberwood, Particleboard

180. Zerbe John I. Opportunities for Greater Self-Sufficiency in Energy Requirements for the Forest Products Industry. AIChE Symposium Series 177: Energy and Environmental Concerns in the Forest Products Industries: American Institute of Chemical Engineers; 1978; 74: 58-64.

Forest products manufacturing industries are significant purchasers of fossil fuel energy. With utilization of forest residues for fuel for power and process steam generation these plants could greatly reduce amounts of fossil fuel purchases. Liquid fuels and other chemical products important to the forest products industries might also be made from forest residues. Another possibility is to grow forest biomass specifically for use as fuel and for production of petrochemical substitutes. There is a current inventory of about a billion dry tons of noncommercial timber, and about 170 tons (dry basis) of wood and bark residues are produced annually in conjunction with milling, harvesting, and tree removal operations. For more intensive utilization of the forest biomass for fuel and petrochemical substitutes, improved systems for residue collection and transport must be developed. Current costs for delivering forest residuals to a central processing location range between $15 and $34 per oven-dry ton. Promising chemicals of use to the forest products industries that might be made from wood include methanol, ethanol, formaldehyde, furfural, and phenol. One possibility for manufacturing chemicals from wood economically appears to be a multi-products plant for making phenol, ethanol, and furfural from hardwoods.

Keywords: Fuel, Residues.

Annex I

ITTO PRE-PROJECT PPD 24/99 (I)

Draft ITTO Guidelines on Increasing Utilization Efficiency and Reducing Losses and Wastes Throughout the Tropical Timber Production Chain

Draft Guidelines on Increasing Utilization Efficiency and Reducing Losses and Wastes Throughout the Tropical Timber Production Chain

Foreword

An important sequel to sustainable forest management is the gearing of utilization practices to gain the maximum volume and value of products from the harvested resources in line with sustainable and best use as well as other environmental considerations. Some of these concerns should be conservation of energy from fossil fuel usage, sequestration of maximum amounts of carbon, recycling and re-use of the resource, and protection of soil, air, and water from increased pollution. Fundamental to all of these objectives are utilization practices that provide maximum efficiencies in product output and minimal waste of the raw material.

In the United States of America the work of the U.S. Forest Products Laboratory has embodied these principles consistent with good forest management for the last 90 years. Utilization efficiency has grown steadily. But, with the gains in utilization efficiency, there have also been increases in opposing forces. Over the years harvests of saw logs have gone to including logs of lesser minimum diameters, and the overall quality of the harvested timber has decreased. Today in the U.S.A. a high priority management problem is small diameter utilization.

In tropical countries these are parallel problems to those of the U.S.A. Perhaps one of the major problems in tropical countries is encountered in attempts to use secondary species. In the U.S.A. as in tropical countries practices in saw milling and plywood manufacture together with the use of products from these processes in secondary and tertiary processing are major determinants in gaining acceptable utilization levels.

Introduction

To gain more knowledge of utilization problems in developing countries researchers at the U.S. Forest Products Laboratory conducted a study under ITTO Project PD 24/99 (I) on wood utilization efficiency and reduction of losses in lumber and plywood manufacturing plants in three tropical countries. The study carried out from June 15, 2000 to September 15, 2000 involved an extensive review of the literature and a survey of mills in Ghana, Malaysia, and Brazil.

The literature review covered a study and abstracting of 179 publications. The mill survey consisted of mailing questionnaires to sawmills, plywood manufacturing plants, sawmill associations, and plywood manufacturing associations in the three representative countries and site visits to mills in the three countries.

With the data from the literature search and the survey, an analysis was conducted to determine the efficiencies in sawmilling and veneer and plywood production; technologies to reduce and use waste in the lumber industry; technologies to reduce and use waste in the veneer and plywood industries; policies, practices, measures, and technologies which influence utilization in sawmilling and veneer and plywood manufacture; and advanced technologies and practices in developed countries which may not be as prevalent in sawmills and veneer and plywood manufacturing plants in developing countries.

Major factors considered for influencing efficiency in sawmilling were obsolescence, breakdown of equipment, and shortage of spare parts; timber cutting regulations, land use planning, and enforcement; controlling personnel performance; cooperative ownership of logging and sawmilling operations; taxes and subsidies; national, regional, or local harvesting codes; prohibition of log exports; reduced impact timber harvesting; impact of debarking on residue utilization; plantations; infrastructure; control of insect infestations; increasing demand for lesser-used species; integrated forest products manufacturing; and training.

Major factors considered for influencing efficiencies in veneer and plywood manufacture were some of the same as those in sawmilling, i.e., obsolescence, breakdown of equipment, and shortage of spare parts; timber cutting regulations, land use planning, and enforcement; taxes and subsidies; national, regional, or local harvesting codes; prohibition of log exports; reduced impact timber harvesting; plantations; infrastructure; increasing demand for lesser-used species; and integrated forest products manufacturing. Also considered, as influencing plywood manufacture, was the shift from plywood to structural flakeboard production.

The following set of draft guidelines represent a starting point for the discussion on two broad areas – policy and legislative implications; and strategies for factors influencing efficiency. The principles and recommended actions might be beyond the current means of some countries. However, it is our hope that the ideas and strategies presented here will generate discussion that leads to overcoming many of the problems that forest industries face today. The challenge now lies in fully developing these guidelines, incorporating ITTO member comments and seeking approval by the ITTC.

1. Policy and Legislative Implications

<u>Policy Development</u>

Principle 1

Establishment and implementation of policies to increase efficiencies and reduce wastage in sawmilling and plywood manufacture will require cooperation of industries, governments, research institutions and universities with international organizations to mitigate adverse impacts of timber harvesting, set up and enforce land use planning, enhance utilization and marketing of secondary species, reward efficient plant operation, and reduce carbon emissions.

<u>Recommended Action 1</u>

a. In countries and regions there should be efforts to gain consensus and support of the FAO harvesting code and ITTO harvesting concepts among industries, governments, research institutions, and universities.

b. National and Regional land use policies should incorporate concepts to assure supplies of timber suited for most efficient processing to lumber, plywood, and other indigenous wood using industries.

c. Research funding for work on utilization of secondary (lesser used) species by National and International agencies should be increased.

d. With development of suitable standards for assessing adequate control of product recovery and waste reduction, there should be governmental tax concessions and/or subsidies such as low-cost loans and accelerated depreciation of equipment to achieve and maintain these standards by cooperating manufacturers. Such actions might also provide job opportunities and community stability.

e. Since increased product yield and reduction of wastes as well as use of wood in place of more energy intensive materials result in lower carbon emissions to the atmosphere, the value of the tons of carbon emissions saved should serve as the basis for guaranteed investment credits.

2. Strategies for Factors Influencing Efficiency

Computerization of Bucking, Log Breakdown, and Defect Sensing Operations

Principle 2

Computerization of Bucking, Log Breakdown, and Defect Sensing Operations are not commonly used in developing countries; but, they are essential to improving product yield. Especially important factors are accurately controlling target size of lumber to prevent wastage from unnecessary over-sizing and bucking logs to minimal needed lengths for the same reason. Other applications of computers include controlling dry kiln and molder operations. One of the most apparent shortcomings in sawmills in developing countries in comparison to practices in developed countries is the lack in application of computer technology to enhance recovery. Software that can be used in these computer applications is readily available, and, in some cases, it is available free of charge.

Recommended Action 2

a. To increase product recovery in sawmills and plywood manufacturing plants such operations should implement use of scanners to measure log size and shape and end cross section outlines; computerized log breakdown equipment; automated defect sensing and remediation devices; and other computerized control to the extent possible.

Saw Configuration and Maintenance

Principle 3

Excessive saw kerf can waste valuable product while causing accumulation of more sawdust. Sawdust is of far lower value at best or, as in many situations, it causes disposal problems. Heavy circular saws may produce a 0.280-inch kerf . Band sawmills applying good current technology typically achieve head saw kerf of ~0.200 inch and resaw kerf of ~0.175 inch. The use of thin rim circular saw blades for resawing cants for pencil slats has resulted in kerf as low as 0.051 inch. For future technology levels kerf is projected to fall to 0.110 inch. Improved alloys such as stellite perform better for thinner saws.

Saw doctoring expertise and performance is important to combat problems and inefficiencies from dull saws, gullet burn in the sharpening process, incorrect and uneven tension, burrs left in the gullet from sharpening, and saw vibration.

Recommended Action 3

a. Saws installed in sawmills should produce the minimum kerf consistent with adequate product quality, have the capability for being well maintained, and be able to produce products at good operational speed.

b. Saw doctoring capabilities for maintaining saws for high performance should be provided at all sawmills.

Obsolescence

Principle 4

Mills and manufacturing plants which have been operating for ten years or more tend to be encumbered with disadvantages from obsolescence that include shortage of spare parts, high waste factors and poor product quality.

Recommended Action 4

a. Operations should be brought up to date with precision cutting tools for overall high-speed performance consistent with minimum malfunctions and down time.

Supervision and Training

Principle 5

Many production and maintenance problems at sawmills result, at least partially, from a scarcity of skilled personnel at all levels.

Recommended Action 5

a. Adequate opportunities for training production workers as well as supervisory and management personnel should be provided.

Sawing Procedure

Principle 6

With smaller logs and logs having crook and sweep being more common, curve sawing and end dogging may result in better recovery factors. To produce defect-free dimension lumber, a cant sawing routine is common; but, live sawing may be preferable. This appears to be the case in sawing smaller diameter and lower grade logs.

Recommended Action 6

a. Where small diameter and misshaped logs are common technologies such as curve sawing and end dogging should be implemented.

b. In situations where conditions warrant technologies such as Chip-N-Saw should be applied.

c. In sawing smaller diameter and lower grade logs, advantages of live sawing over cant sawing should lead to greater use of the live sawing practice.

Value Adding on Site

Principle 7

Often more integrated operations with more processing and use of wood fuel on the same site will result in more product value and less waste from the raw material input. Examples are drying and molding in sawmills and sanding in plywood plants. Similar benefits result from conduct of collateral operations such as finger jointing and manufacture of blockboard, chips and specialty products, together with on-site use of residues for fuel. Concentrating work at one location means less material and contained moisture must be shipped, and there is less chance for degrade. Where surplus residues remain from otherwise efficient processing plants other local outlets for residues such as furniture manufacturing plants and brick and lime kilns can sometimes provide markets.

Niche markets provide a means for plywood producers to add value and manufacture more efficiently in the face of competition from OSB. Survivors in the plywood industry are converting a significant proportion of their production to laminated veneer lumber-type veneers and value-added plywood. Although plywood production in the U.S has dropped significantly since 1995, sanded plywood production has been holding steady. Many plywood producers have identified niche markets such as boat builders, furniture manufacturers, truck trailer companies and other users. The traditional separation of the plywood business into hardwood and softwood segments will blur as product, raw material, and customer demands overlap.

Recommended Action 7

a. Besides taking advantage of opportunities for increased revenue, sawmills and plywood plants should conduct more processing and wood waste usage on-site to increase efficiency and conserve the wood resource.

b. If wood residues cannot be fully utilized on-site other local users such as secondary wood products manufacturers or other potential wood fuel consumers should be sought so that the residues may be sold or given away.

c. Plywood manufacturers should seek new niche markets such as laminated veneer lumber to combat increased competition from products such as OSB and MDF.

Inventory Control

Principle 8

Inventory control is a factor that could be improved to the advantage of many tropical country sawmills and plywood manufacturing plants. Often barcoding would be a big assist to record keeping of inventories of input materials, and product output through the production and distribution chain, but barcoding is seldom utilized. Communication between producers and customers might be improved through Electronic Data Interchange. It would be necessary to affix barcodes on every piece of lumber and plywood and on veneer flitches and to maintain a self-replenishment stock of product at the reload site of the customer. In return a long-term agreement involving the delivery of large volumes of product could be anticipated.

Recommended Action 8

a. Barcoding to facilitate accounting and inventory and to monitor handling of raw material and product should be implemented at mills as an improved efficiency measure.

Statistical Process Control

Principle 9

Statistical Process Control (SPC) is a quality inspection technique. It incorporates procedures to successfully collect, analyze, and interpret lumber size variation. It is designed to be used with the Statistical Process Control-Lumber Size Analysis computer routine developed by the Forest Service of the U.S. Department of Agriculture. The primary objective of production center monitoring is to systematically evaluate and optimize the material passing through. Three key elements to production center monitoring are 1) condition of equipment, 2)maintenance monitoring, and 3) lumber size control.

Recommended Action 9

a. Statistical Process Control (SPC) should be implemented at mills as an improved efficiency measure.

Marketing Intermediate Lengths of Sawn Products

Principle 10

One lumber manufacturer felt strongly that encouraging lumber purchasers to import lumber in a greater variety of length classes would be a most important step to take to increase lumber utilization efficiency. For instance for purchasers of lumber in lengths in multiples of two feet such as 8, 10, and 12 feet, there could be reduction of wastes for producers if they could ship lengths of 7 feet, 8 feet, 9 feet, 10 feet, 11 feet, 12 feet, and 13 feet, instead of only 8 feet, 10 feet, and 12 feet.

Recommended Action 10

a. Lumber purchasers should be encouraged to accept products in a greater variety of length classes.

Debarking

Principle 11

Sometimes when it could lead to better uses of wood chips for such purposes as papermaking debarking is not practiced at mills. How logs are debarked may be important for yield of chips of higher value as well as for facilitating scanning and eliminating rocks and debris that could dull saws.

Recommended Action 11

a. Debarking either by hand or by machine should be more generally practiced.

Pretreatment

Principle 12

Pretreatment of logs or veneer bolts for plywood manufacture can make them more valuable. In order to facilitate peeling to plywood veneer, it is often necessary to pre-treat by heating and soaking some timbers while others, such as mahogany, can be peeled cold. Where pretreatment is required, the manufacturer has the choice to crosscut the plywood log into bolts prior to treatment or to pre-treat the whole log and then crosscut. One study indicated that it may be advantageous to pre-treat all tropical hardwoods in the log form and then to crosscut to minimize degrade during the crosscutting process.

Recommended Action 12

a. Pretreatment of logs for plywood or veneer bolts should be more generally practiced.

Control of Peeler Core Diameter

Principle 13

Control of peeler core diameter and using peeler cores effectively in other products are important to production efficiency and reducing waste. At the U.S. Forest Products Laboratory, a powered back-up roll was designed and built for the purpose of providing auxiliary torque to a veneer bolt. The powered back-up roll can supply a substantial percentage of the required torque. This reduces the likelihood of spin-out occurring and allows a reduction in the final core size when used in conjunction with smaller chucks. A new process developed by an American manufacturer begins by peeling small blocks on an extraordinary 4-foot lathe. The high-speed lathe will peel blocks of an initial diameter of 4 inches or less to a 1-inch core. Larger-diameter peelers (7 inches and more) can go to an 8-foot lathe. Veneer from the 4-foot lathe is end-glued into sheets up to 80 feet long. Random width material can also be glued into sheets of the desired width. After the maximum amount of quality veneer has been peeled and relatively small diameter cores remain, they may be effectively used in such products as pallets, blockboard, pulp chips, and fuel.

Recommended Action 13

a. In rotary plywood manufacturing plants equipment capable of peeling veneers down to a minimal diameter of the residual core, but still of satisfactory veneer quality, should be provided.

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