RAP PUBLICATION: 2001/16

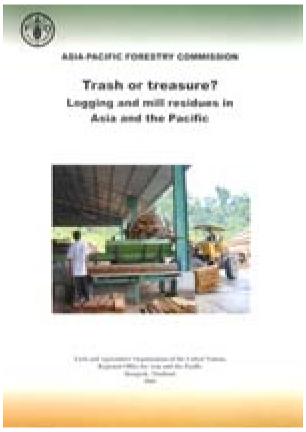
ASIA-PACIFIC FORESTRY COMMISSION

Trash or treasure?

Logging and mill residues in Asia and the Pacific

by

Thomas Enters



Food and Agriculture Organization of the United Nations
Regional Office for Asia and the Pacific, Bangkok
2001

Cover photos: Sarawak Timber Association and Thomas Enters

For copies of the report, write to:

Patrick B. Durst
Senior Forestry Officer
FAO Regional Office for Asia and the Pacific
39 Phra Atit Road
Bangkok 10200
Thailand
Tel: (66-2) 697 4000
Fax: (66-2) 697 4445
Email: Patrick.Durst@fao.org

ISBN 974-7946-12-2

Foreword

For the past several years, efforts in the Asia-Pacific region have focused on achieving sustainable forest management and developing a viable forest industry sector. As a result, we have experienced considerable shifts in policies and legislation as well as institutional arrangements. On the ground, forest management is changing and forest industries continue to adopt new technologies.

While forestry has come a long way, foresters in the region cannot be complacent. One reason for taking a fresh look at how we manage our forests and use wood is the high volume of wood waste or residues produced in this region. In the past, forest industries had assumed an almost infinite supply of raw materials that the region's forests provide. Today, this erroneous perception is not as common as it used to be and raw material shortages are occurring. In response, the industry has looked for resources further afield, largely neglecting a rather different approach, i.e. to explore how wood can be harvested and used more efficiently for the benefit of today's societies and future generations.

One reason why high wood residue volumes persist is that the issue is not viewed as a serious problem. Estimates on available volumes of wood residues are few and often out-dated. They do not distinguish between total biomass and raw material that can be economically extracted and used for further processing, which hinders the development of policies encouraging the proper use of the region's forests. Also, while some have recognized wood "waste" as a valuable by-product for further processing or energy-generation, the majority still struggles with what are perceived to be "waste disposal problems," due to a lack of knowledge about opportunities.

The seventeenth session of the Asia-Pacific Forestry Commission (APFC), convened in 1998, recognized the slow progress of many countries in reducing logging and mill residues. Therefore, the Commission requested a study on the magnitude of the problem and alternative uses for logging and mill residues. In presenting this study, FAO is pleased to continue its support of efforts to promote sustainable forest management in the region. We hope that this publication will help policy makers to better understand the key issues, challenges and opportunities related to logging and mill residues – leading to concrete measures for increasing efficiency and minimizing waste.

R.B. Singh
Assistant Director-General and
Regional Representative for Asia and the Pacific
Food and Agriculture Organization of the United Nations

Acknowledgements

The USDA Forest Service and FAO Regional Office for Asia and the Pacific provided financial support for the study.

Appreciation is acknowledged to those individuals who provided valuable technical documents and guidance throughout the study. The country case studies for China and Indonesia were prepared by Chen Xuhe (Chinese Academy of Forestry, Beijing), and A. Ng. Gintings and Han Roliadi (Forest Product and Socio-economic Research and Development Centre, Bogor), respectively.

Patrick Durst, FAO Senior Forestry Officer (Asia and the Pacific) provided overall supervision and technical guidance for the project and editing support for the publication. Tan Lay Cheng assisted in proofreading the final document. Their professional contributions are gratefully acknowledged.

Table of contents

List of tables

List of acronyms

AFPA	Alberta Forest Products Association
APFC	Asia-Pacific Forestry Commission
ASEAN	Association of Southeast Asian Nations
CPO	crude palm oil
EC	European Commission
GDP	gross domestic product
ITTO	International Tropical Timber Organization
MDF	medium-density fiberboard
R&D	research and development
RIL	reduced impact logging
STIDC	Sarawak Timber Industry Development Corporation
TOF	trees outside forests

__What if__ industry could turn every gram of raw resource into product? __What if__ one company's wastes could be used as raw resources for another? A pipe dream you say. This ideal may be much closer than most people realize.

Norman Brownlee (1998)

Background

One of the greatest challenges of the forestry sector and the wood industries of Asia and the Pacific is the need to address and overcome declining raw material supplies, to fully utilize available resources, and to take advantage of innovations in wood processing. Lingering impediments to the sustainability of forests and forest industries are inefficient utilization of wood raw material and the high volume of residues that are left in the forest and which remain after wood processing. A growing number of timber producers in the Asia-Pacific region are facing raw material shortages and some wood processors are now operating below 50 percent of capacity. This problem is expected to worsen considerably in the next several years.

In this climate of diminishing raw material supplies, logging and mill residues are emerging as a major potential raw material source. At the same time it is hoped that more efficient use of residues can lead to a reduction in the areas logged every year (Dykstra, 2001). Moreover, dumping of waste and residues is now prohibited or very costly, and since the catastrophic fires in 1997/98, restrictions on open burning are enforced more rigorously in some countries. Encouraging opportunities may exist for dealing with these issues, however. The Asia-Pacific Forestry Sector Outlook Study gauged the potential for increasing the utilization of logging and wood-processing residues "high" and "moderate" respectively, in Southeast Asia and the Pacific (FAO, 1998).

In 1998, the Asia-Pacific Forestry Commission (APFC) urged FAO to coordinate "a review of residues availability and their current use, and report the potential availability and implications at the next session." It further urged the consideration of strategies and policy options to encourage more efficient use of available wood residues. Other international organizations are supporting complementary work in this area. Since 1998, the International Tropical Timber Organization (ITTO) has worked to develop guidelines for increasing tropical timber utilization efficiency and the reduction of losses and waste through the production chain (Zerbe *et al.*, 2000). In 1999, the Association of Southeast Asian Nations (ASEAN) identified "Reduction and Utilization of Wood Residues" as a key focus for collaborative forestry research and development (R&D).

In industrial countries, a large share of logging and wood-processing residues is used by the pulp and wood-based panel industries. Alternatively, residues are chipped and burned by wood processors and power plants to produce steam and electricity. Strict environmental regulations concerning waste disposal, the need to reduce fire risks in forests and the high recreational values of many forests in the North (for which logging residues are a detraction) explain this development partially. Perhaps the greatest driving force, however, is the desire to rationalize and increase efficiency.

From burning slash to producing steam and electricity

The elder Armstrong quickly swivels the machine back and forth, delimbing trees and stacking them for loading. He tosses tree tops and fallen branches onto a pile that grows 7.5 metres high.

This "slash" isn't burned as it once was. Instead, the leftovers are fed into a chipping machine capable of chewing up trunks more than half-a-metre across. The chips are burned by sawmills and power plants to produce steam or electricity.

Source: Thompson, 2000

Primary mill residues constitute a particularly attractive resource. They are clean, concentrated at specific locations, and relatively homogeneous. In the United States, 98 percent of such residues are currently used as fuel or to produce other fiber products (Walsh *et al.*, 1999). In the U.S. State of Virginia, mill residues alone account for more than 80 percent of the US$ 82.8 million that wood product manufacturers received for all types of residues in 1996 (Alderman and Smith, 1998).

Utilization of other types of residues, however, continues to be constrained by out-dated perceptions of residues as a waste problem rather than as a valuable "new" product. This helps to explain utilization rates of only around 60 percent in places such as Alberta (Canada) (Brownlee, 1998). Developments are very dynamic, however, as reflected in the establishment of an electronic marketing system for wood residues by the Alberta Forest Products Association (AFPA) in July 1999.[1]

Until recently, the utilization of logging and wood-processing residues in tropical countries has generally lagged behind developed countries. However, over the last five years, the number of wood-based panel producers that utilize mill residues exclusively has increased dramatically. In some countries "shortages" of residues have actually developed as a result of increased local demand for panel production. At the same time, co-generation based on wood and agricultural residues has been adopted by a growing number of factories (Pennington *et al.*, 2000).

It is not uncommon to find more than 50 percent of the wood of the main stems of tropical trees felled for harvest to remain unutilized (Schmincke, 1995), although much higher figures have also been recorded. Timber harvesting recovery rates appear to be particularly low in Asia and the Pacific, where they average only 46 percent, compared to Africa (54 percent), Latin America and Caribbean (56 percent) and the United States (78 percent) (Dykstra, 1992, cited in Pulkki, 1997).[2] Mill process yields are as low as 33 percent of delivered log volume. However, estimates on available volumes of wood residues are few and often out-dated, or do not distinguish between total biomass and raw material that can be economically extracted and used for further processing. In addition, there is no clear consensus on what constitutes "residues." This report strives to fill the gap of understanding related to wood residues in Asia and the Pacific. It is primarily focused on the logging and mill residues of the region's tropical and subtropical countries. The report estimates the amount of wood residues available for further economical uses and discusses opportunities and potential for economic residue reduction and utilization.

Objectives

The overall objectives of the APFC study on logging and mill residues were to:

- estimate and describe of the availability and use of residues in the processing chain (including harvesting, transport, storage and processing) of major forest product industries, from the standing tree to the final and semi-final product; and
- present options for reducing residues in the forest and in wood-processing industries.

Methodology

This overview report is based on country studies and a literature review. Country case studies were commissioned for China, Indonesia, Malaysia and Papua New Guinea, respectively. The country reports for China and Indonesia are included as appendices of this report (unfortunately the studies for Malaysia and Papua New Guinea were not completed). This report also draws heavily on the results of a two-year study on "Extraction and Processing of Forest Residues and Small Dimension
Jaeger, 1999). Additional literature was consulted to fill gaps.

[1] The wood residue inventory is operational on the AFPA web site www.abforestprod.org.

[2] A more recent study indicates that in the United States, between 1952 and 1991, logging residues as a percentage of timber removals from growing stock fell from 10 percent to 7.5 percent for softwoods and from 22 percent to 12 percent for hardwood (Haynes *et al*., 1995, cited by Wernick *et al*., 2000).

Definitions

"Wood residues" refer to wood left over from any conversion process, whether true refuse, wastewood or material destined for further conversion. Residues can refer to logging waste or mill waste.

"Logging residues" refer to any wood lying on the ground as a direct result of logging operations and trees severely damaged during logging operations. Approximately one-third of all logging residues originates from felled trees and the balance from residual trees destroyed or damaged during logging and extraction (Andersen, 1999a). The residues may range from portions of the trees – including high stumps – to entire trees broken during the logging process and left on the ground. They can be roughly divided into the following categories:

- High stumps (leaving usable wood in the stump)
- Stem section above the first branches (top log)
- Branches
- Off-cuts, rotten log parts
- Standing trees broken or severely damaged in the crown
- Standing trees severely damaged (butt trunk and root damage)
- Splintered trees and logs
- Logs lost and not recovered

Logging residues can be found directly in the stump area, along skid trails and roadside landings.

In many publications, residues are only described as those trees that were felled or the parts of felled trees. This explains, in part, the tremendous differences reported among research results. Strictly speaking, damaged trees should also be counted as waste, as they will not contribute to the future crop and could have been harvested during regular felling operations.

The composition of the residues in a particular location not only affects technical options for their use but also determines costs and benefits of their extraction. Furthermore, as the Indonesian case study indicates, residues in the plantation estate sector also need to be considered, especially in the rubber and oil palm sectors.

"Wood-processing residues" or "mill residues" consist of any wood fiber not used during the conversion process at a mill – be it a sawmill, veneer mill, plywood mill, or pulp mill. It includes losses due to improper and lengthy storage. The following categories make up mill residues:[3]

- Discarded logs (rotten or visibly or invisibly damaged)
- Bark
- Sawdust
- Slabs, ribs
- Peeler cores
- Grading off-cuts
- Sander dust
- Shavings
- Rejects

Similar to logging residues, the composition of mill residues determines options for their use. In numerous cases, the residues – including scraps and sawdust – of one mill are the raw material for another, depending on downstream and market integration. In such cases, residues are viewed as by-products rather than waste.

[3] For more detailed definitions and descriptions, see Wan Tarmeze Wan Ariffin *et al.* (1999)

Availability and use of logging residues

Current logging practices in Asia and the Pacific

More than ten years ago, Poore *et al.* (1989) noted that most of the world's tropical forests were unmanaged or managed in unsustainable ways. Since then, considerable progress has been made towards better forest management in the Asia-Pacific region, although most countries are still far from achieving sustainable forest management.

A major obstacle to applying best practices is the destructive form of logging carried out by many operators. "Forest mining" is still common in many countries (Putz *et al.*, 2000a) and conventional crawler tractor/truck harvesting systems developed in the 1960s are still in regular use. Although more efficient and less damaging equipment exists today, it is often more expensive (or perceived to be more expensive) and/or more complicated than older equipment and therefore rarely used (Thurland, 1999).

Logging intensities in the tropical rainforests of Asia and the Pacific are substantially higher than in other regions (Putz *et al.*, 2000b). Pinard and Putz (1996) recorded an average of 154 m^3/ha in the Malaysian State of Sabah. Thurland (1999) estimated intensities between 80 and 125 m^3/ha in Terengganu, Malaysia. In comparison, in the dense rainforests of West and Central Africa, logging intensity is only about 10 m^3/ha (Van Leersum, 1996, cited in Wanders, 1999).

Re-logging (i.e. the premature re-entry into stands that were previously logged) within five to ten years after the first harvest is also common in Asia and the Pacific (Gillis, 1988, cited in Ascher, 1993; Smith and Applegate, 2001). Both frequency and intensity of logging operations are important determinants of logging damage and thus residue volumes.

A recent study in the Malaysian State of Terengganu concluded that largely unsupervised logging practices resulted in average logging damage percentages to residual stands of between 50 and 75 percent (Thurland, 1999). Similarly, Pulkki (1997, p. 4) concluded that "damage to the residual stand in conventional logging operations is excessive and the percent of residual trees damaged ranges from 33-70 percent in areas with higher (>30 m^3/ha) logging intensity."

Sweeping generalizations regarding logging damage are inappropriate, as substantial forest management differences can be observed among countries of the region. Technological sophistication ranges from manual logging (with or without draft animals) to helicopter logging. However, standard estimates of logging residues can appropriately be applied in countries where ground-based systems and the use of crawler tractors are still very common. This includes particularly Malaysia and Indonesia, and other countries where companies from Malaysia and Indonesia operate.

Many countries in Asia have institutionalized total or partial logging bans (Brown *et al.*, 2001). Local wood production is therefore dramatically reduced and total residue volumes are subsequently less significant than in major wood-producing countries. Hence, refining estimates of recovery rates for countries with partial logging bans would have only a negligible effect on total volumes potentially available in the region.

However, adjustments to recovery rates were made for wood-deficit countries, where it can be assumed that higher wood prices are likely to stimulate more thorough collection and use of residues. In extreme cases, where the local population faces woodfuel shortages, virtually all residues are collected for firewood; therefore recovery rates can be considered to be close to 100 percent.

Recovery rates

A traditional "rule-of-thumb" is that for every cubic meter of wood extracted from the forest another is left behind. This rough estimate appears to be generally validated by the Chinese and Indonesian case studies.

Log utilization rates in China range from 53.7 percent in Yunnan Province (in the south) to 70.8 percent in Jilin Province (in the northeast). Average recovery rates have been estimated at 56 percent (see Appendix 1). In Indonesia, recovery rates have been estimated at 47.6 percent for the case study prepared by Gintings and Roliadi (see Appendix 2). In other words, for each cubic meter extracted in the lowland forests of Sumatra, Kalimantan, Sulawesi or Maluku, more than one cubic meter is left behind in the forest. Up to 70 percent of wood being previously logged from natural forests in Sri Lanka was wasted because of poor harvesting methods, inefficient utilization, and the non availability of markets for some wood (Buenaflor and Karunatilleke, 1992, cited in Pulkki, 1997).[4]

A study in the Malaysian State of Sarawak (Noack, 1995) showed that, on average, about 54 percent of the total wood volume (diameter above 20 cm) was extracted in the form of logs. The log utilization rate in East Kalimantan is about 53 percent (McLeish and Susanty, 2000). A recovery rate of 56.4 percent is the average for "normal" concessionaires with little or no downstream woodworking capabilities in Terengganu (Andersen, 1999a). The highest utilization rate of 65.9 percent was found for a concessionaire with large downstream wood-processing facilities. This operator reduced especially the volume of wasted top logs and various off-cuts (Table 1), thus indicating that the potential for reducing waste in the forest is real and can be profitable. It also highlights that not all residues are usable or can be extracted and transported in a cost-effective manner.

Table 1. Composition of logging residues in comparison to log volume used in Malaysia (in percent)

Study	Log used	Stump	Top logs	Branches	Various off-cuts
ATTC, 1993	54.0	8.0	17.0	9.0	12.0
Scharai-Rad, 1995	56.8	9.7	17.1	16.4	incl. in top logs
Noack, 1995*	53.5	4.6	10.4	26.3	5.2
Jaeger, 1999a	65.9	4.8	7.5	17.3	4.5
Jaeger, 1999a	56.4	4.5	14.1	14.5	10.5

*includes data for Malaysia, Indonesia, Ghana and Cameroon

Source: Jaeger 1999a; only residues originating from individual trees.

The available figures indicate a fairly common recovery rate of about 55 percent, with higher rates in the temperate forests of China. Lower recovery rates can be expected during "hit-and-run" harvesting operations or large-scale illegal logging. Reliable statistics on the extent of illegal logging are scarce, but it is prevalent in most countries of the Asia-Pacific region with volumes of illegally cut trees ranging from a few hundred to millions of cubic meters per year. On the other hand, most research has been conducted in the tropical rainforests of Malaysia and Indonesia, where most of the commercial logging is taking place. In drier forest types and in wood-deficit situations, recovery rates are considerably higher, which needs to be considered in assessing the overall availability of raw material.

Moreover, very little is known about recovery rates for plantations in the Asian tropics. Much depends on the end use, distance to markets, standards of the industry, and whether one considers final harvests or thinning operations. Andersen (1999b) estimated that only about 30 percent of the felled trees in an *Acacia mangium* plantation was removed during thinning operations. The 60 m^3/ha (above 5 cm) left behind in the plantation had no commercial value, since there were no wood-based panel producers of chip mills in the plantation's vicinity. In fact, Andersen's study revealed that the extraction of the thinning residues would result in a loss of 65 Malaysian ringgit (or about US$ 17) per m^3. This highlights the importance of the location of plantations vis-à-vis processing facilities. In fact, as Ravn (1999a) has shown for Malaysia, available logging residues are now considered too expensive and wood-based panel and chip producers have begun to invest in their own plantations, since they believe that they can produce their own raw material close to the processing site cost-effectively for less money than the cost of residues.

The recovery rates discussed above are based on studies of individual trees. Hence, they fail to account for what actually happens to a forest during logging operations, including failure to account for damaged or destroyed trees that were not intended for felling and extraction. Based on

[4] Note that Sri Lanka banned logging in natural forests in 1990.

studies by Andersen (1999a), only one-third of the total volume of forest residues originates from the individual trees felled. The other two-thirds consist of trees damaged or destroyed during road construction, logging and extraction. Very different figures are quoted for Indonesia where damaged trees make up less than 5 percent of the total volume of residues (Table 2). The available information does not allow for a detailed analysis of the differences. It is probably safe to say, however, that during harvesting operations in tropical rainforests, for every cubic meter taken out of the forest two cubic meters are left behind, either as residues on the forest floor or as standing damaged or dead trees.

Much higher recovery rates are possible

At present, the problem with plantation residues [in Malaysia] is not solved. The recovery rate of small logs in the ongoing traditional thinning in the Merchang plantation is only about 30 % of the total thinned volume. The logs are used for pallet wood at a recovery rate of about 25 % (similar to rubberwood processing), which means that only 7-8 % of the total felled volume is currently used.

Recently, mechanized whole tree thinning has been tried by Merbok Hilir Resources Sdn. Bhd. in Merchang with promising results. The recovery rate is around 80 % of the thinned volume. The damage level is acceptable and the method effectively solves the problem of labor shortage. The whole trees are chipped [in the forest] for the manufacture of MDF … [medium-density fiberboards] at Merbok Hilir Resources Sdn. Bhd. in Kedah.

Source: Ravn, 1999b

Table 2. Composition of logging residues in Indonesia

Component	Amount (m^3 per ha)	Amount (percent)
Upper portion of the tree trunk including branches, smaller branches and twigs	37.29	45.35
Stump	23.95	29.14
Damaged standing trees, due to felling and skidding,	3.96	4.82
Commercial wood logs of unacceptable qualities, due to knots, crooks, reaction woods and other defects	15.66	19.05
Unknown or non-commercial tree species	1.33	1.62
Total	**82.19**	**100.00**

* Based on observations/assessments in lowland production forests (Idris, 1995, cited by Gintings and Roliadi, see Appendix 2).

All logging operations generate waste. The question is not one of avoidance, but rather of minimization and utilization. The real question is then how much of the total volume can be used economically. Some analysts find it useful to distinguish between "usable" and "economically usable," although clear definitions have not yet been developed (see China case study in Appendix 1). In China, for example, 8 to 15 percent of the logging residues are categorized as usable depending on forest types. Only 5.6 to 9 percent of residues are classified as economically usable.

Detailed measurements in Terengganu, Malaysia, indicated that about 20 percent of the total amount of forest residues is directly usable for primary processing (Table 3). These estimates must be viewed with caution, however, because the extraction of logging residues solely for chips and fiber use is presently not economically attractive relative to the use of mill residues or residues derived from estate crops such as rubber (Azizol Abdul Kadir *et al.,* 1994; Andersen, 1999a).

Moreover, the directly usable volume may not correspond with the volume that loggers are interested in actually recovering, which can lead to a considerable reduction in the amount of residues that could be removed potentially. In the study in Terengganu, loggers extracted only 23 percent of the logs that had been tagged as “recoverable” (Table 4). While there are probably numerous explanations for this phenomenon, a major one is the apparent preference for particular, i.e. the most valuable, species (Table 5).

Table 3. Volume of recoverable and usable logging residues in Terengganu, Malaysia

	No. of pieces	Volume (m^3)	Percent	Species
Top logs from originally tagged trees (first operation)	123*	67.96	3	All species
Top logs from originally tagged trees and severely damaged trees (second operation)	325**	371.39	17	All species
Total volume of recoverable residues	448	439.26	20	All species
Volume of main logs extracted	n/a	2 184.52	100	All species

Source: amended Jaeger, 1999b

* Residues from the first operation were extracted simultaneously with the main logs

**280 pieces or 86 percent originated from severely damaged trees

Table 4. Volume of actually recovered logging residues in Terengganu, Malaysia

	Volume (m^3)	Percentage
Total volume of main logs extracted	2 184.52	
Volume of residues tagged for extraction in second operation	371.39	100
Volume of tagged residues extracted in second operations	88.02	23
Volume of residues extracted in first operation	67.96	
Total volume of residues actually extracted	155.98	

Source: amended from Jaeger, 1999b

Table 5. Volume of recovered residues in Terengganu, Malaysia

	Volume (m^3)	Percentage of total volume tagged for extraction	Species
Total volume of extracted residues	509	5	Chengal, Balau, Meranti and Kempas
Volume of main logs extracted during regular harvesting	10 662	100	All species

Source: amended from Jaeger, 1999b

Results from studies in Brazil (Gerwing *et al.*, 1996, p. 25) indicated that by “eliminating timber losses to trees that are felled but never found [by skidding operators] and losses caused by poor cutting and bucking practices, the amount of timber harvested from each hectare can be increased by an average of 8.3 m^3.” This is more than 20 percent of the average volume (38 m^3) currently recovered. However, analysts warn that “this presupposes the processing and utilization of species that are currently not . 25), which confirms the findings from Malaysia by Jaeger (1999b).

Experiences of concessionaires with downstream processing facilities indicate that utilization rates can easily be raised by close to 10 percent (Table 1) above traditional recovery. The potential utilization rate is probably higher, although it is doubtful whether it is twice as high. For calculating the availability of logging residues that can be economically used without any major changes, i.e. with low investments, a figure of 10 percent will be used for the following calculations. This is half the recoverable volume that is actually suitable for primary processing, but is still between 1.5 and 5 percent above the volume loggers currently show interest in recovering.

Another reason for low recovery rates

Another reason for the low recovery rate is the attitude of the logging crews. It is human to resist changes. After being told to only harvest large dimension logs, it is a great change to get used to extracting forest residues. The productivity will of course go down drastically and it is necessary for the logging contractors to develop a different salary structure when working with forest residues.

Source: Jaeger, 1999b

Logging and wood production

The availability of logging residues is determined in part by logging rates. There are no reliable data on annual logging areas and intensities for most countries of the Asia-Pacific region. A proxy indicator of logging area is roundwood production and, in particular, the production of industrial roundwood, although the indicators do not distinguish between source of material (i.e. from natural forests or plantations). The most comprehensive data on roundwood production (Table 6) are contained in the FAO Yearbook of Forest Products (FAO, 2000). Since they largely reflect official government figures, they do not always accurately portray the actual situation.

Table 6. Roundwood production and consumption in selected Asia-Pacific countries in 1998 (1,000 cum)

Country	Roundwood (R)	Industrial roundwood (I)	Ratio I/R (percent)	Consumption (C)	Ratio R/C (percent	Cum/1 000 capita
Bangladesh	33 058	617	1.87	33 004	100.16	5
Bhutan	1 702	45	2.64	1 702	100.00	22
Cambodia	8 008	1 040	12.99	7 908	101.26	88
China	291 886	100 918	34.57	298 178	97.89	85
India	299 490	25 156	8.40	301 174	99.44	27
Indonesia	193 218	36 195	18.73	193 329	99.94	176
Laos	4 488	689	15.35	4422	101.49	101
Malaysia	29 297	21 735	74.19	23 699	123.62	754
Myanmar	22 430	3 444	15.35	21 757	103.09	62
Nepal	21 474	620	2.89	21 474	100.00	27
Pakistan	33 044	2 270	6.87	33 177	99.60	17
Philippines	42 530	3 484	8.19	42 965	98.99	54
Sri Lanka	10 414	706	6.78	10 411	100.03	38
Thailand	36 302	2 872	7.91	36 580	99.24	52
Viet Nam	36 232	4 525	12.49	36 222	100.03	58
Total of selected countries	1 063 573	204 316	19.21	1 066 002	99.77	n/a
Asia	**1 127 267**	**244 044**	**21.65**	**1 150 664**	**97.97**	**75**
Fiji	594	557	93.77	816	72.79	699
Papua New Guinea	8 772	3 239	44.90	5 761	152.27	352
Solomon Islands	872	734	84.17	172	506.98	321

Note: Minor wood producers in the Pacific were not considered in this study.

Although it is not the objective of this study to assess the validity of the data presented above, it should be noted that drastically different data sets exist for some countries. For example, while FAO (2000) indicated that 1997 industrial roundwood production in Cambodia was

1.04 million m^3, data from four different sources for the same year ranged from 212 000 to 4.32 million m^3 (Castrén, 1999a). For Myanmar, FAO (2000) reported production of 3.44 million m^3, while Castrén's (1999b) estimates were less than 2 million m^3. Gintings and Roliadi (Appendix 2) estimated log production in Indonesia at about 28 million m^3. Other official figures ranged from 29.15 to slightly above 40 million m^3 (FLB, 2000). Barr (2000) calculated production at 55 million m^3, and referred to a 1999 study by Scotland and others which estimated production at 82.3 million m^3, or nearly three times higher than official figures. For China, Chen estimated log production in 1997 was around 64 million m^3 (Appendix 1), while FAO (2000) reported a figure of 109 million m^3 for the same year. Finally, Thailand's industrial roundwood production was approximately 2.9 million m^3, as published by FAO (2000), compared with only 54 800 m^3 (including confiscated timber but apparently excluding wood sourced from plantations), as published by the Royal Forest Department (RFD, 2000).

The observed discrepancies need to be kept in mind in reviewing the availability of logging residues. They indicate that the figures in the next section are rough approximations, which suggest orders of magnitude but not exact figures for economic analysis or similar appraisals.

Availability of logging residues

The main wood and timber producers in the Asia-Pacific region are very diverse in terms of socio-economic variables. Forest cover and the importance of timber industries ranges from very low to extremely high. Hence the 18 Asia-Pacific countries assessed (Table 6) were further sub-divided into three groups according to industrial wood production and per capita consumption of roundwood.

The first group consists of those countries that produce only low volumes of industrial roundwood and/or are characterized by low levels of consumption per person. In fact, in all of these countries, with the exception of Bhutan, a significant percentage of roundwood is produced from trees outside forests (TOF). It can be safely assumed that recovery rates of wood from TOFs are close to 100 percent.

- India (27)[5]
- Pakistan (17)
- Bangladesh (5)
- Bhutan (22)
- Nepal (27)
- Sri Lanka (38)

In the calculations below, a residue factor of only 0.25 is applied for the six countries above. This means that for each cubic meter cut one-quarter of a cubic meter is left behind.

The second group consists of countries whose production does not satisfy demand and whose industrial roundwood production is less then 10 percent of total production. Consumption levels are still below the Asian average of 75 m^3/1 000 persons. Although China has higher consumption levels and produces a considerable amount of roundwood, it is included in this group for two reasons. First, like Thailand and Philippines, it has recently introduced harvesting restrictions. Second, large forest areas are located in the temperate zone, where harvesting damage can be assumed to be lower, especially for softwoods. Chen (Appendix 1) suggested a recovery rate of 56 percent in China, although this appears to exclude the volume that could be recovered from damaged trees. Fiji is also included in this group as it is not a major exporter of logs or wood products like the countries in group 3. For further calculations, a recovery factor of 1.0 (i.e. for each cubic meter cut one cubic meter is left behind) is assumed for the four countries in group 2:

[5] Figures in parentheses represent consumption levels of industrial roundwood in cubic meters per 1 000 capita (FAO, 2000)

- Philippines (54)
- Thailand (52)
- China (85)
- Fiji (699)

The last group comprises the timber producing countries where industrial wood production is higher that 10 percent of total wood production, and countries with consumption levels above the Asian average (with the exception of Viet Nam and Myanmar). Hence, for the first six countries, a residue factor of 2.0 is applied, and for the last two a slightly reduced factor of 1.5:

- Cambodia (88)
- Indonesia (176)
- Laos (101)
- Malaysia (754)
- Papua New Guinea (352)
- Solomon Islands (321)
- Myanmar (62)
- Viet Nam (58)

As discussed above, for the assessment of logging residue availability it is assumed that only 10 percent of the total volume of logging residues can be used economically or is of interest to loggers (Table 7). This ratio appears to be low and is based on the current situation, which to a large extent depends on raw material prices. With rising prices, it can be assumed that the economically usable volume increases, although transport costs may rise at the same time, which further discourages the extraction of logging residues.

Table 7. Availability of logging residues in selected Asia-Pacific countries in 1998 (1,000 cum)

Country	Industrial roundwood (I)	Residue factor	Total volume of residues	Economically usable volume
Bangladesh	617	0.25	154	15
Bhutan	45	0.25	11	1
Cambodia	1 040	2	2,080	208
China	100 918	1	100 918	10 092
India	25 156	0.25	6 289	629
Indonesia	36 195	2	72 390	7 239
Laos	689	2	1 378	138
Malaysia	21 735	2	43 470	4 347
Myanmar	3 444	1.5	5 166	517
Nepal	620	0.25	155	16
Pakistan	2 270	0.25	568	57
Philippines	3 484	1	3 484	348
Sri Lanka	706	0.25	177	21
Thailand	2 872	1	2 872	287
Viet Nam	4 525	1.5	6 788	679
Total of selected countries	204 316	n/a	245 900	24 594
Asia	**244 044**	**n/a**	**n/a**	**n/a**
Fiji	557	1	557	56
Papua New Guinea	3 239	2	6 478	648
Solomon Islands	734	2	1 468	147

Based on the assumptions made earlier, the total amount of logging residues generated in the 15 selected Asian countries in 1998 was 245.9 million m^3, which is almost identical to the total roundwood removals of 244 million m^3 for Asia. In that sense, the rule of thumb that for each cubic meter cut another one is left behind applies, although it may apply evenly to all individual countries.

It cannot be assumed that currently the potentially recoverable residues are also of interest to loggers and the wood-processing industries. As various studies have shown, a maximum of 10 percent is potentially of interest to loggers and the wood-processing industries if logging and wood processing were better integrated. This adds up to 24.6 million m^3 for the 15 Asian countries and 851 000 m^3 for Fiji, Papua New Guinea and Solomon Islands. The reasons for this substantial difference between potentially usable and actually recovered residues are manifold and will be discussed below.

The bulk of economically usable logging residues, i.e. 88 percent, is produced in only three countries, i.e. China, Indonesia and Malaysia. While these three countries probably deserve most of the attention in terms of developing strategies for reducing and/or using logging residues, the figures for each country are only rough estimates. Chen (Appendix 1) estimated only 4.8 million m^3 to be usable, which is slightly less than half the figure derived above (Table 7). Chen based his calculation on an assumed roundwood production of 47.95 million m^3 while the FAO statistics indicated production of 101 million m^3. Since China imposed harvesting restrictions recently, Chen’s calculation appears to be more realistic.

Gintings and Roliadi (Appendix 2) distinguished between those residues generated during timber extraction in Indonesia (29.8 million m^3) and those that were produced during the clearing of unproductive rubber and oil palm plantations (13.44 million m^3). The figures in Table 7 suggest a total of 7.24 million m^3 only for logging residues, which is almost 2.5 times higher than estimates by Gintings and Roliadi. There are two reasons for this discrepancy. First, the Indonesian authors based their calculations on a total log production of only 23.8 million m^3, while FAO estimates production at 36.2 million m^3 for 1998. Second, Gintings and Roliadi applied a residue factor of 1.25, as only 3.96 m^3/ha of roundwood was estimated to be damaged during logging operations. As has been noted above, due to widespread illegal logging, actual log production is probably more than twice the level used by Gintings and Roliadi in making their estimates. Even the FAO statistics appear very conservative; thus it can be assumed that the volume of logging residues in the year 2000 is above 100 million m^3. Hence, while it can be assumed that the total logging residue volume of the 15 selected Asian countries presented in Table 7 is a reasonable estimate, figures for individual countries may differ by as much as 50 to 100 percent.

A more important issue than precise estimation of residue volumes is what measures should be taken to reduce logging residues and make better use of those residues that cannot be avoided.

Potential for reducing residue volumes

In terms of environmental and economic impacts, timber harvesting is usually the most significant aspect of forest operations and management. A considerable body of evidence indicates that forest harvesting operations can damage up to 50 percent of the residual stand (Sist *et al.,* 1998), and even up to 60 percent as reported for Sabah, Malaysia (Tay *et al.,* 2001). Damaged and destroyed trees contribute substantially to logging residues. As discussed above, in the Malaysian State of Terengganu two-thirds of logging residues consist of trees damaged or destroyed during road construction, logging and extraction (Andersen, 1999a). Lower logging intensities reduce damage and in the calculations of the previous section it was assumed that only half the logging residues are composed of damaged trees. It is obvious, however, that reducing the impact of forest harvesting could result in a significant reduction of logging residues. In comparison to conventional logging, applying reduced impact logging (RIL) techniques could probably reduce damage by about 50 percent (Pinard *et al.,* 2000; Tay *et al.*, 2001; Killmann *et al.*, 2001), conserve soil and biodiversity, and help sustain the productive capacity of the residual forest after logging.

RIL can be defined as "intensively planned and carefully controlled implementation of harvesting operations to minimize the impact on forest stands and soils, usually in individual tree selection cutting" (Killmann *et al.*, 2001). RIL emphasizes skills and commitment of forest workers to correctly apply a series of known technical guidelines. It is the application of the skills and efforts of well-trained forest planners, field rangers, supervisors, timber fellers, chokermen and tractor operators that determine the difference between conventional and best-management practices, i.e. differences in logging damage and residue volumes.

During most RIL operations, essentially the same volume of timber is extracted as during conventional cutting and yarding operations. In some cases, however, yields are reduced because less area is logged due to restrictions on tractor access to steep slopes (Tay *et al.*, 2001).

RIL involves a number of distinct modifications to reduce logging damage. These include:

- climber or liana cutting;
- improved design of roads and skid trails;
- tree identification and marking for directional felling;
- pre-planning of skid trails;
- improved road construction;
- directional tree-felling;
- improved skidding and lower skid trail density;
- removal of stream obstructions and drainage of skid trails;
- rehabilitation of landings; and
- maintenance of riparian buffer strips.

While RIL has largely been developed for existing ground-based tractor logging systems, it can be incorporated with cable and skyline systems or helicopter operations. This makes RIL practices some of the best options for sustainable forest management and reducing the current volumes of logging residues.

Although significant steps have been taken in the Asia-Pacific region to introduce RIL and other improved forest management practices,[6] only a small forest area is currently benefiting from RIL. The main reason is that costs associated with RIL appear to outweigh benefits. While this is disputed by some studies (Holmes *et al.*, 2001; Natadiwirya and Matikainen, 2001), the perception that RIL stands for "reduced income logging" persists. Furthermore, RIL requires significant efforts in training, capacity building and changes in die-hard habits.

Potential for extracting and utilizing residues

The adoption of RIL will reduce the volume of logging residues but will not eliminate them. Hence extraction and utilization of residues still have to be addressed. Loggers and the processing industry are only interested in a limited amount of recoverable residues. A number of basic questions have to be answered to assess what steps need to be taken to make better use of this underutilized raw material.

1. Which parts of the tree can be used?
2. When should they be extracted?
3. Who should extract residues?
4. What equipment is needed?
5. What are the costs (and benefits)?
6. What are current constraints?

[6] In 1998, the APFC published the Code of Practice for Forest Harvesting in Asia-Pacific (FAO, 1998). In 2000, the APFC produced the Regional Strategy for Implementing the Code of Practice for Forest Harvesting in Asia-Pacific (APFC, 2000). Several countries and local administrations have developed forest harvesting codes or harvesting guidelines.

Composition of logging residues

Table 1 illustrates that on average (in Malaysia) about 58 percent of the tree is extracted; about 6.5 percent is left in the stump; about 14 percent is in top logs; various off-cuts make up 9 percent; and branches comprise about 14 percent. At present, potential users are interested mainly in the stump and the top logs. In addition, damaged trees of commercial species are also of interest.

Timing of forest residues extraction

The cutting of the excess stump would be the first step in minimizing logging residues. It should be part of the normal logging operations. Other activities could be performed during the original logging operations or at a later point in time.

The success of forest harvesting depends to a large degree on minimizing the damage to the residual stand that will make up the future crop. Even very careful logging has an impact on the residual stand, which cannot be avoided. Extracting logging residues would result in additional environmental impacts. However, this can be minimized by applying directional felling of damaged trees that may be without a crown (Thurland, 1999) and by conducting additional operations as soon as normal logging is completed. Minimizing environmental impacts is only one aspect of timing. Costs can also be reduced by re-entering the forest immediately after the normal logging, as existing roads and skid trails are still usable at that time.

Who should extract residues?

Ideally, valuable residues are collected during the normal operations by the logging crews. This begs the question of why they are not already taking what others may consider valuable. There are a number of explanations for this. First, due to size limitations, many damaged and untagged trees have to remain in the forest; in some cases it could actually be illegal to remove them. Second, much of the material left behind is too small to be handled by the large, heavy equipment currently used by most operators. Such operators are not currently able to remove it cost-effectively. The alternative would be removal by a second crew with lighter and more flexible equipment.

Too big to be cost-effective

It is not economical using a big crawler tractor to extract 2 or 3 small pieces of residue logs using the 28 mm wire, as the efficiency is negatively affected…. The alternative is a second crew, specially trained, taking out residues as a special assignment, in a second operation immediately after extraction of the normal logs is completed.

Source: Andersen, 1999a

Extracting residues is costly, suggesting the need for lower royalty rates. This is another reason why alternative crews should be introduced. If original crews would be allowed to extract logging residues, they might be motivated to increase residue volumes with a concurrent decrease in normal logs extracted in order to qualify for reduced royalty rates. The result would be higher profits for them but would fail to meet the objective of improving forest management.

Specialized equipment

Andersen (1999a) concluded that logging residues could be handled by existing equipment but warned that efficiency was low and costs were too high, as current equipment used was dimensioned and fitted for felling and extracting large and heavy logs. He suggested smaller, faster, lighter and more flexible equipment including:

- Lighter chainsaws (maximum 50 cm bar)
- Smaller diameter cables (15-19 mm)
- Smaller and faster-operating winches (60-90 m/min)
- Smaller crawler tractors or rubber-tired skidders

Costs and benefits of extracting and utilizing logging residues

Most logging contractors in the Asia-Pacific region rely on used equipment. Most of the logging equipment in Peninsular Malaysia is bought second-hand or made from used parts, except for chainsaws (Thurland, 1999). Some equipment is more than 40 years old. The situation in other countries is not much different. Even during favorable financial periods, investment in new logging equipment has been low. It reached a minimum during the recent financial crisis. Profit margins have been reduced and costs are scrutinized with even more care before investment decisions are made.

Very little research on the cost of increasing the utilization of logging residues has been conducted. Azizol *et al.* (1994, p. 7) observed that when their study was conducted, "the sale price could not even offset the extraction costs." Havelund (1999) summarized his findings as follows (p. 297):

> "The present variable cost of logging is estimated in the range of 38 - 49 RM/m^3 (about US$ 10 to 13) ex logyard. Extraction of forest residues and small-dimension logs is expected to be more expensive. A conservative estimate gives variable logging costs in the range of 59 - 76 RM/m^3 (about US$ 16 to 20) ex logyard as the costs of extracting the best 10 percent of the forest residues, which is equivalent of an additional 20 percent of the normal volume harvested."

While alternative financial analyses may arrive at lower costs, in fact costs may even be higher if the expenses for retooling, purchasing new equipment and training are included in the calculations. In any case, the price of logging residues is very high relative to mill residues, which ranged from 12 to 20 RM/m^3 (about US$ 3 to 5) in Malaysia during 1998 (Ravn, 1999b).

Current attitudinal constraints and lack of clear guidelines

The transformation of the forest sector has taken place with unprecedented speed. Considerable investments have recently been made in the wood-processing sector, particularly in the wood-based manufacturing and pulp and paper facilities. Rubberwood has been transformed from waste material to a much sought after raw material (Balsiger *et al.*, 2000). In some countries, mill residues are utilized to the extent that occasional shortages are reported. In response, wood processors have initiated their own plantation programs, with the pulp and paper sector taking the lead. Developments are so dynamic that it is also likely that interest in logging residues will increase in the future. However, there are numerous barriers that need to be lowered or eliminated to make logging residues more attractive. Innovative incentive schemes and royalty and fee schemes need to be developed, and premiums and other fixed costs kept at a minimum to reduce costs.

Habitual and attitudinal constraints should not be underestimated. RIL and extracting logging residues require a change of habits and perceptions. Good fellers and yarders are currently characterized by the size of their paychecks, which increase with the size of the trees they fell and yard (Havelund, 1999). The prevailing attitude is that anyone with a chainsaw can be a feller and anyone who can operate a bulldozer or crawler tractor can be a yarder. The results of such an attitude are low skill levels, not only confined to workers but include contractors and forest agency staff. In fact, the majority of people working in the forest lack basic understanding of sustainable forest management, a constraint that will continue as long as there is inadequate training for forest workers and contractors. Appropriate training courses need to be offered together with adequate income compensation systems so that trained participants do not experience a loss of income.

A lack of clear guidelines and poor supervision are additional constraints that need to be overcome. These are probably the easiest to tackle for forestry agencies. Legislative and administrative constraints need to be eliminated by introducing more flexible rules. It should be possible to extract accidentally cut and heavily damaged trees. However, this requires a relationship of trust between foresters and loggers. Foresters need to increase their presence in the forest during logging operations. They need to take their supervisory role more seriously and spend more time in the forests to deal with day-to-day problems. Increased interaction in the field will facilitate the extraction of logging residues (Havelund, 1999). Cutting limits need to be reviewed and current license agreements need to be amended.

There is still a considerable lack of solid research results to make a case for the increased utilization of logging residues. The limited research results that are available should stimulate forest agencies to review their guidelines, to assess the marketing situation for logging residues, and to initiate concerted training efforts.

Availability and use of mill residues

According to comparisons of ten countries (Dykstra, 1992, cited in Pulkki, 1997), only about 53 percent of felled timber is actually available for further processing. After logs are extracted from the forest, loading and transport losses and damages reduce volumes further. Such losses are often not considered, but can be nonetheless substantial. In Papua New Guinea, 10 to 35 percent of the anticipated export volume was left at the harbor after failing to meet export grade rules (Kilkki, 1992, cited by Pulkki, 1997).

Statistics for the wood-processing sub-sectors in Asia-Pacific are extremely weak with few exceptions. Wood processing is very diverse and has in recent years experienced a slow but steady shift towards the production of wood-based panels and pulp (Table 8). The following discussion on the availability and potential uses of mill residues will take account of the existing situation. It focuses on residue generation in sawmills and plywood mills, which together account for the biggest share of the wood-processing sector. Second, although the share of wood-based panel producers is slowly increasing, from a residue-generation point of view, with the exception of plywood, this can only be welcomed. Plywood processing recovery rates are below 50 percent. In the other panel sub-sectors, however, rates are substantially higher. Chen (Appendix 1) estimated the recovery rate for particleboard to be 70 percent and for MDF 93 percent. Considering that some of the latest production lines installed recover all of their waste for energy production, virtually no waste remains.

Table 8. Wood processing in Asia from 1994 to 1998 (1,000 cum, pulp in 1,000 MT)

Production	1994	1995	1996	1997	1998
Sawnwood	98 045	95 767	98 248	88 723	73 846
Veneer sheet	2 608	2 348	2 409	1 738	2 389
Plywood	23 797	28 467	25 989	28 944	21 069
Particleboard	5 791	9 135	8 143	8 711	7 897
Fiberboard	4 346	4 246	4 976	6 728	6 364
Hardboard	n.a.	1 830	2 008	2 097	2 018
MDF	n.a.	1 582	2 190	3 737	3 583
Insulating boards	320	598	697	1 190	1 350
Wood pulp	17 665	18 641	18 645	19 774	18 175
Total	n.a.	164 609	165 301	163 639	138 689

Source: FAO, 2000

Recovery rates of sawmills and plywood mills

Numerous factors influence the volume of mill residues. The recovery rate is especially dependent on log dimensions. For logs in the range of 30 to 70 cm in diameter, recovery rates drop to about half when the log diameter is halved (Ravn and Jensen, 1999). Recovery rates are also determined by log quality, tree species, defects, sawmilling equipment, mill maintenance, production methods, grading, storage and drying. Ravn (1999a) estimated that improvements in these factors could reduce residue volumes by 5 to 10 percent. However, log dimensions have been decreasing in Asia and the Pacific, and will decrease even further in the future. Hence, even investing in more efficient equipment will not increase overall recovery from present levels, but rather will only avoid further declines. In the short term, however, and for individual mills where equipment upgrades are made, improvements are tangible.

Small-spindle rotaries reducing residue generation

The growing adoption of small-spindle rotaries by Indonesian plywood producers may be having just the same effect [i.e. accelerate the pace of forest destruction]. Introduced in the mid-1990s, the new rotaries allow panel producers to peel logs as small as 15 cm in diameter, leaving a core of 6-8 cm. The old, large-spindle rotaries, by contrast, would generally leave a 15-25 cm core that could not be peeled. According to several producers interviewed, the use of the new technology has had the practical effect of raising their log recovery rates – particularly when their preexisting machinery had become highly depreciated – from the 45-50 percent range to that of 55-60 percent.

Source: Barr, 2000

According to detailed studies in numerous countries, sawmill recovery rates range from 42 to 60 percent with an average of 50.8 percent. Plywood recovery rates range from 43 to 50 percent with an average of 46.9 percent (Table 9). In 1998, researchers interviewed 24 mill managers in the State of Terengganu, Malaysia representing about 70 percent of the production in the State. According to the responses of the managers, sawmills recovered about 52 percent and plywood mills about 49 percent of total input (Ravn, 1999b). Recovery rates can also be substantially lower, however. In Lao PDR, average recovery rates in the sawmilling sub-sector are estimated at 30 to 40 percent (Thongleua Southavilay and Castrén, 1999). This is because of the use of inappropriate machinery that was originally installed to process large-diameter timber but now has to accept smaller dimensions. The teak export mills of the Myanmar Timber Enterprise turn about 65 percent of the log input into waste (Castrén, 1999b). Tze (1999, cited in Zerbe *et al.*, 2000) reported an even lower recovery rate of 30 percent for teak logs with sawmill quality.

There are no clear discernable trends over time. It appears that any increases in recovery rates are balanced by declines in log dimensions and quality.

Table 9. Recovery rates in the sawnwood and plywood sub-sectors

Mill type	Recovery rate	Location	Source
Sawmill	52	Pen. Malaysia	Tech 5, 1998 [a]
Plywood mill	n.a.	Pen. Malaysia	Tech 5, 1998 [a]
Sawmill	52	Pen. Malaysia	Ravn, 1999b [a]
Plywood mill	50	Pen. Malaysia	Ravn, 1999b [a]
Sawmill	46	Pen. Malaysia	FRIM, 1997 [a]
Plywood mill	48	Pen. Malaysia	FRIM, 1997 [a]
Sawmill	55	Pen. Malaysia	Poyry, 1998 [a]
Plywood mill	44	Pen. Malaysia	Poyry, 1998 [a]
Sawmill	50	Southeast Asia	IUFRO, 1992 [a]
Plywood mill	48	Southeast Asia	IUFRO, 1992 [a]
Sawmill	56	Pen. Malaysia	TSFD, 1998 [a]
Plywood mill	43	Pen. Malaysia	TSFD, 1998 [a]
Sawmill	46	Indonesia	IUFRO, 1992 [a]
Plywood mill	50	Indonesia	IUFRO, 1992 [a]
Sawmill	48	Philippines	IUFRO, 1992 [a]
Plywood mill	47	Philippines	IUFRO, 1992 [a]
Sawmill (1984)	50	Sabah, Malaysia	Bhargava and Kugan, 1988 [b]
Plywood mill (1984)	44	Sabah, Malaysia	Bhargava and Kugan, 1988 [b]
Sawmill	50	Asia-Pacific	Dykstra, 1992 [b]
Plywood mill	48	Asia-Pacific	Dykstra, 1992 [b]
Sawmill	42	USA	Dykstra, 1992 [b]
Plywood mill	48	USA	Dykstra, 1992 [b]
Sawmill	60	China	Chen, 2000 [c]
Plywood mill	50	China	Chen, 2000 [c]
Sawmill	54	Indonesia	Gintings and Roliadi, 2000 [c]
Plywood mill	43	Indonesia	Gintings and Roliadi, 2000 [c]

Note: [a] cited by Ravn (1999b), [b] cited in Pulkki (1997), [c] from Appendices 1 and 2 of this publication

Composition, types and attributes of mill residues

The large-scale use of mill residues demands considerable investments in transport and processing capacities. Investments will only be made if a constant supply of raw material can be assured, which, as noted earlier, is already causing problems for some users of mill residues. In addition, the composition and quality of mill residues must be well known.

The composition of mill residues depends on a number of factors. Sawmills produce quite different residues, or by-products, than plywood mills (Tables 10 and 11). Basically, mill waste can be divided into two main groups. The first is made up of larger pieces, the bulk waste, while the second group, consisting of shavings, sawdust and sander dust, is made up of fine wood particles. Waste in the first group are easier to segregate and handle, which explains the increase in their use.

Finally, waste or mill by-products are categorized by six main attributes that determine their appropriateness for further use and processing (Wan Tarmeze Wan Ariffin *et al.*, 1999):

- Species
- Segregation (species mixture)
- Purity (clean or contaminated)
- Moisture content
- Storage (in silos, bins or left on the ground)
- Size

Table 10. Types of residues generated during sawmilling (10-country average)

Volume	Process	Residues (m^3)	Percentage
Log volume at sawmill 8 612.1m^3			
	Debarker residues	140.4	1.6
	Sawdust	767.9	8.9
	Slabs and edgings	1994.9	23.2
	Board end trimmings	403.5	4.7
	Other conversion losses	1450.8	16.8
Sawnwood produced 3 854.7			
	Storage and transport losses	56.3	1.5
Sawnwood delivered to market 3 798.4			**43.3**

Source: adapted from Dykstra, 1992, cited in Pulkki 1997

Table 11. Types of residues generated during the production of plywood (10-country average)

Volume	Process	Residues (m^3)	Percentage
Log volume at sawmill 1 705.5m^3			
	Debarker residues	58.8	3.5
	Cores and lathe roundup	197.1	11.6
	Spur knife trim	19.3	1.1
	Veneer waste and clippings	227.4	13.3
	Drying losses	19.4	1.1
	Panel trimmings	34.3	2.0
	Sander dust	12.1	0.7
	Other conversion losses	31.2	17.7
Plywood delivered to market 835.9 m^3			**49.0**

Source: adapted from Dykstra 1992, cited in Pulkki, 1997

In assessing the volume of residues that are actually available and can be used, horizontal and vertical integration of processing facilities are crucial. The recovery of solid mill off-cuts, which make up a substantial percentage of total sawmill residues, depends on the degree of integration in market and downstream production (Ravn and Jensen, 1999). Therefore, it is crucial to distinguish between real waste that can only be disposed of by dumping or burning, and by-products that can be used as firewood, livestock bedding or further production processes. Even bark can be used as mulching material, although the cost-effectiveness of such an alternative depends on a number of factors.

Integration turning waste into useful by-products

Sawmills with little integration have few opportunities for recovery of short-length pieces. If supplying a moulding plant, small dimension pieces down to 60 cm can be delivered, raising recovery rate. A moulding plant also using finger jointing can use pieces as short as 20 cm, thereby reducing the amount of remaining mill residues.

Source: Ravn and Jensen, 1999

Potential availability of sawmill and plywood mill residues

Estimating the volume of mill residues available for further processing is difficult. Production figures are often not reliable. Recovery rates vary within and among countries depending on log sizes, dominant species processed, standard of processing equipment and level of horizontal and vertical integration. Hence aggregate figures should be viewed with caution.

The total amount of residues produced per year in the sawmilling and plywood sub-sectors in the selected countries is about 42 million m^3 (Table 12) and 19 million m^3 (Table 13), respectively. Close to 90 percent of the sawmill residues is generated in only four countries (i.e. China, India, Indonesia and Malaysia). More than 95 percent of the plywood mill residues is generated in only three countries (i.e. China, Indonesia and Malaysia). These percentages were even greater before the financial crisis that began in June 1997. For example, in 1996 Indonesia produced 7.3 million m^3 of sawnwood compared to 2.5 million m^3 in 1998 (FAO, 2000). In Malaysia, sawnwood production decreased by almost 40 percent and in China by 30 percent between 1996 and 1998. The decline in the plywood sector was not as drastic but also quite pronounced in the main producer countries. Hence, total volumes prior to the crisis were probably 30 to 40 percent higher.

Depending on the assumptions that calculations are based upon, estimated volumes of residues vary (e.g. compare results in Tables 12 and 13 with the case studies in the Appendices 1 and 2). Gintings and Roliadi estimated the total residues generated in the wood-processing sector in Indonesia at 11.6 million m^3 per year. Chen estimated a similar volume of 11.3 million m^3 for China (Appendix 1).

Unlike the very small volume of logging residues currently being used, it is apparent that much larger percentages of mill residues are already utilized. Thus, the total estimated volume of mill residues (61 million m^3 per year) is not the volume that is currently available. Especially in wood-deficit areas, residues are unlikely to simply be dumped. Rather, the residues are likely to be used by local people as fuelwood or claimed for further industrial processing. This indicates that, although primary processing may produce huge volumes of residues, in many countries they are not viewed as "waste" but as by-products that are already used by the urban and rural populations, the informal sector and/or secondary wood-based industries.

Table 12. Sawnwood production and residues in 1998 (1,000 cum)

Country	Sawnwood	Assumed recovery rate	Mill residues
Bangladesh	70	50	70
Bhutan	18	50	18
Cambodia	40	50	40
China	18 733	60	12 489
India	17 460	50	17 460
Indonesia	2 545	54	2 168
Laos	560	40	840
Malaysia	5 241	52	4 838
Myanmar	326	40	489
Nepal	620	50	620
Pakistan	1 051	50	1 051
Philippines	216	50	216
Sri Lanka	5	50	5
Thailand	426	50	426
Viet am	721	50	721
Total of selected countries	48 032	n.a.	41 450
Asia	**73 846**	**n.a.**	**n.a.**
Fiji	131	50	131
Papua New Guinea	218	50	218
Solomon Islands	12	50	12

Table 13. Plywood production and residues in 1998 (1,000 cum)

Country	Plywood	Assumed recovery rate	Mill residues
Bangladesh	1	47	1
Bhutan	5	47	6
Cambodia	16	47	18
China	4 979	50	4 979
India	245	47	276
Indonesia	7 015	43	9 299
Laos	125	47	141
Malaysia	3 904	50	3 904
Myanmar	7	47	8
Nepal	0	n.a.	0
Pakistan	36	47	41
Philippines	244	47	275
Sri Lanka	7	47	8
Thailand	39	47	44
Viet Nam	37	47	42
Total of selected countries	16 660	n.a.	19 041
Asia	**21 069**	**n.a.**	**n.a.**
Fiji	6	47	7
Papua New Guinea	10	47	11
Solomon Islands	0	n.a.	0

Large quantities of mill residues are used as fuelwood for brick making, tobacco curing and domestic cooking in Terengganu, Malaysia. Smaller amounts are used for fencing, resawing for fish boxes and local furniture production. The secondary wood processors in Peninsular Malaysia discovered rubberwood as a valuable raw material during the 1990s and now hardly use hardwood residues. Hence, not all mill waste is considered a useful by-product. In the State of Sarawak, on the other hand, mill residues are used to the extent that shortages of raw materials are locally imminent (Ravn, 1999a). The efforts of the Sarawak Timber Industry Development Corporation (STIDC) to promote the use of wood waste appear to be “too successful”.

There is a serious lack of data indicating the extent to which the potentially available mill residues are already being used. The volume that is not used and may be of interest from a financial point of view probably does not surpass 45 million m^3 per year.

Successful transformation

The situation is quite different in East Malaysia [Sarawak], where a substantial number of secondary processing facilities have been set up during the last 3-4 years [second half of the 1990s]. The raw material is mill residues of *mixed hardwood species*. The chipboard and MDF plants, chipping stations, co-generation and boiler plants and briquetting and carbonizing plants in Sarawak are all modern, large-scale operations.… The total investment in the plants visited amounts to around 600 million RM [at that time about US$ 240 million] invested in 1995, 1996 and 1997. This development can be credited to the efforts of industrial development made by the State of Sarawak through the Sarawak Timber Industry Development Corporation (STIDC).

Source: Ravn, 1999a

Potential utilization of mill residues

Many sawmills in Asia are set up and managed in traditional ways (i.e. they are equipped with bandsaws and set up to cut large-diameter logs). It is difficult to envision significant investments in this sector in the near- to medium-term future as log supplies are uncertain in many areas. However, some retooling should be considered to increase recovery rates by raising the performance and productivity of breakdown saws and resaws. Water storage of logs or sprinkler storage can also minimize waste experienced during dry periods (Havelund, 1999).

Even substantial investments in the sawnwood and plywood sub-sectors would likely reduce mill residues by only 5 to 10 percent. Thus, the question of how best to utilize residues remains.

Wan Tarmeze Wan Ariffin *et al.* (1999, p. 7) disaggregated potential utilization into three broad categories:

1. Energy production, such as:
   - Boiler fuel for kiln-drying, wood conditioning, lacquer-curing, etc.
   - Co-generation plant fuel
   - Industrial fuelwood (e.g. for brick making, noodle production, tobacco curing, and steam generation.
2. Secondary raw materials to be used by the wood-based industries for:
   - MDF
   - Particleboard
   - Block board
   - Laminated board
   - Charcoal briquettes
   - Parquet
   - Pallet manufacturing
   - Small-scale wood products, e.g., in cottage industry
   - Use in paper and pulp industry
3. Secondary raw materials to be used by industries outside the wood industry sector:
   - Fertilizer and mushroom growing
   - Livestock litter/bedding

In addition, sawmill residues are an important raw material for the moulding industries, and in the small-scale artisan sector in the rural areas, wood waste is used in a myriad of ways (see also Appendix 2). Horticultural and agricultural uses are also possible.

Any wood-waste management strategy should follow the “4R” approach (i.e., reduce, reuse, recycle and recover) (Wan Tarmeze Wan Ariffin *et al.*, 1999).

- **Reduce**: minimize waste during primary processing and storage
- **Reuse**: use waste in downstream industries without changing its mechanical structure (e.g. off-cuts to the joinery)
- **Recycle**: use waste for reconstituted panel production such as MDF
- **Recover**: use residues as fuel

The most attractive options for using large volumes are turning waste into charcoal briquettes, using it for co-generation, and using it as secondary raw material within the wood-based panel sub-sector.

Charcoal briquettes[7]

Wood briquetting includes the conversion of loose wood waste into a dense, compact and consolidated unit through the application of high temperature and pressure (Wan Tarmeze Wan

[7] For more information on briquettes visit http://www.frim.gov.my.

Ariffin *et al.*, 1999). Both sawdust and bark are suitable for briquetting, although sawdust is the preferred raw material (Ravn, 1999a). Briquettes can also be carbonized to create charcoal of very high quality. In 1998, there were 11 briquetting factories in Malaysia. Briquettes have to compete with other fuels, such as wood and agricultural residues, kerosene and diesel, which are often cheaper. Hence, most briquettes are exported from Malaysia. Major markets include South Korea and Japan. Due to the economic downturn, the commissioning of new plants has slowed down, although financial analysis conducted by the Forest Research Institute Malaysia (FRIM) indicates that the industry is attractive to new investors (Hoi, 1999, cited by Ravn, 1999a).

Co-generation

Co-generation is the process by which a factory uses its waste energy to produce heat or electricity. The steam produced can provide large amounts of lower-temperature energy for such applications as kiln drying. Considerable overall energy savings can be obtained, and investment in co-generation is thus very attractive with short payback periods.

Investments in co-generation have been supported by the EC-ASEAN COGEN Programme, an economic co-operation program between the European Commission (EC) and the Association of Southeast Asian Nations (ASEAN). It aims to accelerate the implementation of proven co-generation technologies within the industrial sectors of the ASEAN region through partnerships between European and ASEAN companies. COGEN provides information services and maintains databases on European technology suppliers and potential ASEAN customers. It supports the development of full-scale demonstration projects by providing 15 percent seed money for approved projects.[8]

> *The reasons for investing in a new boiler and a complete biomass co-generation plant were the energy potential of wood waste and our growing concern to reduce pollution.*
>
> Leong, C.S., Plant Manager of Sim Hoe Wood Industry Sdn. Bhd.

COGEN has been involved in more than 15 full-scale demonstration projects in Southeast Asia. Investments for individual facilities range from less than US$ 500 000 to above US$ 7 million with typical payback periods of 1 to 3.5 years after commissioning (Table 14).

Table 14. Examples of co-generation plants constructed in Asian countries in the late 1990s

Sim Hoe Wood Industry Sdn. Bhd. Co-generation plant supplying all the electricity needed for a sawmill and moulding factory, as well as 4 tonnes of steam for kiln drying operations **Location**: Bentong, Pahang, Malaysia **Main suppliers**: Belgium and Germany **Cost**: US$ 1.6 million **Payback period**: 3.5 years	**Guthrie MDF Sdn. Bhd.** Efficient combustion for MDF manufacturer using rubberwood and facing a collection and disposal problem **Location**: Kulim, Kedah, Malaysia **Main suppliers**: Sweden **Cost**: US$ 5.5 million **Payback period**: 2.5 years
PT Kurnia Musi Plywood Industries Efficient wood waste-fired boiler for an integrated plywood manufacturer with 850 m^3 of log input per day **Location**: Pulau Borang, Palembang, Indonesia **Main suppliers**: Denmark **Cost**: US$ 1.6 million **Payback period**: 1 year	**Laem Chabang Industry Co. Ltd.** Kiln drying through wood-waste energy for a wooden frame manufacturer that also decided to invest in a dust extraction and storage system **Location**: Laem Chabang, Thailand **Main suppliers**: Singapore **Cost**: US$ 342 000 **Payback period**: 3 years

[8] For more information on COGEN visit http://www.cogen.ait.ac.th.

Co-generation as a solution to greenhouse gas mitigation

A wood waste-fired co-generation plant with a capacity of 1.65 Mwe installed at a wood-working complex in Malaysia would result in a reduction of 4 677 tons CO_2 equivalent compared to the old system where fueloil was used for the boiler while a diesel gen-set provided electric power and the wood waste was burnt in the open.

Source: De Castro et al., 1999

Considerable cost reductions can be achieved and negative environmental impacts can be drastically reduced through co-generation and the installation of new technologies that replace conventional diesel engines. Co-generation is particularly attractive since the costs for wood waste will not fluctuate as extremely as the prices for fossil fuels. In addition, bioenergy offers opportunities to meet Kyoto Protocol commitments. Bioenergy is thus increasingly being incorporated into national energy policies. Co-generation would become even more attractive if the factories could feed their surplus energy to national grids, as is the case in the United States of America.

Wood chips, particleboards and MDF

Sawmill and plywood mill residues of mixed hardwood species can form an important raw material for the chip and board industries. This is particularly attractive for large-scale uses where mills have the opportunity to sell their unwanted waste in a cyclic, well-organized manner based on long-term contracts. In fact, under such conditions, wood residues are no longer viewed as a problem. Rather, they are viewed as valuable by-products that can help increase profit margins (Ravn, 1999a). However, the relative location of residues and markets for final products have to be analyzed carefully.

World production of five major wood-based boards was 106 million m^3 in 1990 and reached a maximum of over 150 million m^3 in 1997 (Table 15). Due to the downturn in many Asian economies, consumption and production fell in 1998. Plywood production was most affected while particleboard and MDF producers registered slight increases. This difference can probably be explained by the very different raw material requirements. Particleboard and MDF manufacturers have a considerable comparative advantage in that they can make use of much cheaper raw material. This price divergence will probably continue, as new technologies make it increasingly possible to use mixed tropical hardwoods. In the future, the role of wood residues as raw material for the expanding particleboard and MDF sub-sectors will increase and, as has already been reported in Sarawak, local raw material shortages and higher prices for mill residues will likely result.

Table 15. Production of major boards during the 1990s (million cum)

Board type	1990	1991	1992	1993	1994	1995	1996	1997	1998
Plywood	48.2	46.5	48.3	49.1	50.5	55.3	52.4	56.0	46.2
Hardboard	-				0	7.0	7.1	7.3	7.4
Insulating board	7.4	7.3	5.7	5.4	5.3	5.5	5.2	4.9	4.7
MDF	-				0	7.8	9.3	12.3	12.7
Particleboard	50.4	48.6	49.3	51.7	59.5	64.6	66.6	70.4	72.8
Total	**106.0**	**102.4**	**103.3**	**106.2**	**115.3**	**140.2**	**140.6**	**150.9**	**143.8**

Vertical and horizontal integration in wood processing favors the use of wood residues, as transport costs are a significant factor in pricing raw material. The price ultimately determines availability as Walsh *et al.* (1999) have shown for the biomass feedstock availability in the United States. The estimated annual cumulative forest residue quantities nearly doubled when prices were increased from US$ 30 to US$ 50/dry ton delivered. However, such price levels are much higher than those reported in Ravn's case studies in Sarawak (1999a), which ranged from RM 12 to RM 40 per MT (RM 3.8 = US$ 1). Hence, non-use of residues in Sarawak is much lower.

A thorough analysis of raw material availability and spatial distribution should indicate strategic locations for additional secondary wood processors as well as chipping plants, to avoid concentration of factories and subsequent shortages of raw material.

Conclusions

What is the real potential of wood residues in the tropical and sub-tropical countries of the Asia-Pacific region? How realistic are our hopes that their more efficient use can contribute to a reduction in annual areas logged and thus to forest conservation? What alternative uses are available for logging and mill residues?

This report has attempted to find answers to these three questions based on country studies for China and Indonesia and a review of available literature. Some of the findings presented in the report are not new, while others should stimulate APFC member countries to examine the issues for their particular situations in more detail.

Available information on the generation of wood residues remains inadequate. In part, this can be explained by the lingering misperception that residues represent a waste problem. This perception is out-dated for two reasons. First, the disposal of wood residues through dumping and burning has become more costly – in financial and economic terms – in recent years. Especially since the catastrophic forest fires of 1997/98, burning wood residues is no longer an acceptable option as many countries have begun enforcing existing laws more strictly. Second, as examples (particularly from Malaysia) indicate, mill residues have already made the transition from waste to valuable by-products and secondary wood processors have even reported supply shortages. In addition, statistics on production are unreliable, with considerable discrepancies among different sources of information. Production of illegally felled and extracted timber remains unreported. Hence, the figures used for calculating the overall availability of wood residues need to be viewed with caution, as they are most likely higher than estimates derived from official production figures.

The rule of thumb that for every cubic meter extracted from the forest another one is left behind is confirmed by this study. The study focused on the major industrial roundwood producers of the Asia-Pacific region and concluded that the 18 selected countries produce approximately 250 million m^3 of logging residues annually, which is slightly above the industrial roundwood production for all of Asia. However, much of the available material has little or no financial value. The economically usable or attractive volume is therefore only about one-tenth of that amount (i.e. about 25 million m^3). This is by no means a negligible amount and ways and means need to be pursued urgently to reduce waste and make better use of the remainder.

A different situation exists with regard to mill residues. The study focused on those two sub-sectors with the lowest recovery rates (i.e. sawnwood and plywood for which recovery rates are on average 50 and 47 percent respectively). The total volume of residues generated through sawmilling is annually about 61 million m^3 in the 18 countries selected for the study. Another 19 million m^3 are generated by the plywood sub-sector. Most mill residues in wood-deficit countries are probably already used. Even in the major producing countries, an increasing amount of mill residues is used for further processing or for producing energy and steam. While no clear picture emerges, it can be assumed that of the 61 million m^3 of residues generated annually, only about 45 million m^3 are currently available for further use.

The total volume of logging and mill residues that is potentially available and of interest to the industries is estimated at about 70 million m^3 each year. Can we expect that using this volume or a percentage of it can reduce pressure on the remaining forests? At least two conditions need to be met for this to happen. First, wood processors need to be operating at close to full capacity. If they operate below capacity, the impact of additional raw material in the form of logging and mill residues would be zero (i.e. logged volumes would not be reduced), as Barr (2000) has argued for Indonesia.[9]

Can increased efficiency translate into forest conservation?

Efficiency becomes associated with conservation because it is assumed that investments in efficiency will produce greater volumes of processed output without generating increased demand for raw materials. Yet, there is little evidence to indicate that either logging companies or processing firms would voluntarily place a cap on their earnings by restricting the volume of timber they harvest or process, if access to this timber were not otherwise constrained. On the contrary, basic economic theory would suggest that firms able to raise profits through increased efficiency would have an incentive to expand their operations, thereby increasing their demand for logs.

Source: Barr, 2000

Second, as also suggested by Barr (2000), access to timber needs to be restricted to literally force wood processors to make more use of residues and to increase recovery rates. While such restrictions are sure to be opposed by a number of stakeholders in the forestry sector, the imposition of harvesting restrictions in various member countries of the APFC during the 1990s indicates that drastic measures have been taken before and can be taken again.

As long as industrial capacities remain high in the major wood-processing countries and access to timber is not slowly reduced, the 70 million m^3 of available residues will not reduce pressure on the remaining natural forests. Under certain conditions, it may even increase pressure (i.e. when wood residues are in short supply and wood processors establish plantations to provide for steady and reliable future raw material supplies). If the past is an indication of the future, some of these plantations will replace natural, albeit degraded, forests.

With respect to logging, the first step is to avoid the generation of residues as far as possible. Applying RIL practices can reduce damage to the residual stand by up to 50 percent, which would have a significant impact on residue volumes while leaving a more productive stand for future wood production. In fact, the increased use of logging residues should only be promoted in combination with improved harvesting techniques.

Conditions vary among countries and blanket recommendations should be avoided. However, the most feasible option for extracting economically usable material would be through additional crews that follow the original harvesting operations and use lighter equipment. In relatively flat terrain and where road conditions are adequate, the use of mobile chippers should also be contemplated. They are appropriate in plantations where recovery rates are currently as low as 30 percent. Any option for using more logging residues requires considerable investments, not only in equipment but also in training. As long as current attitudes and habits regarding logging in the tropical forests of Asia and the Pacific remain, it is unlikely that such investments will be made.

---

[9] Dykstra (2001, p. 4) on the other hand has recently argued that a 1 percent increase in the amount of wood recovered from forest harvesting, “would reduce the total area of tropical forest disturbed over the 50-year

The need for changes in attitudes appears to be less important when it comes to the profitable utilization of mill residues. It is rather difficult to assess how much of the total volume of mill residues is currently being used, hence is no longer available. The informal sector clearly uses a significant share. In addition, industries that rely solely on mill residues for producing chips or reconstituted wood-based boards have expanded in recent years. MDF and particleboard producers are today processing sizeable amounts of mill residues as the examples from Malaysia (particularly Sarawak) indicate. Co-generation has emerged as an alternative to dumping with very attractive payback periods. The recent increase in oil prices and the tremendous fluctuation in the prices of fossil fuels should make co-generation an even more attractive option. Briquetting is an option that can make use of material for which there is otherwise not much demand.

The changes that have been taking place over the last five years indicate that an enabling environment has already been created for utilizing more mill residues. The question that remains is what should be done so that an even larger share of the 70 million m^3 that are available each year will be used.

Recommendations

Frequently, it is only possible to make informed guesses on the volumes of residues that are available. No investor will come forward if a solid basis for decision making cannot be created. The "user-friendliness" of some rather voluminous reports also needs to be questioned. A rare exception is the "Guidelines for Management of Wood Waste from the Wood Processing Industry" published by the Forest Research Institute Malaysia. What is required is the repackaging of existing information in a way that addresses the questions of decision makers in the private and public sectors. The EC-ASEAN COGEN Programme is an excellent example of what could be done to raise awareness within the industry.

Electronic marketing is a tool that needs to be explored further. It should build on thorough analysis of the distribution of existing resources and potential users of logging and mill residues. Spatial analysis should highlight those areas where producers and consumers are located close to each other.

The legal framework for supporting increased utilization of logging and mill residues is in most countries weak. Most laws refer to pollution control but provide little incentives to potentially interested investors. The 1992 National Forestry Policy of Malaysia promotes "efficient harvesting and utilization within the production forest for maximum economic benefits from all forms of forest produce." While such policies provide clarity, they need to be followed by concrete measures to achieve actual efficiency increases and sustainable forest management.

Innovative royalty and fee schemes need to be developed to make the extraction of logging residues more attractive (Klassen, 1994). Closer collaboration between contractors and foresters needs to be encouraged to address potential conflicts on site (i.e. in the forest during harvesting operations). While the provision of incentives can go a long way, a stricter enforcement of existing restrictions is also needed. According to the Indonesian case study, contractors are fined Rp. 50 000 (less than US$ 6) if they generate more than 1 m^3 of waste per hectare. Such very low penalties are not effective deterrents. What is required is the development of criteria and indicators for allowable residue volumes. If acceptable levels of residues are exceeded, severe penalties should be imposed. Ultimately, clear guidance and supervision are necessary to avoid misunderstandings and to stimulate collaboration in searching for solutions.

The implementation of codes of forest harvesting or timber-harvesting guidelines need to be accelerated and incentives need to be created for the adoption of RIL to minimize damage and hence logging residues. Along with a commitment to improving forest-harvesting practices, financial resources need to be made available for necessary training activities (Vergara, 2001).

Finally, industrial operating capacities need to be reduced. This is easier said than done. However, the longer countries procrastinate in taking the necessary steps, the more drastic will be the actions that have to be taken in the future.

, T. 1999b. Timber trade and wood flow-study Myanmar.
www.mekonginfo.org/mrc-en/doclib.nsf/0/6590A35F0AD9B4B5C7256832000A …/FULLTEXT.HTM

De Castro, J., Mathias, A.J. & Kong, H.W. 1999. Modern biomass energy technologies. *Wood Energy News* 14(3): 10-12.

Dykstra, D.P. 2001. The old and new of reduced impact logging. *Tropical Forest Update* 11(2): 3-4.

FAO. 1998. *Asia-Pacific forestry towards 2000*. Report of the Asia-Pacific Forestry Sector Outlook Study. Rome, Food and Agriculture Organization of the United Nations.

FAO. 2000. *FAO yearbook forest products (1994-1998)*. Rome, Food and Agriculture Organization of the United Nations.

FLB. 2000. Forest Liaison Office of the European Union in Jakarta. www.eu.flb.or.id/statistiks/supply-demand.htm

Gerwing, J.J., Johns, J.S. & Vidal, E. 1996. Reducing waste during logging and log processing: forest conservation in eastern Amazonia. *Unasylva* 187 (47): 17-25.

Jaeger, M.R. 1999a. Quantification of forest residues and small dimension logs. *In* K.K. Tai and M.R. Jaeger, eds. *Study on extraction and processing of forest residues and small dimension logs*. Technical Reports Volume 2, pp. 68-148. Kuala Lumpur, Forest Department Peninsular Malaysia.

Jaeger, M.R. 1999b. Guidelines and procedures for extraction of forest residues in permanent forest reserves. *In* K.K Tai and M.R. Jaeger, eds. *Study on extraction and processing of forest residues* *and small dimension logs.* Technical Reports Volume 2, pp. 329-358. Kuala Lumpur, Forest Department Peninsular Malaysia.

Havelund, S. 1999. Financial and economic incentives to increase extraction of forest residues and small dimension logs. *In* K.K Tai and M.R. Jaeger, eds. *Study on extraction and processing of forest residues and small dimension logs.* Technical Reports Volume 1, pp. 297-373. Kuala Lumpur, Forest Department Peninsular Malaysia.

Holmes, T.P., Boltz, F. & Carter, D.R. 2001. Financial indicators of reduced impact logging performance in Brazil: Case study comparisons. Paper presented at the International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities, Kuching, Sarawak, Malaysia, 26 February to 1 March 2001.

Killmann, W., Bull, G.Q., Schwab, O. & Pulkki, R. 2001. Reduced impact logging: does it cost or does pay? Paper presented at the International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities, Kuching, Sarawak, Malaysia, 26 February to 1 March 2001.

Klassen, A.W. 1994. Avoidable logging waste. Report for Office of Agro-Enterprise and Environment. Jakarta, USAID.

McLeish, M. & Susanty, F.H. 2000. Yield regulation options for Labanan. Report by the Yield Regulation Development Group Berau Forest Management Project. Technical Note No. 6. Edinburgh, University of Edinburgh.

Natadiwirya, M. & Matikainen, M. 2001. The financial benefits of reduced impact logging: Save money and the forest – a case from Labanan, East Kalimantan. Paper presented at the International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities, Kuching, Sarawak, Malaysia, 26 February to 1 March 2001.

Noack, D. 1995. Making better use of tropical timber resources. *Tropical Forest Update* 5(2): 12-13.

Pennington, M., Lacrosse, L. & Gonzales, A.D. 2000. Implementing clean and efficient energy projects within the wood sector of ASEAN. *In* FAO. *Options for Dendro Power in Asia: Report on the Expert Consultation*. Field Document No. 57. Regional Wood Energy Development Programme in Asia, pp. 86-92. Bangkok, Food and Agriculture Organization of the United Nations.

Pinard, M.A. & Putz, F.E. 1996. Retaining forest biomass by reducing logging damage. *BIOTROPICA*, 28(3): 278-295.

Pinard, M.A., Putz, F.E. & Tay, J. 2000. Lessons learned from the implementation of reduced-impact logging in hilly terrain in Sabah, Malaysia. *International Forestry Review* 2(1): 33-39.

Poore, D., Burgess, P., Palmer, J., Rietbergen, S & Synnott, T. 1989. *No timber without trees: sustainability in the tropical forest*. International Tropical Timber Organization, London, Earthscan Publications.

Pulkki, R.E. 1997. Literature synthesis on logging impacts in moist tropical forests. Working Paper GFSS/WP/06. Global Fibre Supply Study Working Paper Series. Rome, Food and Agriculture Organization of the United Nations.

Putz, F.E., D. Dykstra and R. Heinrich. 2000a. Why poor logging practices persist in the tropics. *Conservation Biology* 14: 951-956.

Putz, F.E., Redford, K.H., Robinson, J.G., Fimbel, R. & Blate, G.M. 2000b. Biodiversity conservation in the context of tropical forest management. Environment Department Papers No. 75, Biodiversity Series-Impact Studies 1. Washington D.C., The World Bank.

Ravn, B.M. 1999a. Potential use of mill residues. *In* K.K Tai and M.R. Jaeger, eds. *Study on extraction and processing of forest residues and small dimension logs.* Technical Reports Volume 2, pp. 210-261. Kuala Lumpur, Forest Department Peninsular Malaysia.Study on Extraction and Processing of Forest Residues and Small Dimension Logs.

Ravn, B.M. 1999b. Survey of Mills Residues in Terengganu. *In* K.K Tai and M.R. Jaeger, eds.

Study on extraction and processing of forest residues and small dimension logs. Technical Reports Volume 2, pp. 149-209. Kuala Lumpur, Forest Department Peninsular Malaysia.

Ravn, B.M. & Jensen, A. 1999. Processing of forest residues and small dimension logs. *In* K.K Tai and M.R. Jaeger, eds. *Study on extraction and processing of forest residues and small dimension logs.* Technical Reports Volume 1, pp. 94-213. Kuala Lumpur, Forest Department Peninsular Malaysia.

RFD. 2000. *Forestry statistics of Thailand*, 1998. Bangkok, Data Center, Information Office, Royal Forest Department.

Schmincke, K.H. 1995. Forest industries: crucial for overall socio-economic development. *Unasylva* 182, 46: 46-53.

Sist, P., Nolan, T., Bertault, J.G. & Dykstra, D. 1998. Harvesting intensity versus sustainability in Indonesia. *Forest Ecology and Management* 108: 251-260.

Smith, J. & Applegate, G.B. 2001. Trading forest carbon to improve tropical forest management. Paper presented at the International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities, Kuching, Sarawak, Malaysia, 26 February to 1 March 2001.

Tai, K.K. & Jaeger, M.R., eds. 1999. *Study on extraction and processing of forest residues and small dimension logs*. Technical Reports Vols. 1 and 2. Kuala Lumpur, Forestry Department Peninsular Malaysia.

Tay, J., Healey, J & Price, C. 2001. Financial assessment of reduced impact logging (RIL) techniques in Sabah, Malaysia. Paper presented at the International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities, Kuching, Sarawak, Malaysia, 26 February to 1 March 2001.

Thompson, D. 2000. Lumber-ing up. *Bangkok Post.* Outlook Section, 29 October, p. 5.

Thongleua Southavilay & Castrén, T. 1999. Timber trade and wood flow-study Lao PDR. www.mekonginfo.org/mrc-en/doclib.nsf/0/A72AEECB53D0194DC72568310032…/FULLTEXT.HTM

Thurland, M. 1999. Environmental analysis of selective logging and extraction of forest residues. *In* K.K Tai and M.R. Jaeger, eds. *Study on extraction and processing of forest residues and small dimension logs.* Technical Reports Volume 1, pp. 214-296. Kuala Lumpur, Forest Department Peninsular Malaysia.

Vergara, N.T. 2001. Recent advances in training strategy development. Paper presented at the International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities, Kuching, Sarawak, Malaysia, 26 February to 1 March.

Walsh, M.E., Perlack, P.L., Turhollow, A., de la Torre Ugarte, D., Becker, D.A., Graham, R.L., Slinsky, S.E. & Ray, D.E. 1999. Biomass feedstock availability in the United States: 1999 state level analysis. Bioenergy Information Network. Bioenergy Feedstock Development Program. Oak Ridge National Laboratory, Oak Ridge, TN. http://bioenergy.ornl.gov/resourcedata/

Wan Tarmeze Wan Ariffin, Hashim W. Samsi & Pudd Elham. 1999. *Guidelines for management of wood waste from the wood processing industry*. Kuala Lumpur, Forest Research Institute Malaysia.

Wanders, Ir.T.H.V. 1999. Research on the yields of logging operations in Cameroon. Hattem, The Netherlands, FORM Ecology Consultants BV (unpublished report).

Wernick, I.K, Waggoner, P.E. & Ausubel, J.H. 2000. The forester's lever. *Journal of Forestry* 98(10): 8-14.

Zerbe, J.I., Erickson, J.R., Ross, R.J. & Wang, X. 2000. *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. ITTO Pro-Project PPD 24/99(I). Yokohama, International Tropical Timber Organization.

Appendix 1
Assessment of wood residues in China

Chen Xuhe[10]

Introduction

One impediment to the sustainability of forests and forest industries is the low wood utilization efficiency and the amount of residues, which occur both in the forest and during wood processing. Wood residues have emerged as a major potential raw material and, if more efficiently used, could contribute to a reduction in areas logged every year. The extent of logging waste reported in the literature generally range from 30 percent to 50 percent of the extracted volume. Wood volume losses or wastes also occur at roadside landings, mill yards and in manufacturing itself. Mill process yields have been reported to be as low as 33 percent of delivered log volume.

This assessment for China forms part of a regional study commissioned by the Asia-Pacific Forestry Commission. The overall objectives of the study are to:

- present an overview of the availability of wood residues in the processing chain (including harvesting, transport, storage and processing) of major forest product industries, from the standing tree to the final and semi-final product; and
- assess the raw material in terms of its source: natural forests, plantations (including trees outside forests).

Background to the forestry sector

The national forest resource inventory (1989 to 1993) indicates a forest cover of 128.5 million ha (excluding plantations), only 13.92 percent of the total land area of China. The total growing stock is about 11.8 billion m^3. Natural forests (naturally in origin with a tree crown cover of more than 30 percent) cover about 108.6 million ha (84.5 percent), 16.1 million ha (12.5 percent) are classified as economic forests (designated for the production of timber and non-timber forest products) and 3.8 million ha (2.95 percent) are bamboo forests. About 63.0 million ha of wasteland are to be afforested. The total growing stock in China is about 10.7 billion m^3 (excluding the forest resources of Taiwan Province and that beyond Tibet's control line).

The most extensive forest area with the largest industrial wood resources is the natural forests of the northeast provinces. Other important forests are natural forests in the southwest and plantations in the southern provinces (Table 1). Forest ownership is mixed; about 45 percent of the forest is owned by the State and administrated by the State Forestry Administration. The remainder is owned collectively but managed according to forest laws and monitored by the State Forestry Administration.

In recent years, about 5 million ha have been reforested annually. The man-made forests cover 34.25 million ha (26.7 percent of the total forest area) (Tables 2 and 3). About 4.5 million ha are fast-growing and high-yielding timber plantations. They will provide raw material for industries in the future.

Forestry in China has developed into an industrial sector. More than 52 000 organizations are engaged in afforestation, forest management and harvesting, and wood processing. In 1998, the total output of the sector reached 84.87 billion yuan RMB, accounting for 1.07 percent of gross domestic product. The total number of employees in the sector is about 2.36 million. The total staff numbers of the state-owned units are 2.07 million, and have recently decreased.

[10] Chinese Academy of Forestry, Beijing, China

Table 1. Forest cover by region (million ha and million cum)

Region	Standing stock		Forest area		Forest stand growing stock		Timber forest growing stock	
	Volume	%	Area	%	Volume	%	Volume	%
Northeast/Inner Mongolia	3 476.5	32.4	36.6	28.4	3 002.7	33.1	2 683.8	39.8
Sichuan and Yunnan	222.8	26.3	20.9	16.3	2 410.6	26.5	1 398.8	20.7
Collective forests in 10 southern provinces	1 826.6	17.0	46.6	36.3	1 457.7	16.0	1 225.9	18.2
Tibet	1 262.1	11.8	4.0	3.1	1 231.1	13.6	878.3	13.0
Other provinces and municipalities	1 347.7	12.5	20.4	15.9	985.1	10.8	556.6	8.3

Source: Forestry Yearbook of China, 1994.

Table 2. Distribution of plantations by region (million hectare)*

Region	Area	Percentage
Northeast/Inner Mongolia	4.0	11.7
Sichuan and Yunnan	3.7	10.9
Collective forests in 10 southern provinces	18.3	53.4
Other provinces/municipalities	8.2	24.0

* including timber plantations, shelterbelts, economic forests, and planted bamboo forests

Table 3. Distribution of timber plantations by region (in million hectare and cum)*

Region	Area	Percentage	Growing stock	Percentage
Northeast/Inner Mongolia	2.98	17.0	86.59	14.9
Sichuan and Yunnan	2.02	11.5	55.08	9.5
Collective forests in 10 southern provinces	10.06	57.4	357.14	61.7
Other provinces/municipalities	2.46	14.0	80.36	13.9

* man-made forests for supplying wood for pulp and paper, panel products, furniture and other industrial purposes

Table 4. Exports and imports of forest products in 1997 (value in US$ 1,000)

Items	Exports				Imports			
	Volume	Value	1997 as percentage of 1996		Volume	Value	1997 as percentage of 1996	
			Quantity	Value			Quantity	Value
Chips	1.95 mill. tons	154 370	105	95	2 100 tons	1 029	19	75
Logs	63 300 m^3	29 455	99	100	4.47 million m^3	677 788	140	148
Sawn timber	387 200 m^3	193 049	101	100	1.32 million m^3	267 823	142	149
Particleboard	14 700 m^3	9 271	162	197	12 810 m^3	28 484	137	143
Fiberboard	34 500 m^3	9 146	66	83	432 m^3	105 937	136	151
Plywood	437 900 m^3	151 536	248	243	1 488.5 m^3	605 498	84	94
Wood pulp	16 400 tons	8 648	139	108	1 529 ton	741 000	105	97
Paper and paper board	269 100 tons	269 250			5 524 tons	2 827 012		
Waste paper	3 500 tons	311	66	68	1 618 tons	175 750	118	91

Since the 1990s, the Government has taken a series of significant measures to promote sustainable forest management. This includes the formulation and implementation of various key programs and policies, such as the Forestry Action Plan for China's Agenda 21 and the Outline of China's

Ecological Development Program. The 2010 development goal is to raise the level of forestry to that of countries with a medium forestry development level.

Timber harvesting

The results of excessive overcutting and annual consumption levels exceeding annual growth are reduced growing stocks and environmental degradation. Since 1990, China has increased its forest area and stock volume. The Government has adopted a quota system for logging operations and strictly controls resource consumption to ensure that annual removals do not exceed annual growth. The quotas are determined once every five years. The Government appoints forest resource commissioners and organizations that are stationed in key forestry provinces and forest industrial enterprises to control log volumes, amount of timber transported and timber sales. In 1997, the national logging quota was about 226 million m^3, although far less was actually harvested. Approximately 85 percent of the logged volume is sourced from natural forest.

To prevent further degradation of the environment, the Government has decided to phase out logging gradually in key ecological areas and to adopt selection and improvement cutting systems. The national cutting quota for the year 2000 has been reduced by 16 million m^3 compared to the 1997 quota. The goal is that by 2010 about half of the timber will be sourced from plantations and by 2050 timber supply from the plantation is envisioned to increase to 70 percent.

Logging operations vary among different parts of China. In the more mountainous southern provinces, trees are pre-processed and cut into shorter logs to facilitate transport. In the northern forest areas, whole trees are transported. In the State-owned forest areas, the forest bureaus are responsible for logging, wood transportation and storage. In the collective forest areas, the forest departments establish working stations for purchasing logs harvested by collective units and individual forest farmers. The timber is transported to the mills by train, truck, and via water bodies (in the south) (Annex 1).

The average percentage of mechanization in forest harvesting and timber transport is around 87.7 percent; 90 percent in the northeast forest region and 40 to 80 percent in the rest of the country. The degree of mechanized felling (refers mainly to the use of chainsaws) is 91 percent in the northeast and 40 to 60 percent in other parts of the country. The degree of mechanized yarding is 83 percent in the northeast, Inner Mongolia and Jilin and reaches only about 25 percent in the southwest and south. Regeneration and silvicultural treatments are mainly manual.

At present, tree fellers use mainly YJ4 and GJ85 chainsaws that are produced in China. YJ4 chainsaws are mainly used in the southern provinces and the more powerful GJ85 chainsaws with long handles, stable performance and low oil consumption are widely used in the northeast. Cableways and tractors are mainly used in skidding operations. Over 85 percent of the cableways are used in the south and tractors are used in the north. Most yarding equipment is produced in China. According to a national study conducted in 1995, most of the equipment currently in use is out-dated. Only 17 percent can be considered advanced.

The wood-processing sector

The wood-based industry in China plays an important role in social and economic development. The total annual consumption of roundwood (including fuelwood) is about 250 million m^3 and is comparable to the consumption levels of steel and plastic. Due to insufficient forest resources, the use of wood residues and plantation timber as raw materials in the wood-based panel industry is crucial. The production of wood-based panels in 1997 was 16.49 million m^3 (Table 5).

Sawmilling: The annual log production is about 65 million m^3, of which 40 to 50 percent are sawlogs. There are about 2 000 sawmills in China with a total capacity of about 25 million m^3. Most are small or medium size with annual processing capacities below 5 000 to 10 000 m^3. Sixty percent of the milling equipment was installed during the 1950s and productivity is low.

Wood residues are used for the production of parquet, toothpicks, chopsticks, and woodchips mainly for the domestic market. The production of chips and parquet in 1997 was 5.29 million m^3 and 18.94 million m^2, respectively.

Table 5. Production of forest products in China (1,000 cum)

Year	Sawn timber	Wood-based panels					Pulp (1 000 t)	Paper & paper board (1 000 t)
		Grand total	Plywood	Fiberboard		Particleboard		
				Total	MDF			
1981	13 011	996	351.1	568	--	77	4 063	5 402
1985	15 908	1 616	538.7	895	50	182	6 153	9 112
1990	12 849	2 359	758.7	1 172	87	428	8 350	13 719
1995	41 838	16 846	7 592.6	2 164	537	4 351	18 620	24 000
1997	20 120	16 490	7 584.5	2 759	1 059	3 604	17 380	27 436
1998	17 876	10 563	4 465.2	2 195	--	2 663	--	--

Wood-based panels: The wood-based panel industry is quite technology-intensive and has benefitted from the import of foreign equipment since 1980. However, the average capacity of mills is low compared to world standards (Table 6), which limits efficiency to some extent. At present, the number of mills is about 3 000, of which 240 have an annual capacity of over 10 000 m^3. Data for overall capacities in the wood-based panel industry are very limited. Estimates for plywood are 10 million m^3, blockboard 2 million m^3, particleboard 4 million m^3 , medium-density fiberboard (MDF) 3 million m^3 and hardboard 0.7 million m^3.

Table 6. Average capacity of wood-based panels mills (1,000 m^3/year)

Sector	World average	China
Particleboard	50	6.5
Hardboard	50	3.7
MDF	100	30
Plywood	10	3.3

Plywood: In 1997, plywood production reached 7.58 million m^3, accounting for 45 percent of the total panel production. At present, 2 000 plywood mills are operating. More than 100 mills exceed an annual capacity of 10 000 m^3 and 7 mills exceed 100 000 m^3 capacity each. Most mills are located in the more developed eastern coastal region. Both local and imported equipment is used. Some smaller mills still rely on out-dated equipment.

Particleboard: There are about 550 particleboard mills in China. Only one mill exceeds a capacity of 100 000 m^3, 17 mills manage about 50 000 m^3 each. There are 120 smaller mills, with an average annual capacity of 10 000 m^3 each. The small units account for approximately 62 percent of total production. Some new mills are equipped with advanced technologies. Particleboard uses low-grade raw materials and has various applications with promising prospects.

Fiberboard (including hardboard): There were 400 mills with a capacity of 2 000 to 15 000 t/year in operation. At present, only 70 mills operate because of water pollution concerns.

Medium-density fiberboard (MDF): MDF production started in the early 1980s and the sector has developed rapidly. Forty sets of foreign machinery with annual capacities of 30 000 to 50 000 m^3 each were imported (total capacity of 1.5 million m^3). Seventy sets of locally made equipment with an annual capacity of 15 000 to 30 000 m^3 each are also operating. By the end of 1996, 108 plants were producing MDF with total annual capacity of 2.77 million m^3. This makes China the second largest MDF-producing country in the world. It was estimated that MDF capacity in the country would reach 4 million m^3 by the end of 2000.

Surface finishing and other panel products: Production of surface finishing products started in the 1960s. At present, the production reaches 150 million m^2. In 1997, production of other panels, including blockboard, wood cement particleboard and wood gypsum particleboard, reached 2.8 million m^3.

Further efforts need to be made to improve the quality and variety of products. A 1994 study indicated that only 8 out of 10 plywood mills complied with national quality standards. Tests conducted between 1995 and 1997 showed that only 36.6 percent of particleboard and 62.5 percent of MDF were of high quality. Major defects include problems with dimension, density, swelling and formaldehyde emission.

Pulp and paper: Since 1980, paper and paperboard production has increased by 10.1 percent annually. In 1997, production reached 27.4 million tons of 600 paper products. Import figures are as follows: 1.54 million tons of wood pulp, 5.52 million tons of paper and paperboard and 168 000 tons of waste paper. Total consumption reached 27.33 million tons, which makes China the second highest paper and paperboard consumer in the world.

Policy environment

Forest harvesting

Forest harvesting and regeneration were covered by the legal system when the "Forest Law" was enacted in 1984 and the "Provisions of Rules and Regulations of the Forest Law" were published in 1996. In 1987, the "Regulation for forest cutting and regeneration" was formulated. This regulation prescribed harvesting operations and silvicultural treatments in various ways. In the revised "Forest Law," promulgated in July 1998, the Government stipulated that the following measures were to be encouraged and adopted:

- Quotas for forest harvesting; tree planting and afforestation of hillsides and expansion of forest cover
- Provision of funds or long-term loans for collective and individual plantings and silviculture
- Comprehensive and efficient use of wood and development and use of wood substitutes
- Strict controls of harvested volumes
- Harmonized annual timber production plans
- Control of various forms of selective, clear and shelterwood cutting for mature stands
- Issuance of cutting licenses

Wood processing

China advocates efficient wood use and encourages the development and utilization of wood substitutes. Since 1980, the Government has financially supported the modernization of wood-based panel enterprises. In 1990, the forestry department issued a notice to encourage forest enterprises to reduce and use wood wastes. Since 1991, the State Tax Office provides 3-year tax breaks for State-owned forest enterprises of the northeast and Inner Mongolia forest regions, which use wood wastes as raw materials in the production process. These policies have encouraged the wider use of logging and mill residues.

The availability of large dimension timber from the natural forest is declining and the total amount of timber, in general, is also insufficient. This has triggered a shift from sawntimber and plywood to non-veneer wood-based panels and paper products. Also, production will shift gradually from cities to the timber producing areas to increasingly add value locally.

Sawmilling industry: Sawmilling in the timber-producing regions will be promoted. This will include drying and preservation. Value-added processing, including finger jointing and laminating, will be developed. The percentage of artificial timber drying will be increased from the current 20 percent to 50 percent.

Wood-based panel industry: MDF, structural particleboard, bamboo plywood and other new products will be developed. It is expected that capacity will be increased by 520 000 m^3. The particleboard and hardboard industry will benefit from the expansion of raw material resources, modernized technologies, improved pollution control, and better product qualities. The raw material base for plywood production will be broadened and attention given to the development of sliced thin veneer, if raw materials are available.

Pulp and paper industry: China aims to produce 30 million tons of paper and paperboard by 2000. Pulp production will reach 25 million tons (3.32 million tons derived from wood as a raw material). Consumption of pulp per capita is expected to increase from 23.4 to 26 kg. Every effort will be made to increase the raw material base for paper production, including the use of logging and mill residues. In 2010, the production of paper and paperboard is expected to reach 40 million tons and production of wood pulp 14 million tons.

To increase efficiencies in the logging and wood-processing sectors, the former Ministry of Forestry formulated the "Policy Outlines on Forestry Equipment" in 1996. Its objective is to foster a modernization process for forestry equipment by the year 2010. In particular, more attention will be directed at:

- Development of appropriate logging equipment to improve efficiency and reduce logging residues.
- Quality of forestry operations to improve logging and increase recovery rates.
- Development of energy-efficient technologies.
- Development of effective processing technologies based on wood waste.
- Formulation of favorable policies to encourage research and development by forestry enterprises to improve their technical skills.
- Training of forest workers to raise technical level in the forestry sector.

Recovery rates

Information on recovery rates by forest type does not exist. Table 7 provides average figures for State-owned wood harvesting and processing enterprises. Estimates for the private sector are not available.

Table 7. Recovery rates of State-owned forestry enterprises (percent)

Item	Recovery rate of sawntimber*			Utilization rate of harvested forest resources **		
Region	**1995**	**1996**	**1997**	**1995**	**1996**	**1997**
National	54.85	51.6	56.0	63.01	64.0	63.0
Inner Mongolia	63.13	60.5	52.0	60.27	66.8	65.2
Jilin	56.66	53.6	53.3	69.68	70.8	71.4
Helongjiang	49.11	49.0	51.2	62.73	63.1	59.5
Daxinganling	54.74	-	67.6	66.33	62.5	63.6
Sichuan	43.57	35.0	51.2	54.32	53.8	54.9
Yunnan	45.64	63.5	61.3	65.00	53.7	68.3

* Production of sawn timber/consumption of logs
**Production of logs/stocking volume of harvested forests

Logging residues

Although the forestry sector suffers from a shortage of raw materials, large quantities of logging residues are potentially available for use. The industrial utilization rate of wood residues may be as low as 17.4 percent. The main uses of logging residues include:

- Production of wood chips, particularly because smaller dimensions from thinnings become increasingly available. Wood chips are an important raw material for the panel and paper industries. Exports of wood chips from Heilongjiang Forest region total about 3 000 tons (oven dry) annually.
- Use of small-dimension wood and production of small wooden products such as carvings, tool handles, wooden boxes, toys, parquet, furniture, balls, etc.
- Production of charcoal.
  - Chemical processing of wood to produce feed, feed additives, protein, vitamin, resin, turpentine, tannin extract, yeast, alcohol, etc.

The following problems hinder the increased use of logging residues:

- Logging residues are quite scattered, harvesting operations are seasonal and working conditions are poor. Felling, skidding, transport and storage pose additional difficulties. The transport cost per cubic meter of logging residues to the mill is 50 to 60 yuan (RMB) excluding management costs. Therefore, the use of logging residues is financially unattractive.
- Logging residues are often available in hilly areas and alternative uses have to compete with firewood.
- Product diversity and low quality.
- Lack of supportive policies. Wood processors criticize the high costs of wood chips, which are probably due to high taxes for logs (30 percent of the purchasing price) and the high transport and chipping costs (about 30 percent of the purchasing price) since most forest farms are located in the hills. As a result, large quantities of logging residues remain underutilized. The Government should formulate favorable tax policies to make logging residues more attractive.

According to a 1995 study in Daxinganling Forest region, logging residues include brushwood, tree tops, withered and damaged wood, and low-quality wood. The volume of logging residues (over 5 cm in diameter and over 1 m in length) is 8.44 m^3/ha. Losses also occur during collection, loading and transport. The loss rate is about 7 percent, i.e. 0.59 m^3/ha. Therefore, the usable volume of residues is reduced to 7.85 m^3/ha. In Daxinganling Forest region, the timber production is about 70 m^3/ha, which means that usable residues make up only about 11 percent of the harvested volume. Accordingly, a forest bureau with annual production of 350 000 m^3 of timber can obtain 39 250 m^3 of logging residues.

The same study also indicated that workers of the forest farm use 6 to 8 m^3 of wood as firewood annually per household. About one-third of the firewood could be used as sawntimber and the other two-thirds could be chipped, which would result in greater economic benefits. However, that would deprive people who do not have any alternatives of an important energy source.

Lack of skills also lead to an increase in logging residues. A common problem is high stumps. In some areas stump height can reach 90 cm. Smaller logs are at times left behind or good quality logs mixed with firewood resulting in avoidable wastes.

According to a study by the Lushuihe Forest Bureau (Jilin Province), 792 m^3 of wood is wasted every year. This includes small logs and short pieces (less than 2 m in length and less than 8 cm in diameter). Also, over-mature and partially rotten trees are left uncut. The total additional volume potentially available amounts to 10 459 m^3.

Another study showed that logging residues in Jilin were about 15 percent of total log production. Sixty percent of the residues could have been used. Improvements in bucking could also make a considerable difference. Off-cuts often amount to 30 percent of the total log production and 90 percent of the wastes could be avoided. Another study in Fujian highlighted that logging wastes can account for 40 percent of the harvested volume, although not all of the material can be used. Branches account for 14, bark for 20, butts for 4 and off-cuts for 2 percent, respectively.

The usable logging residues, including branches over 3 cm, and off-cuts account for 10 percent of log production (Table 8). However, economically usable wastes are only about 7 percent.

Table 8. Usable rate of logging residue in Fujian (percent)

	Percentage of log production			
	Small-size poles	Small-size logs	Pulpwood	Total
Over 3cm branches	1.4	-	4.6	6
Tops	0.8	1.2	-	2
Off-cuts	-	2	-	2
Total	2.2	3.2	4.6	10

Mill residues

Wood waste from processing includes mainly strips, sawdust and other wastes. In the forest areas, some strips are used for cooking and heating. The amount of strips is about 15 percent of the volume of sawntimber produced. Eighty percent of this amount can be utilized. Sawdust is difficult to collect and the useable amount is about 6 percent of sawntimber produced. Fifty percent of it can be economically used for energy production and other purposes.

The amount of wastes generated during wood processing is determined by the quantity of wood processed and the processing itself, i.e. the equipment used. Recovery rates in the different wood-processing sub-sectors range from 50 to 93 percent (Table 9). The average recovery rate is about 65.5 percent. Assuming a log production of about 60 million m^3 and a weighted recovery rate of 60 percent, 12.38 million m^3 of waste is generated every year during wood processing.

Table 9. Average recovery rates (percent)

Utilization rate of harvested forest resources	Logging	Wood processing (average)	Sawmilling	Plywood	Particleboard	MDF	Blackboard	Finger jointed wood
63.3	56	65.5	60	50	70	93	75	90

The highest wood utilization rates are obtained by the MDF, particleboard and parquet sub-sectors. The role of technology and equipment used in the production process is very important (Annex 1). It determines not only the quality of the final products but has also a considerable influence on the generation of wastes. For example, the Fuzhou MDF plant with an annual production of 120 000 m^3 has received numerous First Class, Second Class and Special Class awards for producing high standard boards. It relies on raw materials composed of wood chips and logging and mill residues (sawdust, waste fiber, wood powder, slabs, off-cuts). In 1995, the mill imported a continuous flat-pressing process MDF production line from Germany. Wastes generated during the production process are used for energy production. The wood chip consumption per cubic meter of board has gradually decreased (Table 10).

Table 10. Consumption of wood chips in MDF production at the Fuzhou mill

Item/Year	1997	1998	1999*
Consumption of wood chips (m^3)	70 955	83 950	82 494
MDF production (m^3)	41 754	53 335	53 261
Unit consumption of chips per cum panel (m^3/m^3)	1.70	1.57	1.55

* includes only January to October

Usable volume of logging and mill residues

Logging residues

There are considerable differences in logging residue generation depending, among others, on stocking density, volume of branches and trees species. For example, the tree branches in Wanqing Forest Bureau (Jilin Province) make up 10.43 percent of the total stock volume. In Tieling Forest Bureau (Heilongjiang Province), this ratio reaches 20.68 percent. Huge differences exist even for the same tree species. Branches of larch make up 5.96 percent of the total stock volume in Huzhong Forest Bureau (Daxinanling), 24.09 percent in Dashiton Forest Bureau (Jilin Province) and 23 percent in Shangganling Forest Bureau (Heilongjiang Province).

National log production is estimated to decrease from 63 948 000 m^3 in 1997 to 47 950 000 m^3 in 2000, i.e. a decrease of about 16 million m^3. In forest cutting areas in the northeast, Inner Mongolia and the southwest, the potentially usable logging residues (L_n) and economically usable logging residues (L_{ne}) are 15 percent and 9 percent of the total log production, respectively. Log production of these forest regions is 48 percent of the total national production. Therefore, the L_n and L_{ne} can be calculated as follows:

L_n = 47 950 000 x 48% x 15% =3 452 400 m^3

L_{ne} = 47 950 000 x 48% x 9% = 2 071 400 m^3

On the basis of figures from Fujian Province, L_s and L_{se} of logging residues of the remaining forest regions are set at 8 and 5.6 percent, respectively. Total log production is 52 percent of total national log production. Accordingly, L_s and L_{se} can be calculated as follows:

L_s = 47 950 000 x 52% x 8% = 1 994 700 m^3

L_{se} = 47 950 000 x 52% x 5.6% = 1 396 300 m^3

Therefore, the total volume of potentially usable L_f and economically usable L_{fe} (excluding tree tops) for all of China in 2000 can be calculated as follows:

L_f = 3 452 400 m^3 + 1 994 700 m^3 = 5 447 100 m^3

$L_{fe=}$ = 2 071 400 m^3 + 1 396 300 m^3 = 3 467 700 m^3

According to a study conducted in Jilin Province, L_b and L_{be} of cutoff tree tops is about 3 and 2.7 percent of the log production, respectively. Thus, L_b and L_{be} can be calculated as follows:

L_b = 47 950 000 m^3 x 3% = 1 438 500 m^3

L_{be} = 47 950 000 m^3 x 2.7% = 1 294 700 m^3

The total potentially usable and economically usable logging residues are therefore 6 885 600 m^3 and 4 762 400 m^3, respectively. In other words, nearly 10 percent of the residues generated during timber harvesting are real wastes in the sense that the materials have a direct economic value.

Mill residues

The volume of mill residues is determined by log consumption and the recovery rates in the different processing sub-sectors. According to various studies, average recovery rates are 34.4 percent of the log production for processing (Table 11), i.e., every 10 000 m^3 of logs processed will generate 3 440 m^3 of wastes. Strips, wood shavings, waste veneers and cutoff tops make up about 71 percent or 2 442 m^3. Sawdust accounts for the remaining 29 percent or 998 m^3. The sawmilling sub-sector accounts for about 60 percent of log production. Hence the volume of sawmilling residues can be calculated as follows:

47 950 000 x 60% = 28 770 000 m^3

Taking account of log imports (about 4 million m^3), the total production of wastes from processing in the whole country in 2000 is estimated to be:

(28 770 000 m^3 + 4 000 000 m^3) x 34.4% = 11 272 880 m^3

Under the present conditions, 80 percent of this amount, i.e. 9 018 304 m^3, can be economically used. This means that while logging and wood processing generate about 18 158 480 m^3 of residues, only about 13 780 704 m^3 can be used economically. This is about 27.7 percent of the log production in 2000.

Table 11. Ratio of residues in different operations (percent)

Operation	Location	Amount of residues /log production	Ratio of usable residues	Usable residues /processed logs
Logging	Northeast, Inner Mongolia and southwest forest regions	15	60	
Bucking		3	90	
Logging +Bucking	All the other regions	10	70	
Processing	National			34.4

Necessary conditions for reducing residues

The following aspects need to be considered to effectively reduce logging and mill residues:

- Development of appropriate logging equipment to improve efficiency of harvesting operations.
- Upgrading of timber harvesting management aimed at reducing butt heights and collecting usable wood raw materials.
- Reduction in firewood use.
- Development of processing technologies, especially for utilizing sawdust.
- Training for all forestry operations, especially for tree fellers.

Conclusions

Due to a lack in nation-wide data, the diversity of forest harvesting operations and equipment employed in the forest and wood processing sub-sectors, the estimates presented in this report have to be treated with care. However, based on numerous case studies and a careful consideration of the observed differences, it can be concluded that the amount of wastes generated by the forest sector is substantial. Logging and wood processing generate about 18 158 480 m^3 of usable residues, although only about 13 780 704 m^3 can be used economically (Table 12). This is still about 27.7 percent of the log production in 2000. The potential to make use of this amount as raw materials in the pulp and paper and wood-based panel sub-sectors is considerable.

Table 12. Estimates of useable wood residues (million cum)

Usable residues				Economically usable residues			
Logging	Bucking	Processing	Total	Logging	Bucking	Processing	Total
5.45	1.44	11.27	18.16	3.47	1.3	9.02	13.79

Management must be strengthened to improve efficiencies in most sub-sectors and recovery rates in logging operations need to be increased through better collection and transport. Further impetus for reducing wood residues can be provided through appropriate training and the modernization of ailing enterprises. Some of China's wood-based panel enterprises have integrated the use of wood wastes in their production processes. However, there are still quite a number of old and inefficient wood-processing mills. Many small-scale enterprises contribute substantially to the generation of wastes and need to be either upgraded or closed down.

Policy options

To increase efficiencies in the logging industry and the wood-processing sector, the following activities are recommended:

- Develop appropriate logging equipment to improve efficiency of harvesting operations;
- Improve management aimed at increasing recovery rates in forest harvesting;
- Reduce the reliance on firewood as an energy source;
- Develop processing technologies that can profitably make use of wood wastes, including sawdust and bark;
- Provide training for forestry workers in forest management, particularly in harvesting;
- Formulate favorable tax policies to support the use of logging residues; and
- Design policies to support the large- and medium-scale wood-processing enterprises in establishing high-quality timber plantations, especially in the south and coastal areas.

Annex 1
Utilization of wood residues at typical mills

Sichuan Leshan Jixiang Artificial Forest Products Co. Ltd. (1 000 m^3)

Item	1998	Remarks
Unprocessed logs	185	100% from plantations
Amount of other raw materials	0	
Recovery rate of wood (percent)	100	
MDF Technology & equipment Annual capacity Product standard Total wood raw materials used Ratio of logs used (percent) Recovery rate of wood (percent)	 Schenck, Germany 115.8 Enterprise standard 178 100 100	
Parquet Technology & equipment Annual capacity Product standard Total wood raw materials used Ratio of logs used (percent) Recovery rate of wood (percent)	 Imported from Germany 1,800 Enterprise standard 36 99.7 99.69	(10 000 m^3)

Hunan Wood-based Panels Company, Changsha, Hunan (1 000 m^3)

Item	1990	1998	Remarks
Unprocessed logs reached transported by trains	12.4	Shut down	100% from natural forests
Amount of other raw materials: branches	 25 330	 86 928 t	
Recovery rate of wood (percent)	70.6	90	
Plywood Technology & equipment Capacity/production Product standard Total wood raw materials used in which ratio of logs (percent) Recovery rate of wood (percent)	 Imported 50/3.8 National 12.4 100 30.7	 Shut down	
Particleboard Technology & equipment Capacity/production Product standard Total wood raw materials used Recovery rate of wood (percent)	 Imported 50/15.5 National 25.3 90	 50/36.3 National 47.5 90	
MDF Technology & equipment Annual capacity/production Product standard Total wood raw materials used Recovery rate of wood (percent)		 Bison 30/ 22.5 Enterprise 39.4 90	

Songjiang Plywood Company Ltd. Harbin, Helongjiang (1 000 m^3)

Item	1980	1990	Remarks
Unprocessed logs arrived transported by trains	4.86	4.85	All from natural forests
Recovery rate of wood (percent)	52.9	43.2	
Sawntimber			
Technology & equipment	Locally made	Locally made	Shut down
Production	5/4.8	5/3.8	
Product standard	National	National	
Total logs used	2.58	1.8	
Recovery rate (percent)	66.2	65.2	
Plywood			
Technology & equipment	Some imported	Some imported	Shut down in 1998
Production	2/1.55	2/1.3	
Product standard	National	National	
Total logs used	37.6	38.3	
Recovery rate (percent)	41.8	34	
Particleboard			
Technology & equipment	Some imported	Some imported	Equipment rejected in 1991
Capacity/production/year	2.3/1.77	2.3/0.4	
Product standard	Enterprise	Enterprise	Only use waste veneer of the mill
Recovery rate of wood (percent)	70	70	

Ningxia Yimu Group Wuzhong, Ningxia (1 000 m^3)

Item	1990	1998	Remarks
Wood used, in which	5.4	7.9	
Thinnings (percent)	100	63	
Chips (percent)		35	All from plantations
Sawmilling waste (percent) transported by trucks		2	
Recovery rate of wood (percent)	83	98	
Major products:			
Particleboard			
Technology & equipment	Local	Imported	
Capacity/production/yr	7/4.5	16.8/7.8	
Product standard	National	National	
Recovery rate of wood (percent)	83	98	

Beijing Wood Working Company (Beijing) (1 000 m^3)

Item	1980	1990	1998	Remarks
Unprocessed logs reached transported by trains	110	760		100% from natural forests
Amount of other raw materials: Branches Chips			 15% 85%	 from plantations & single trees
Recovery rate of wood (percent)	94	95	96	
Sawn timber Technology & equipment Annual production Product standard Total logs used Recovery rate of wood (percent)	 Local 60 National 80 75	 Local 30 National 40 75	 Local 6 National 8.5 71	
Plywood Technology & equipment Annual production Product standard Total logs used Recovery rate of wood (percent)	 Local 12 National 30 41	 Local 10 National 34 34 	 Local 3 National 3.06* 98	
Particleboard Technology & equipment Annual production Product standard Total wood used, in which Branches (percent) Chips (percent) Shavings(percent) Recovery rate of wood (percent)	 Local 10 Enterprise 14 30 71	 Bison 17 National 23.8 16 54 30 71	 Bison 15 National 21.1 15 80 5 71	
MDF Technology & equipment Annual capacity Product standard Total wood used, in which Branches (percent) Chips (percent) Recovery rate of wood (percent)			 Siempelkamp 100 National 216 3 97 95	From plantations
Blockboard Technology & equipment Annual capacity Product standard Total wood raw materials used, in which ratio of logs (percent) Recovery rate of wood (percent)	 Local 5 Enterprise 5.3 78	Closed	Closed	
Finger jointed wood Technology & equipment Annual production Product standard Total wood raw materials used Recovery rate of wood (percent)	 Local 1 Enterprise 1.052 95	 Local 2.028 Enterprise 2.134 95	 Local 1 Enterprise 1.052 95	

References

Chen Xuhe. 1999. Wood industry and sustainable development. *China Forest Products Industry*, No. 1: 6-8,13; No. 2: 3-5, 9.

Du Jun *et al*. 1996. Investigation and utilization of logging residues, *Forestry Monthly Report*, No. 1: 15.

Forest Law of the Prople's Republic of China. 1998. Beijing, China Forestry Publishing House.

He Zhizheng *et al.* 1990. *Supply and demand of timber in China*. Beijing, China Science and Technology Publishing House.

Li Weiming. 1991. Recommendations on comprehensive use of wood residues. *Forestry Reconnaissance Design*, No. 1: 4-8.

Li Yuannin. 1998. Prospects on plywood production in China. In *Proceedings of development of wood industry in China in the 21st century*, Beijing, China Wood Industry Association, pp. 101-106.

Liu Jingyi *et al*. 1996. Rational use of forest resources. *Forestry Reconnaissance Design*, No. 2: 26-27.

Liu Junyi. 1995. A study on available logging residues. *Forestry Engineering*, 111: 1-3.

Ministry of Forestry. 1995-1997. *China Forestry Statistic Data*. Beijing, China Forestry Publishing House.

Ministry of Forestry. 1997-1998. *China Forestry Year Book*. Beijing, China Forestry Publishing House.

Shi Kunshan *et al*. 1998. *The development of China's forestry: review and prospects*. Beijing, China Environment Science Publishing House.

State Forestry Bureau. 1999. *Forestry development in China 1949-1999*. Beijing, State Forestry Bureau.

Wang Kai *et al.* 1995. *Proceedings of development of wood industry in the 21st century.* Beijing, China Wood Industry Association.

Wang Kai *et al.* 1997. *Proceedings on supply and demand of timber*. Beijing, China Wood Industry Association.

Yin Yuancheng *et al.* 1997. Rational use of logging residues. *Forestry Science and Technology*, No. 2: 52-53.

Zhang Shougong & Chen Xuhe. 1999. *Outlook of plantations in China*. Beijing, Chinese Academy of Forestry.

Zhou Xinnian. 1993. Forest logging and regeneration in China. *Forestry Reconnaissance Design*, No. 2: 2-10.

Zhu Yuanding. 1998. Prospects on wood based panels production in China. In *Proceedings of development of wood industry in China in the 21st century*, Beijing, China Wood Industry Association, pp. 22-25.

Appendix 2
Assessment of wood residues in Indonesia

A. Ng. Gintings[11] and Han Roliadi[12]

Introduction

In Indonesia, biomass residues include the materials left in the forest after logging; over-aged and unproductive plantation species that need to be replaced by young seedlings; and mill wastes (residues) generated during wood processing. Disposal of these residues by burning has encountered objections mainly because of environmental concerns. Residues may also have a considerable economic value. If they are used more efficiently, dependency on conventional and regular wood materials could be reduced, and timber extraction might be scaled down.

For these reasons, wood residues should be managed properly. The purpose of this study is to assess the potential of wood residues in Indonesia, and to propose efforts to deal with them. The Indonesian case study forms part of a regional study commissioned by the Asia-Pacific Forestry Commission. The overall objectives of the study are to assess the availability of wood residues availability in the processing chain (including harvesting, transport, storage and processing) of major forest products industries; and to evaluate the raw materials in terms of its source (e.g. natural forests, estate sector, and wood processing industries).

The Indonesian forestry and estate crops sectors

Indonesia has 144 million ha of forestland, classified as 18.8 million ha conservation forest, 30.3 million ha protection forest, 30.5 million ha conversion forest, and 64.4 million ha production forest (Anon, 1998a). The production forests are allocated for the extraction of timber or non-wood products (e.g. rattan, cayeput oil, dammar, resin/turpentine, gutta percha).

Forestry in Indonesia is an important social and economic sector (Anon, 1999a). Forest products not only help to develop the nation's economy but also provide income to people living in and around the forests. The contribution of the forestry sector to the Indonesian gross domestic product (GDP) increased from Rp. 14.43 trillion in 1993 to Rp. 16.69 trillion in 1997, although in relative terms the contribution of the forestry sector to the GDP has decreased from approximately 4.29 percent (1993) to 3.82 percent (1997). In addition, Indonesia's forests provide valuable local and global environmental services (Schweithelm, 1998).

Rubber plantations, oil-palm estates, and plantations of other estate crops (e.g. clove, tungseed, nutmeg, and cashew nut) cover 3.5 million ha, 2.2 million ha and 1.2 million ha, respectively (Statistical Estate Crops, 1997). The Indonesian production of rubber increased from about 1.4 million tons in 1993 to 1.6 million tons in 1997. The role of rubber in the nation's economy is regarded as important. This is reflected by the increase in exports from 1.2 million tons (valued at US$ 977 million in 1993), to 1.3 million tons (valued at US$ 1.9 billion in 1996). Palm oil is also an important commodity in social and economic terms (Anon, 1998b). In 1997, Indonesia produced 5.4 million tons of crude palm oil (CPO). CPO exports totaled 3.3 million tons, valued at US$ 1.5 billion. The oil-palm sector employs some 3.4 million families. By the end of 1998, the oil-palm estate sector had increased from 2.2 million ha to about 2.6 million ha, capable of producing 5.9 million tons of CPO.

Other estate crops cover approximately 1.2 million ha. In 1995-1996, annual exports totaled about 690 tons of cloves, 9 536 tons of nutmeg, 27 886 tons of cashew nuts, and

[11] Director of Forest Product and Socio-economic Research and Development Centre (FPRC) and Coordinator for this paper
[12] Senior Research Staff of FPRC and Secretary/Draft formulator of this paper

137.9 tons of tungseed, which were valued at US$ 1.7 million, US$ 19 million, US$ 23.8 million, and US$ 787 000, respectively (Statistical Estate Crops, 1997).

Forest harvesting and wood processing

The 64.4 million ha production forests consist of mangrove forests, swamps, lowland and mountain forests. Lowland tropical forests make up about 26 percent of the total area (Dennis, 1998). As lowland forests are the most accessible, they are more affected by logging (timber harvesting) than other types of production forest.

Timber extracted from the production forests is partially exported, with the remainder supplying domestic wood-processing industries. Log production between 1992/1993 and 1996/1997 averaged 27 739 400 m^3 per year (Forestry Statistics of Indonesia, 1997/1998).

Indonesia's wood-processing industries can be categorized into two types, i.e. the primary industries (e.g. sawmills, veneer/plywood, particleboard/flakeboard, fiberboard/medium-density fiberboard (MDF), and pulp/paper), and secondary industries (e.g. furniture, handicrafts and toys, crates and containers, household articles and kitchen utensils, housing components, and other solid wood products). The wood-processing industries that are officially listed and significantly consume wood raw material include sawmills, veneer/plywood, and pulp/paper manufacturers. Their products are in demand domestically and some are exported. Indonesia is also a major producer and exporter of secondary processed wood products (Johnson, 1997).

Indonesian policies on sustainability and environment

The Indonesian Government has classified natural forest according to conservation, protection, production, and conversion objectives. Due to overcutting, illegal logging and forest fires, the forest sector has experienced numerous difficulties in recent years. In response, conversion forests have been allocated for industrial forest plantations (timber estates) to raise raw material supplies for some affected sub-sectors.

To reduce air pollution and the risk of widespread fires, the burning of old and unproductive rubber trees and oil palms is discouraged by the Government and alternatives are currently sought. The dumping of wood wastes into water bodies is also discouraged to reduce water pollution. Primary and secondary wood-processing industries are encouraged to treat wastes and residues by means other than burning to reduce air pollution.

In general, environmental policies take the form of suggestions or encouragement, and unfortunately still remain weak. However, the recently disastrous Indonesian forest fires have raised the awareness of the Government and the Indonesian people (Anon, 1998a). Hence, wood waste generation and disposal are now receiving more attention by Indonesian authorities.

Recovery rates

Logging residues

According to information on logging operations predominantly in the lowland forests of Sumatra, Kalimantan, Sulawesi, and Maluku (Idris, 1995; Martawijaya and Sutigno, 1990; Kliwon *et al.*, 1995), average log production is 65.6 m^3 per ha. This includes trees with diameters of 50-160 cm. Logging residues average about 82.2 m^3 per ha and are composed of various products (Table 1). Wood residues thus constitute 125 percent of the timber removed during harvesting. Assuming a logging rate of 363 415 ha per year in lowland production forests (Idris, 1995), about 23.84 million m^3 of logs are produced and logging residues constitute approximately 29.8 million m^3 annually from this forest type. Detailed studies on logging rates and waste generation have not yet been conducted for other forest production types (e.g. mangrove forests, swamps, and mountain forests). The lack of data from other forest types makes it difficult to calculate the total amount of logging wastes. Hence the figures in Table 1 should be viewed cautiously.

Table 1. Composition of logging residues*

Component	Amount (m^3 per ha)	Amount (percent)
Upper portion of the tree trunk including branches, smaller branches and twigs	37.29	45.35
Stump	23.95	29.14
Damaged standing trees, due to felling and skidding	3.96	4.82
Commercial wood logs of unacceptable qualities, due to knots, crooks, reaction woods and other defects	15.66	19.05
Unknown or non-commercial tree species	1.33	1.62
Total	**82.19**	**100.00**

* Based on observations and assessments in lowland production forest (Idris, 1995)

Estate crops

The crops described here are those dominating in terms of area and production, i.e. rubber and oil palm. Rubber plantations and production increased slightly between 1993 and 1997 (Table 2).

Table 2. Indonesian rubber production between 1993 and 1997

Year	Area (ha)	Rubber production (tons)	Rubber productivity (tons/ha)
1993	3 405 023	1 475 438	0.433
1994	3 472 379	1 499 424	0.432
1995	3 495 901	1 573 303	0.450
1996	3 518 441	1 574 026	0.447
1997	3 516 571	1 548 609	0.441

Source: Statistical Estate Crops of Indonesia, 1997

The replanting rate of old and unproductive rubber plantations is about 3.33 percent per year (117 500 ha) of the total rubber plantation area. Felled rubber trees can potentially produce some 35 m^3 of wood material per hectare (Albaladejo, 1997; Anon, 1978; Susila *et al.*, 1988). Hence, 4.11 million m^3 of wood, currently regarded as wastes, could be produced per year.

The Indonesian oil-palm estate covers an area of about 2.6 million ha. The replanting rate of unproductive oil-palm trees is about 5.46 percent per year (120 000 ha). What is currently regarded as wastes can potentially produce 78 m^3 of raw material (i.e. woody items) per hectare (Anon, 1998b; 1998c; and Statistical Estate Crops, 1997) or about 9.36 million m^3 per year.

Wood-processing industries

Discussed here in brief are the primary wood-processing industries (i.e. sawmill, veneer/plywood, and pulp/paper); and those of secondary type.

Sawmilling industries

In 1995, 330 sawmills operated in Indonesia with a total installed capacity of about 4.3 million m^3 (Syafii and Sudohadi, 1996). Indonesian production of sawnwood between 1992/1993 and 1996/1997 ranged from 1.7 to 3.5 million m^3 per year (Forestry Statistics of Indonesia, 1997/1998), on average about 2.6 million m^3 per year. A study of five sawmills in Kalimantan indicates recovery rates between 40 to 60 percent (by volume) of the raw material intake (Martawijaya and Sutigno, 1990; Sarajar, 1989). On average, 54.24 percent (by volume) of the sawnwood production was turned into wastes. These figures are comparable to the 40 to 60 percent recovery rates employing conventional sawmilling techniques in other mills (Tsoumi, 1993).

Veneer/plywood

About 120 veneer/plywood factories operate in Indonesia. Their total production capacity is around 12 million m^3 per year (Syafii and Sudohadi, 1996). The domestic production of veneer/plywood between 1992/1993 and 1996/1997 ranged from 8.1 to 10.9 million m^3 per year, with an average of 9.6 million m^3 (Forestry Statistics of Indonesia, 1997/1998). Studies of several veneer/plywood factories in Java, Sumatra, and Kalimantan reveal recovery rates for plywood of about 40 to 55 percent (by volume) of wood input (Martawijaya and Sutigno, 1990). The estimates are comparable with results from other mills in the country that use conventional technologies (Haygreen and Bowyer, 1989; Tsoumi, 1993). On average, about 57 percent of the raw materials is turned into wastes.

Pulp and paper

Wood is the principal raw material for the pulp and paper industries. A few companies also use bamboo, agricultural residues, or waste paper (Anon, 1999b). In 1995, 71 pulp and paper mills operated in Indonesia, with a total installed capacity of 2.0 to 3.8 million tons of pulp and paper per annum. Six of them were State- or Government-owned factories, while the rest were operated by the private sector (Syafii and Sudohadi, 1996).

Since most of the Indonesian pulp and paper mills use wood (i.e. mostly hardwood or short-fibered wood species), chemical pulping processes are used. Their recovery rate is assessed to be about 45-50 percent (Smook and Kocurek 1982; Tsoumi 1993). A study of 11 private pulp/paper mills with a total production capacity of 3.5 million tons (as output) per year indicates that they exploit about 685 532.5 ha of plantation forests, which potentially produce about 15.06 m^3 of wood material per hectare (or 10.3 million m^3) per year (Anon, 1997a). This translates into about 5.2 million tons of wood (as input). Recovery rates are therefore about 67 percent and much higher than the rates quoted above.

Residues in the pulp and paper processing may be in the form of log butts, sawdust, and fines (Anon, 1995; Haygreen and Bowyer, 1989). In total, the portion of residues reaches some 40 percent of the wood material input (Sarajar, 1989; Suchsland and Woodson, 1986).

Other primary processing facilities

Other primary processing facilities include the particleboard and MDF industries. In 1996, there were about 39 particleboard factories with a total of production about 470 000 m^3 per year. Six MDF mills were officially recorded with a total production of approximately 550 000 m^3 per year. There are no data on recovery rates for these mills (Anon, 1997a; and Syafii and Sudohadi, 1996). In comparison to the major wood processors, particleboard and MDF production is not very significant. In addition, they generate less waste, as smaller wood dimensions can be utilized (FAO, 1963; Tsoumi, 1993).

Secondary wood processing

Secondary wood processing includes the manufacturing of furniture, handicrafts and toys, and housing components. In 1995, about 553 units produced secondary processed wood products with a total production capacity of 2.5 million m^3 per year (Syafii and Sudohadi, 1996). Data on residue generation do not exist, although rough estimates are in the order of 25 percent (Sarajar, 1989).

Assessments of residues generated from forestry, estate sector, and wood industries

Forest harvesting and estate crops residues

Forest harvest/logging residues

Logging residues were as much as 82.0 m^3 per ha, and the rate of forest logging (timber harvest) was about 0.36 million ha per year (Idris, 1995). Therefore, the total amount of logging residues is about 29.8 million m^3 per year. Residues are generally left in the forest to decay. Attempts to utilize logging residues are currently being investigated. Small amounts of residues are used by local people for construction, housing, firewood, or other purposes.

Estate sector

The total amount of residues from unproductive rubber trees and oil palms is 13.44 million m^3 per year. Residues from other estate crops (e.g. clove, tungseed, nutmeg, and cashew nut) are negligible.

Summary

The total amount of residues generated during timber extraction and the regeneration of rubber and oil-palm plantations is about 43.14 million m^3 per year (Table 3). In reviewing the estimates, one has to keep in mind that they are based on only a small number of studies. Also, it is not possible to consider illegal logging operations, and timber plantations were excluded from the analysis. Hence, the actual total amount of residues is likely to be even higher and the figures below should be viewed as very conservative.

Table 3. Residues generated during logging and by the estate sector

Wood residues source	Amount (million m^3/year)
Forest logging (a)	29.70
Plantations (b)	
Old rubber trees	4.11
Unproductive oil-palm trees	9.33
Total from plantation	13.44
Overall total (a + b)	43.14

Sources: Idris, 1995; Statistical Estate Crops of Indonesia, 1997

Residues from wood-processing industries

Primary wood industries

The Indonesian sawmilling industry produces about 2.6 million m^3 of sawnwood per year. On average, residue generation is estimated at 54.24 percent of sawnwood production (Martawijaya and Sutigno, 1990; Sarajar, 1989). Therefore, the total volume can be estimated at 1.4 m^3 per year. Based on a recovery rate of 43 percent (Martawijaya and Sutigno, 1990), the plywood/veneer sector generated 4.6 to 6.2 million m^3 per year, or an average of 5.5 million m^3 of wastes.

Pulp/paper

On average, 2.6 million tons of pulp and paper are produced annually (Anon, 1997a, 1997b, 1999b). Therefore, approximately 10.3 million m^3 of wood materials are required each year as input. Residue generation in this sector is about 4.1 million m^3 per year.

Secondary wood industries

Secondary wood processing generates about 562 000 m^3 per year.

Summary

The total amount of residues generated by the wood-processing industry reaches 11.57 million m^3 per year (Table 4).

Table 4. Generation of residues by the wood processing sectors

Wood industries	Outputs of production (ranges and averages)	Approximate amount of residues (m^3/year)
I. Primary wood-processing		
Sawmills [1]	1 729 839 - 3 534 356[3] (2 589 826)[6]	938 265 - 1 917 035 (1 404 722)
Veneer/plywood[1)]	8 066 400 - 10 947 633[3] (9 586 889)	4 597 848 - 6 240 151 5 464 521)
Pulp/paper[2]	1 314 300 - 4 267 000[4] (2 586 280)	2 102 880 - 6 859 200 (4 138 048)
Total (I)		7 638 993 - 15 016 385 (11 007 291)
II. Secondary wood-processing (i.e. furniture, handcraft and kitchen utensils, crate and containers, other solid wood products)	2 500 000[5]	375 306 – 766 814 (561 889)
Overall total (I + II)		8 014 299 - 15 783 199 (11 569 180)

1) From 1992/1993 - 1996/1997; 2) From 1994 – 1998; 3) Unit = m^3/year; 4) Unit = tons/year; 5) In 1996
6) Figures in parenthesis are average values

Suggested efforts to minimize the generation of wood residues

Improvement of forest harvesting practices

Two main approaches to improving forest harvesting have the potential to reduce wastes during log extraction, i.e. technical and institutional approaches.

Technical approach

Numerous improvements can be made in timber harvesting operations. Foremost are reductions in stump height and the introduction of directional felling that have the potential to considerably decrease damage to the residual stand. Furthermore, improved road planning and construction can also help to reduce damage and waste. Better skidding techniques, such as the use of arches on skidders, will also minimize the breakage of logs.

Institutional approach

The introduction of penalties could also result in waste reduction. For example, loggers could be fined Rp. 50 000 if they generate more than 1 m^3 of waste per ha (Idris, 1995). Royalties can also be adjusted upwards for poor logging operations. Such disincentives should ensure that wasteful harvesting operations are discouraged.

Possible improvement in the wood processing

A number of innovations could raise sawmill efficiency, such as reducing kerf and variability in thickness. Milling technologies also need to be optimized and logs accurately positioned for the cutting process (Haygreen and Bowyer, 1989). Several ways should be considered in improving the efficiency of veneer/plywood processing, including methods of production, log characteristics, and wood shrinking/swelling (Tsoumi, 1993).
The amount of residues generated in pulping is not only affected by the pulping processes, but also

by improving methods, such as wood preparation, debarking, chipping, and chip screening (Anon, 1995; Smook and Kocurek, 1982).

Utilization of wood residues

Wood residues can also be converted into useful products (Haygreen and Bowyer, 1989; Peterson and Leenhouts, 1997; Sjostrom, 1981; Tomich *et al.*, 1998; and see Annex 1):

- Solid wood products: furniture components, handicrafts/toys, sports items, household appliances;
- Housing and vehicle parts, crates, and containers;
- Wood composites: veneer and plywood, particle/flake board, wood-cement board, strain board, and glued-laminated beams;
- Pulp and paper: paper, liner board, tissue paper, corrugating medium, sack paper, and paperboard;
- Products chemically derived/converted from wood material: rayon/artificial silk, celluloid, cellulose acetate, charcoal, wood gas, alcohols, acetic acid, furfural, and wood tars; and
- Fertilizer: being biodegradable, woody biomass residues can be utilized as organic compost for soil conditioning or improving soil fertility.

Converting residues into useful products not only solves disposal problems but can also influence logging rates in that less timber needs to be harvested. This is important because the recent Indonesian forest fires reduced the production forest area to 62 percent of its original size (Anon, 1998a). However, the increased utilization of residues will not come about if technical, socio-economic, political and environmental aspects are not considered properly.

Technical aspects on the utilization of wood residues into useful products

Residues from forest-logging and wood-processing industries

The Indonesian tropical rainforests are characterized by their biodiversity and boast a variety of timber species with different properties and sizes.

The strength of the wood is affected proportionally by its specific gravity which, for Indonesian tropical timber, can range from 0.25 to slightly above 1.00. The variation in specific gravity results in different strengths. Information about strength is necessary to convert wood residues into useful products, such as solid-wood structures, laminated beams, veneer/plywood, wood composites, and mechanical pulp.

The chemical characteristics of wood residues are important for pulping. Wood with low lignin concentration is easier to process into unbleached and bleached pulps since it requires less processing chemicals. Understanding the aspects of related chemical substances (e.g. types and concentrations) is crucial if wood residues are to be chemically converted into products like pulp and paper or other cellulose derivatives.

Most Indonesian wood residues consist of short fibers that produce pulp and paper with lower strength properties than the longer fibers of softwoods. This aspect needs to be considered in promoting the use of wood residues of Indonesian hardwoods.

Information about the utilization or conversion of wood residues in Indonesia is limited. Recent research indicates that the properties of wood residues are generally comparable to those of regular woods. However, due to various characteristics as listed below, wood residues remain classified as low grade (Koch, 1960; Sandwell, 1960; Syafii and Sudohadi, 1996):

- undesirable species;
- available only in small sizes (i.e. diameter and length);
- short;

- crooked; and
- presence of defects such as knots, shake, rot, insect damage.

These undesirable characteristics need more attention if wood residues are to become more attractive to wood processors. The following steps can be taken to improve the situation: removal of defects followed by re-assembly into pieces of desirable dimensions; addition of other materials to enhance strength; mechanical flaking, chipping, or grinding followed by reconstitution (with additives); and chemical digestion and reformation, which results in a variety of pulp and paper products, each with special properties.

Residues from estate crops

Utilization of rubber and oil-palm residues is still being researched (Albaladejo, 1997). Rubberwood possesses a number of properties adequate for further processing but requires intensive treatment to enhance its durability (Budiman, 1978). Oil-palm residues can be used for a variety of products such as particleboard. Conversion of rubber to pulp remains difficult as the pulping process requires significant amounts of chemicals, yields are low and pulp negatively affects metal equipment (Anon, 1998c).

Summary

The conversion of residues into useful products is hampered by a number of constraints, e.g. "weight losing"[13] usually occurs in or during processing; residue supplies are often scattered at their source location and only available in small quantities; and raw material continuity is difficult to ensure. The potential of using residues is determined by raw material characteristics, mill size and location, investment requirements, manufacturing costs, and profitability (FAO, 1963; Sandwell, 1960; Suchsland and Woodson, 1986). Although difficulties remain, they are not insurmountable as the industry is in urgent need of raw materials, and wood composites produced from residues can meet standard requirements and have become acceptable to consumers (Musttaqin and Soedjatmiko, 1998). The Government is also encouraging the use of logs of smaller diameters (especially of less known and non-commercial species) and wood residues by charging a reduced royalty to Rp. 4 000 per m^3 (Anon, 1997c). This compares with a royalty of Rp. 11 000 to 21 000 per m^3 for logs with diameters above 50 cm.

Conclusions and recommendations

The logging operations, the estate crop sector (mainly unproductive rubber and oil-palm plantations), and wood-processing industry (i.e. primary and secondary processors) are the main sources of biomass residues in Indonesia.
The total amount of residues generated during timber extraction/logging and the replanting of old and unproductive rubber and oil-palm plantations is about 43.14 million m^3 per year. The total amount of residues generated by the wood-processing industry reaches 17.78 million m^3 per year. There is a concern about their disposal, which can lead to air and water pollution. Although the wood industry in Indonesia is to some extent facing supply shortages of raw materials, residues are still insufficiently used. Operators in the forests and managers in the wood industries should pay serious attention to remedy this situation rather than resort to over-cutting and illegal procurement of logs.

In reviewing the estimates, one has to keep in mind that they are based on only a small number of studies. Also, it is not possible to consider illegal logging operations, and timber plantations were excluded from the analysis. Hence, the actual total amount of residues is higher and the assessed figures as obtained should be viewed as very conservative.

[13] Weight losing is the weight loss that occurs during processing.

Although there are a number of ways in which residues could be used more efficiently, various constraints have until now hampered attempts to make their widespread use more acceptable. Among the policy options to improve the current situation are the following:

- strict law enforcement;
- provision of incentives to reduce open-burning and to encourage the utilization of residues for energy generation;
- providing a conducive environment for processing residues into useful products; and
- raising awareness for technical options among the general public, policy-makers and industries.

Acknowledgments

The financial support from the Asia-Pacific Forestry Commission for carrying out the study is gratefully appreciated. The authors are also grateful for the assistance of Kayano Purba, Paribotro Sutigno, Askari, and Gustan Pari who all have sought and provided some significant and beneficial data and information. Further appreciation is extended to Syarief Hidayat, Djudju Djuhariah, Ida Srimulyati, and Eko Martianingsih who provided useful supplementary assistance.

References

Ahmad, N.R. 1989. Management aspects on wood residues' utilization industries. In *Proceedings of wood residues' utilization*, pp. 30-38. Bogor, Indonesia, the Faculty of Forestry, Bogor Agricultural University, in cooperation with Yasasan Sarana Wana Jaya, INHUTANI I, and UNESCO (in Indonesian).

Albaladejo, J.L. 1997. The potential of rubberwood. *Tropical Forest Update*, 7(4): 9-10.

Anon. 1978. Fuel from wood residues and agricultural wastes in Indonesia recently and their prospects. Working paper for Annual Seminar by the Indonesian National Committee - World Energy Conference, Forest Products Research Institute, Bogor, Indonesia, 25-26 May 1978 (in Indonesian).

Anon. 1995. Indonesia emerging as pulp and paper production giant. *TAPPI*, 78(6): 43-49.

Anon. 1997a. Pulp and paper industry faced with the scarcity of basic materials. Industry profiles. *Indonesian Commercial Newsletter*, 23 June. Jakarta, P.T. Data Consult Inc.

Anon. 1997b. *Indonesian pulp and paper directory*. Jakarta, Indonesian Pulp and Paper Association, PT Gramedia.

Anon. 1997c. *Kajian pasokan-permintaan dan kebijakan distribusi kayu di Indonesia (Kasus Jawa)*. Laporan Proyek DPL 1996/1997. Bogor, Indonesia, Tim Peneliti Sosial Ekonomi Kehutanan. Pusat Penelitian dan Pengembangan Hasil Hutan dan Sosial Ekonomi Kehutanan.

Anon. 1998a. Kebakaran hutan dan lahan di Indonesia, Jilid I: Dampak, faktor, dan evaluasi. Jakarta, Kantor Menteri Negara Lingkungan Hidup Republik Indonesia and United Nations Development Program.

Anon. 1998b. Summing-up on 1998 International Oil-Palm Conference. Nusa Dua, Bali, Indonesia, 23-25 September 1998.

Anon. 1998c. Project proposal: Pulp and paper from empty oil-palm bunch. Jakarta, P.T. Triskisatrya Daya Pratama and P.T. Chatama Agro Indofin.

Anon. 1999a, Pengelolaan dan pengusahaan hutan alam Indonesia, WWF Indonesia. Paper disampaikan pada Seminar Pencapaian pengelolaan hutan berkelanjutan di ambang abad ke 21, Departemen Kehutanan dan Perkebunan, Bogor, Indonesia, 5 October 1999.

Anon. 1999b. Pulp and paper industries saved by exports. Industry profiles. *Indonesian Commercial Newsletter*, 12 October. Jakarta, P.T. Data Consult Inc.

Budiman, S. 1978. Perkembangan pemanfaatan kayu karet. *Majalah Dwi-bulanan: "Sasaran"*, No. 4.

Dennis, R. 1998. A review on fire projects in Indonesia (1982-1998). CIFOR, ICRAF, UNESCO, and European Commissions. Joint Research Center. Institute for Remote Sensing Applications.

FAO. 1963. Plywood and other wood-based panels. Report of an International Consultation on Plywood and other Wood-based Panel Products. Food and Agriculture Organization of the United Nations, Rome.

Forestry Statistics of Indonesia. 1997/1998. Jakarta, Secretary General of Forestry, Ministry of Forestry and Estate Crops, Bureau of Planning.

Haygreen, J.G. & Bowyer, J.L. 1989. Forest products and wood science: An introduction. 2nd. Ed. Ames, Iowa State University Press.

Idris, M.M. 1995. Kecenderungan meningkatnya nilai faktor eksploitasi di hutan produksi alam. *Prosiding Ekspor Hasil Penelitian dan Pengembangan Hasil Hutan dan Sosial Ekonomi Kehutanan*. Bogor, Indonesia, Badan Penelitian dan Pengembangan Kehutanan.

Johnson, S. 1997. Secondary processed wood products. *Tropical Forest Update* 7(4): 5-6.

Kliwon, S., Iskandar, M.I. & Effendi, R. 1995. Studi pemanfaatan limbah eksploitasi hutan di Kalimantan Barat untuk industri papan partikel. *Bulletin Fakultas Kehutanan UGM* (Jogyakarta - Indonesia) No. 28.

Koch, P. 1960. Better utilization of low-grade woods. *Proceedings of the Fifth World Forestry Congress*. Seattle, University of Washington.

Martawijaya, A. & Sutigno, P. 1990. Increasing the efficiency and productivity of wood processing through the minimization and utilization of wood residues. Seminar on Wood Technology, Jakarta, 22 January 1990 (in Indonesian).

Musttaqin. M.Z. & Soedjatmiko. 1998. "No burn" land clearing in forest management: A business perspective. Paper presented in the Final Regional Workshop on Strengthening the Capacity of ASEAN to Prevent and Mitigate Transboundary Atmospheric Pollution. Sponsored by ADB and Association of South East Asian Nations, Jakarta, Indonesia, 21-23 June 1998.

Peterson, J. B. & Leenhouts, B. 1997. What wildland fire conditions minimize emissions and hazardous air pollutants and can land management goals be met? Progress and issues. www.westar.org.

Sandwell, P.R. 1960. Feasibility of small pulp and paper mill operation. In *Proceedings of the Fifth World Forestry Congress, Vol. 3.* Seattle, Washington, University of Washington.

Sarajar, C.G. 1989. *Technology of wood residues' utilization.* Bogor, Indonesia, Faculty of Forestry, Bogor Agricultural University in cooperation with and funds from Yasasan Sarana Wana Jaya, INHUTANI I, and UNESCO, pp. 46 -54 (in Indonesian).

Schweithelm, J. 1998. The fire this time. Discussion Paper. Jakarta, World Wide Funds for Nature Indonesia, WWF Indonesian Programme.

Sjostrom, E. 1981. Wood chemistry: Fundamental and application. San Francisco, Sydney.Academic Press, Inc.

Smook, G.A. & Kocurek, M.J. 1982. *Handbook for pulp and paper technologists*. Joint Textbook Committee of the Paper Industry. Atlanta, USA, TAPPI.

Statistical Estate Corps of Indonesia. 1997. Jakarta, Directorate General of Estate, Ministry of Agriculture.

Suchsland, O. & Woodson, G.E. 1986. *Fiberboard manufacturing practices in the United States.* Agricultural Handbook No. 540. Washington, D.C., USDA Forest Service.

Susila, W.R., Anwar, C. & Situmorang, A. 1988. Pengelolaan kayu karet tua untuk kelestarian perkebunan karet rakyat. *Berita P4TM* No. 39.

Syafii, W & Sudohadi, Y. 1996. Development of wood industries and research trend in Indonesia. Paper presented at the International Wood Science Seminar, Kyoto, Japan, 6-7December 1996.

Tomich, T.P, Fogi, A.M., de Foresta, H. & Stolle, F. 1998. Indonesia's fire: Smoke as a problem, smoke as a symptom. *Agroforestry Today*, January-March, 1998.

Tsoumi, G. 1993. *Science and technology of wood: Structure, properties, and uses*. New York, NY Van Nostrand Reinhold.

Annex 1

Types of wood residues, sources of generation, and possible utilization/conversion into useful products other than fuel

Sources/location of generation	Types of wood residues (and/or their composition)	Potential uses
Forest logging (timber harvest)	-Remaining standing stumps -Upper portion of the tree trunks, with branches, smaller branches, etc. -Wood logs of unacceptable qualities -Damaged standing trees -Unkown or in commercial species	-Veneer/plywood -Solid wood structures (lumber and laminated beams) -Packing materials -Chips (for pulp/paper/fiberboard) -Particle and flake boards
Unproductive estate crops, trees	-Predominantly rubber and oil-palm plantations	-Chips -Solid wood structures -Particle/flake boards
Wood industries		
Primary wood processing		
-Sawmills	Log ends	-Small-size lumber -Packing materials
	Pith and small dimension wood materials	-Packing materials -Small-size lumber -Chips
	Trimming materials	-Joints and laminated wood materials -Toys -Chips
	Sawdust and bark	-Charcoal -Particleboard
-Veneer/plywood	Log ends	-Lumber core -Packing materials -Chips
	Core	-Lumber core -Packing materials -Chips
	Rejected veneer	-Particleboard
	Rejected plywood	-Packing materials -Core materials
	Trimmed plywood	-Core materials
-Pulp/paper	Log butts Oversize chips (after rechipping) Bark Sawdust and fines	-Chips
Secondary wood-processing (e.g. handcraft, moulding, furniture, housing parts, and other solid wood products)	Trimming and ripping materials Rejected materials Cutter removal materials	Chips -Core materials -Packing materials -Particleboard

Sources: Ahmad, 1989; Haygreen and Bowyer, 1989