1.0 Overview of Activity

1.1 Activity Context

The Malaysian timber industry is one of the major contributors to the Malaysian economy. Timber and timber products makes a significant contribution to Malaysia's foreign exchange earnings. The sector provides employment to about 187,000 workers. Malaysia is one of the world's largest exporters of tropical timber and timber products and 10th largest exporter of furniture (second in Asia). Malaysia has also established itself as a major producer and exporter of sawn timber, panel products (plywood, MDF and particleboard) flooring, doors and other joinery products.

In 2004, Ramin have been proposed to be listed in Appendix II in Convention International Endangered Species of Wild Flora and Fauna (CITES). As Ramin has been part of CITES listing, the trade must be controlled in order to avoid utilization incompatible with their survival. This has been proved when the production of Ramin log annually in Sarawak had decrease to about 59% in Sarawak. Today's scenario needs import and re-export of Ramin to be certified by the Management Authority of the State of export and re-export.

However, the action taken by CITES alone, may not be strong enough to conserve the Ramin species in forest. Hence, wood processing sector in Malaysia should be seen as an inductor to prevent the detrimental exploitation of the Ramin species.

One factor that contributes enormously to the rapid depletion of the country's timber resources is wastage of wood during log processing. If wood waste is minimized in the country's sawmills, the number of trees cut of annum for lumber will be reduced. As resource scarcity become more and more severe, primary processing mills such as sawmills and plywood mills should undergo restructuring to compete with the others composite board plant such as MDF and chipboard where the utilization of residue become a major part of raw material.

There is the need for sawmill and plywood mills to maximize their processing recovery rate as the size of timber for the next decade also will reduce as being expected.

1.2 Activity Objectives

The specific objectives of the Activity are as follows:

i. To determine the recovery rate of Ramin logs for the manufacture of sawn timber and plywood; and

ii. To develop a technique for quantifying wood waste from sawmilling and in plywood production.

2.0 Background to Activity

2.1 Characteristics and Availability of Ramin

Ramin, which has other common names like Melawis, Pulau Miang, Gaharu Buaya and etc, belongs to the genus *Gonystylus*. At present, the genus *Gonystylus* consisting about 30 species of tall trees and some shrubs, is distributed throughout the Malesian area (Indonesia, Malaysia, the Philippines, Papua New Guinea, Singapore and Brunei Darussalam) with the majority of species found in Borneo with the exception of central and east Java and the Lesser Sunda Islands.

Figure 1: Ramin sawn timber.

Seven species of Ramin in the Peninsular Malaysia, where most of them occur in the Inland Dipterocarp Forest except for *G. bancanus* that can be found in peat swamp forest. Among the species in the peat swamp forest (PSF), *G. bancanus* has special attractions and many studies have been carried out on this species. It is the most important source of *Gonystylus* timbers and considered as one of the major export timbers of South-East Asia. Reports from

CITES in 2002 and 2008 also indicated that there are six of Ramin species that can be have the commercial value.

Although many species of *Gonystylus* are recorded, only *Gonystylus bancanus* is commercially importance. This kind of timber is greatly appreciated and valued for its colour, brightness, hardness, and its special resistance to address environmental conditions. It is also suitable for general light construction, and for interiors decoration such as panelling, flooring, moulding and counter tops. Technically, *G. bancanus* timber from 11-year old thinning stock showed an acceptable strength property and could be used for several uses. Based on physical and mechanical properties, this timber could be used in furniture manufacturing, internal joinery, holders and wooden toys. In other country such as United States, Ramin is the most valuable tree species for baby cribs, and picture frames.

Figure 2: Ramin products - component of baby cot.

Figure 3: Ramin baby cot.

2.2 Anatomical Characteristics of Ramin

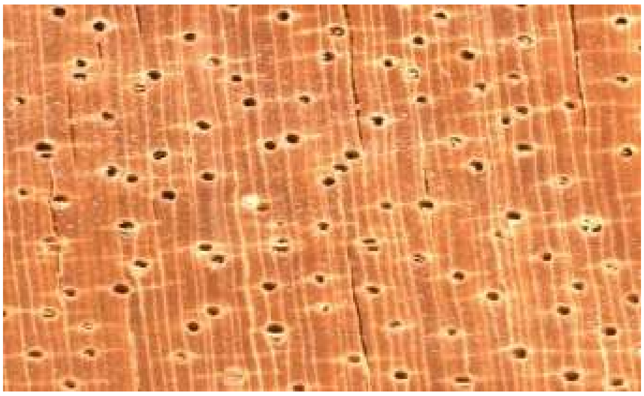
2.2.1 Growth Ring

Sometimes, growth ring can be see easily, result from the difference in thickness of the cell wall and its colour. However, sapwood is poorly defined from heart wood which is white to creamy yellow.

2.2.2. Vessel

Most of the vessel is self-supported, but some of them are in a bundle of 2 to 4 or sometimes 5 along the tangential part. It is small in tangential mostly 0.05 to 0.1 mm, but sometimes even more larger. Frequency of distribution is about 5 cells in every 1 mm^2, in circle or oval, and without xyloses. In this case, the frequency of vessel is about 6 to 22 in every 1 mm^2 with the tangential diameter of 75 to 150 micron and the vessel lines can be seen because it shiny in colour because it contain extraneous material which is in red colour.

Figure 4: Anatomy of Ramin



2.2.3 Parenchyma

Parenchyma is quite many, with most of paratracheal as a thin layer on the vessel and further become aciform or sometimes in confluent. Apotracheal in diffuse location and result of tangential lines which is short and small.

2.2.4 Fibers

Fibers consist of thin cell wall with large lumen in storied form. These fibres are arranged in radial part, thin wall (3 micron), wider lumen, 1,050-1,950 microns in width.

2.2.5 Intercellular Vessel

It does not contain intercellular vessel.

2.3 Physical Characteristics of Ramin

The timber of *G. bancanus* is categorized as light heavy hardwood with a wood density of about 655 kg m^{-3}. The dry weight of *G. bancanus* found that the air dry specific is between 0.516 and 0.600 (Table 1), while other reports found that the density in lb/cu.ft at 15% moisture content (Table 2).

Table 1: Air dry specific gravity of several *Gonystylus* species.

Species	Minimum	Mean	Maximum
G. affinis		0.78	
G. brunnescens	0.64	0.66	0.67
G. confuses	0.62	0.70	0.78
G. forbesii	0.57	0.68	0.83
G. bancanus	0.46	0.64	0.84
G. keithii	0.51	0.65	0.74
G. macrophyllus	0.46	0.61	0.81
G. maingayi	0.62	0.71	0.78
G. velutinus	0.51	0.59	0.69
G. xylocarpus		0.72	

Table 2: Density of *Gonystylus bancanus* expressed in lb/cu.ft at 15% moisture content.

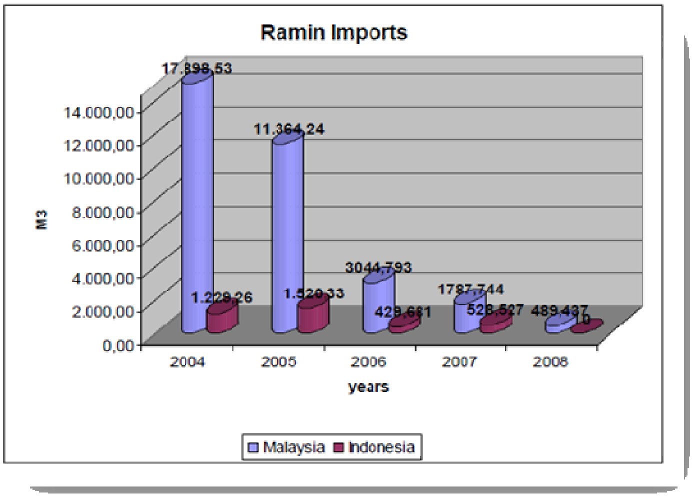
No of samples	Low	High	Mean	Source of data
5	35.2	38.0	36.3	Sabah
3	39.2	44.0	42.0	Sarawak
n.a.	37.0	47.0	42.0	Sarawak
13	33.7	43.1	38.0	Peninsular Malaysia

Gonystylus bancanus is a medium sized to large tree, occasionally attaining 90 cm diameter at breast height (dbh) and 45 m height with a clean straight bole of 20 to 30 m. Diameter of Ramin can be classified into 3 categories, >15 cm, >30 cm and >45 cm. FDPM noted that the *Gonystylus spp*. density for trees >15 cm dbh in Peninsular Malaysia on average 1 to 3 stems per hectare in all forest types and also noted that for dry land forest the tree density is <1 stem per hectare. In peat swamp forest, *G. bancanus* is often the most abundant large tree with up to 20 trees/ha with a diameter above 50 cm and is locally the single dominant species.

The timber seasons fairly slowly with moderate cupping, bowing, surface checking and staining as the main sources of degrade. The timber is prone to post beetle attacks.

In a survey in Sarawak, it was revealed that more than half (63%) of the mills surveyed are working on Ramin. Thus, in 2004, CITES come out with the data that most part of imported timber (70-92%) came from Malaysia, while a very small quantity originated from Indonesia, (8-30%). Figure 5 below shows the imports of *Gonystylus spp.* from Malaysia and Indonesia.

Figure 5: Imports of *Gonystylus spp.* from Malaysia and Indonesia.



Source: CITES, 2008.

Report from International Tropical Trade Organization (ITTO), 2007 noted that the EU has suspended imports of Ramin wood from Malaysia. The suspension was related to the listing of Ramin in CITES (where Malaysia is one of the member). The inclusion of Ramin in listing took effect in January, 2005 regulating its trade. The species are categorized as vulnerable because of the heavy logging and habitat destruction. The most heavily traded species *G. bancanus* has been listed by FAO as over-exploited and vulnerable.

Table 3 below indicates that the production of Ramin is fluctuated over the years. As a future pre-plan the industries need to adapt with the greater efficiency in managing the timber resource especially in wood processing sector as being done in bigger countries. For instance, United States have develop sawmill improvement programs to improve mill efficiencies. The result shows that in an average, efficiencies increase of about 4% in the amount of timber recovered. Incremental improvements for example, replacing a single machine, improving sawing patterns and flow through the mill, and better maintenance can all result in improve grade and volume, conversion, and mill profit.

Table 3: Ramin log production by year (m^3).

Year	Peninsular Malaysia	Sarawak	Total
2000	70,337	67,042	137,379
2001	45,076	57,334	102,410
2002	51,033	32,045	83,078
2003	49,499	25,095	74,594
2004	29,203	21,372	50,575
2005	23,892	8,654	32,546
2006	15,933	4,964*	20,897

Note: * January-November 2006.

Source: CITES, 2008.

Efficiency of the mills can be asses in three ways; log conversion efficiency (recovery rate), labour productivity, and mill capacity utilization.

2.4 Sawmilling Recovery

Sawmill process raw logs in a few simple operating steps. Logs are debarked and cut into “cants” that are further out into finished of lumber using either circle saws or band mills. Once lumber is cut to size, it may be sold as “green” lumber or may be stacked and dried to specific moisture content through air or kiln drying.

Figure 6: Ramin at mill log-yard.

Figure 7: Ramin half-logs.

On the other hand, plywood mills are more complex than sawmills. Raw logs are debarked, cut into sizes, and heated with steam or hot water. The resulting "flitch" is rotated on a large lathe and pressed against a long, sharp blade to peel off a continuous layer of wood called veneer. Sheets of veneer are then sprayed with glue, stacked on the top with the grain of the wood alternating directions and sandwiched in a hot-press that forces the pieces together to cure the glue. The recovery rate of sawn timber and veneer will be an important subject in this study to determine the growth of sawmills and plywood mills as well as the residues utilization in Peninsular Malaysia.

It has been found that mills processing Ramin logs in Sarawak had slightly higher recovery than those other species. The rate was 46.2% for the Ramin mills and 41.9% for other species. In general, the higher the recovery rate, the lesser is the quantity of waste generated. However, it cannot be taken into account as the recovery is not much affected by wood species.

Latest, according to detailed study in numerous countries, sawmill recovery rates range from 42 to 60% with an average at 50.8% while plywood recovery rates range from 43 to 50% with an average of 46.9%.

Recovery rates vary with local practices as well as species. While FAO, denoted that recovery rate may vary within and among the countries depending on log sizes, dominant species processed, standard of processing equipment and level of horizontal and vertical integration. Relying to various FAO and ITTO reports, sawmill recovery rates range from 42 to 60% with an average of about 50%. Average recovery in Malaysia was reported at around 54% with mills in Peninsular Malaysia showing a recovery rate of 55.6%, Sabah with 52.9% and Sarawak 45.7%.
In an interview of 24 mills managers in the State of Terengganu Malaysia representing about 70% of the production in the state, it was reported that the sawmills recovered about 52% and plywood mills about 49% of total input.

In another study of sawn timber processing in the State of Pahang, it was found that medium production (15,000 to 25,000 m^3 log input per year) has highest recovery rate, followed by high production (above 25,000 m^3 log input per year) with 66%, and low production (less than 15,000 m^3 log input per year) amounted 64%.

It was also reported that recovery of true green veneer *i.e* veneer available before clipping for the 8 mills was found to range from 41.5 to 75.9%. Furthermore, their research also found that the wood classes (heavy, medium, and mixed hardwood) not too much affect the lumber recovery. However, for the diameter range 40 to 49.9 cm had the highest recovery with 80.3% and for diameter range 30 to 39.9 cm with 66.9%.

2.5 Factors Affecting Recovery Rate

The recovery rate is especially dependent on log dimension. For logs in the range of 30 to 70 cm in diameter recovery rates drop to about half when the log diameter is halved. It has been found that log diameter of 56 to 60.9 cm produced the highest recovery rate with 70% and diameter with below 20.9 cm had the lowest recovery with 57%.

Log sizes of the same group increase in percentage recovery with increase in diameter due to the sawing of wider and thicker boards with less saw dust waste. The reduction of taper in large diameter log, may also lead to increase recovery. The reason for this is that taper increases already considerable problem sawyer (or computer) faces in removing rectangular solids (lumber) from a truncated cone (log). The more tapered the cone, the shorter the rectangular solid that can be removed from outside of this cone.

In fact the recovery rates for veneer were lower for logs with more taper because of the increase in amount of fishtail produce from tapered log. They found that recovery rates per bolt in veneer production, varied between 40 to 70%; as function of bolt size and taper; the bigger and more cylindrical the bolts, the higher the recovery rates. On average, about 64% of bolts volume was recovered as veneer. Bolt size was the main variable affecting lathe productivity and recovery rates, and bolt taper also had significant effect.

Figure 8: Ramin wood.

Defects such as shakes, flattened section, heart-rot, off-centre heart, log felling and cross cutting damage, insect infection, fungal attack, log straightness, split and brittle heart are just a few of the common defects which will affect sawn wood recovery. While in veneer production, spinout and split-out are the most common defects. Spinout occurs when the torque needed cutting is greater than the torques delivered by the chucks that trip and turns the block ends. Split-out happens when the combination of cutting and driving forces from the chucks exceeds the ability of the bolt to resist splitting. This is most likely to occur with blocks of old-growth wood that have large diametric splits or ring shake, like Douglas-fir and oak.

Studies have also successfully proven that the recovery is influenced by the types of machines used. Mills that using a frame gang saw gave a higher recovery (62%) than the other mills that using a hand fed-re-saw (46%). Production in the first mill was also more than double of the second mill. However, today's log showing decreasing in size, thus having frame saw in mills seem to be uneconomical, because the design in the saw is not suitable for handling the small size of logs as the saw's component are different.

Circular saws, particularly those used for the initial log breakdown have a wider kerf than band-saw. Circular saws commonly have a kerf of from 9 to 13 mm compared to 7 mm kerf with band saw. A band saw with kerf of 0.14 inch would result in as increase in lumber recovery of about 10%.

It has been shown that when the kerf width was reduced from 12/32 inch to 9/32 inch, yield in the board feet increased on average of 7% (for logs 5.5 to 12 inch in diameter).

2.6 Sawmill and Plywood Mill Residues

Mill residue consists of three categories; primary processing, plywood mills, and secondary processing.

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 consists of shavings, saw dust and sander dust is made up of the wood fine particles.

Figure 9: Waste at sawmill.

It was estimated that one-third of the volume of logs processed in sawmills and plywood mills become mill residue. In the total volume of logs processed estimated at 5.53 million m^3 in Peninsular Malaysia last year, the available volume of mill residue amounted to 1.84 million m^3.

Generally, the amount of wood waste generated by sawmill is approximately 45 to 50% from the total log input, in the form of; logs ends, bark, slabs, saw dust, and lumber edges.

During the sawn timber processing, about 12% is waste in the form of bark. Slabs, edgings and trimmings amount to about 34%, while saw dust constitutes another 12% of the log input. After kiln-drying the wood, further processing may take place resulting in another 8% waste (of log input) in the form of saw dust and trim end (2%) and planer shavings (6%).

Figure 10: Breakdown of log.

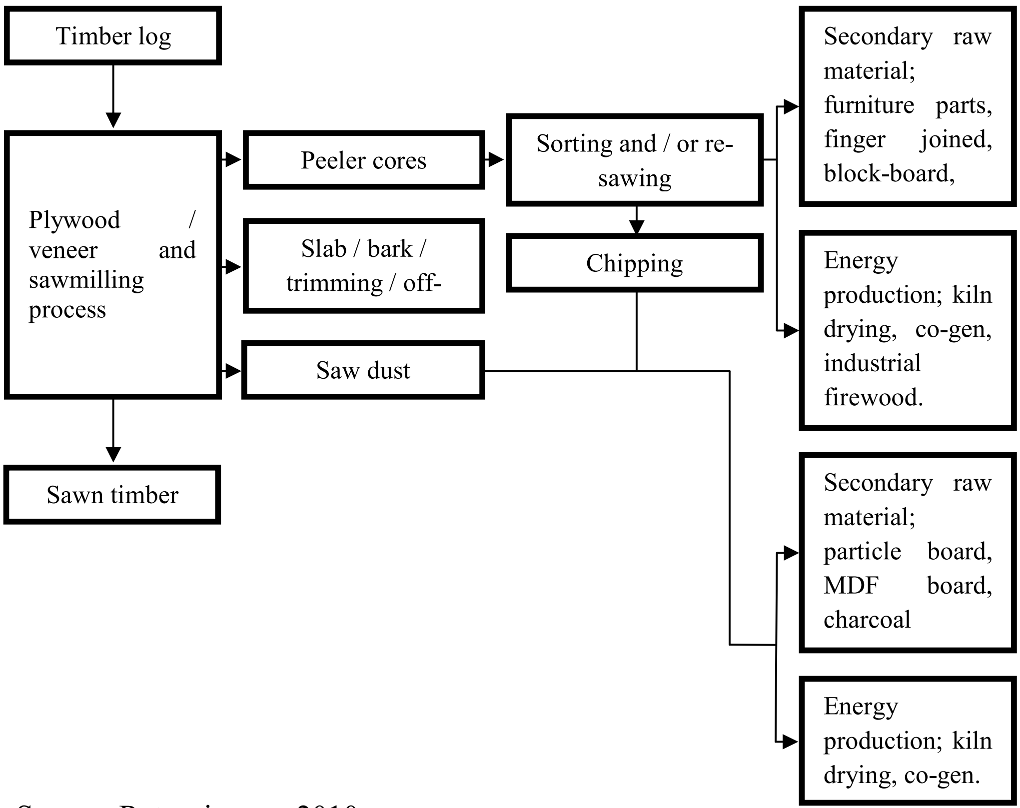
The amounted of residues produced per year in the sawmilling and plywood sub-sector in the selected countries is about 42 million m^3 and 19 million m^3 respectively. Close to 90% of the sawmill residues is generated in only four countries (China, India, Indonesia and Malaysia).

During the plywood processing, the main forms of waste are log ends and trims (7%), bark (5%), log cores (10%), green veneer waste (12%), dry veneer waste (8%), trimmings (4%) and rejected plywood (1%). These form the largest amount of waste while sanding the plywood sheets results in another loss of 5% in the form of sander dust.

Wood residues from primary timber processing have been made into usable product for many decades. In large country, such as United States, nearly all particle board has been made from the mill residues. Mill residues can be disaggregated into three broad categories; energy production (such as boiler fuel for kiln drying, wood conditioning, lacquer-curing, cogeneration plant fuel and industrial generation), secondary raw material to be used by the wood-based industries (MDF, particle board, laminated board, etc.) and secondary raw material to be used by industries outside the wood industry sector (fertilizer and mushroom growing, livestock litter / bedding).

Large quantities of mill residues are used as fuel wood for build making tobacco curing and domestic cooking in Terengganu Malaysia. Smaller amounts are used for fencing, re-sawing for fish boxes and local furniture production.

Figure 11: Utilization of Ramin wood residue.



Source: Ratnasingam, 2010.

3.0 ACTIVITY PERFORMANCE

In this study, data was collected by two ways. The first step was through the review of historical Ramin sawn timber and plywood production data archived at the Forest Department Peninsular Malaysia (FDPM). The second step involved a field survey of selected mills where processing of Ramin was taking place, which provided hand-on data for the yield and wastage estimation.

Based on the archived data obtained from the FDPM, it was found that no Ramin plywood production activities have been recorded since 2007, while the sawn timber production was confined to only three sawmills located in the States of Pahang and Terengganu. Nevertheless, as the supply of Ramin saw logs was sparse, the processing at these mills was limited, and FDPM were in close contact with the millers to ensure that data collection could be carried out during the processing stages.

As a result, the study was delayed substantially as the millers were not processing Ramin logs until the third quarter of 2010, and therefore, only preliminary data were collected throughout the 2010 period. Final data collection was pursued from March to June 2011 to establish the yield and wastage during Ramin sawmilling activities.

3.1 Activity Location

The data were collected primarily from the following mills, which cooperated closely with the FDPM.

i. Chye Hin Sawmill Sdn. Bhd. Kemaman, Terengganu.

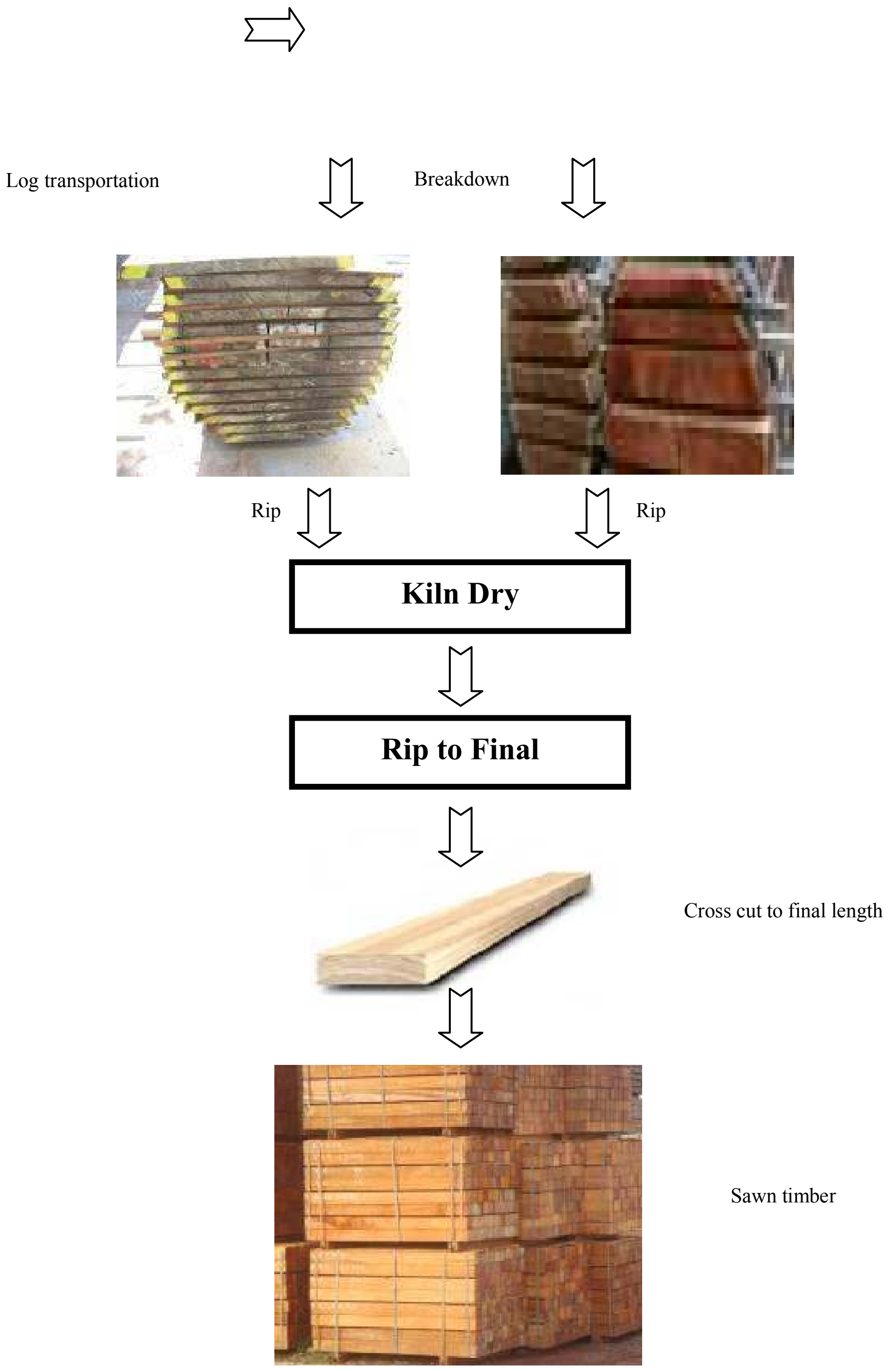
ii. Kilang Papan Pahang Timur Sdn. Bhd., Gambang, Pahang.

3.2 Activity Processes

Unlike previously described, the sawmilling of Ramin in Peninsular Malaysia adopted a method quite similar to the saw-dry-rip (SDR) technique. In this process, the saw logs were ripped into flitches of 1, 1.25 and 2.50 inches in widths, which are then dried to the final moisture content of below 10%. After the drying period, the flitches are ripped into the final sawn timber sizes, as per the requirement of the customers.

According to the millers, such a technique allows for better recovery and reduced wastage in Ramin processing. The process flow in the typical Ramin sawmill in shown below.

Figure 12: Process Flow in Ramin Sawmilling



3.3 Activity Personnel

The activity was implemented by a team of consultants from the Faculty of

Forestry, Universiti Putra Malaysia, involving two researchers and two field assistants.

3.4 Activity Schedule

Table 4: Activity schedule.

Activity	Time Frame
Desk Top Survey	January to August 2010
Preliminary Data Collection	September to December 2010
Final Data Collection	March to June 2011
Analysis and Report Writing	July to August 2011

3.5 Activity Output

The activities undertaken will be able to establish the recovery and wastage rates during Ramin sawn timber production processes. It will also provide recommendations on minimizing the waste production during the sawmilling operation. The compilation of the data and the ensuing recovery and wastage rates were done according to the formula shown in Appendix (wherever applicable). This is considering the fact the amount of primary data collected during the field survey were limited due to the lack of Ramin sawmilling activities.

Since, no activities related to Ramin plywood processing was recorded both in historical data as well as current industrial production data, this report will not cover the Ramin plywood production processes.

4.0 ACTIVITY OUTCOMES

4.1 Achievement of specific objectives.

Based on the preliminary desk-top research on historical data as well as the field survey undertaken, it was apparent that the sawmilling recovery of Ramin in Peninsular Malaysia was higher than previously thought. The mean data presented shows that the average recovery of Ramin sawn timber was in the range of 73%, although, this will depend largely on the diameter of the input saw logs as well as its quality.

As mentioned previously in this report, no part of this report involves plywood processing recovery as no Ramin plywood processing has been recorded in Peninsular Malaysia over the last few years.

Table 5: Average Recovery of Ramin Sawn Timber.

Average Saw Log Diameter	23”
Common Sizes of Flitches	1”, 1 ¼ ”, 2 ½”
Sawing Variations	8 – 12%
Common Sawn Timber Sizes Produced	1”, 2”
Average Recovery Rate (%)	73%
Average Wastage Rate (%)	27%

On the other hand, the wastage rate in Ramin sawmilling operations was in the range of 27% from which 9% was made up of saw-dust, while 18% was made up of unusable off-cuts and wane. It must be emphasized that the sawmilling process-flow, which involves the production of flitches which is dried prior to final sawing to dimensions, allows the highest possible recovery of the Ramin wood.

From the field survey, it was found that Ramin saw logs were predominantly sound with minimal defects, hence, the input volume of saw logs were more or less converted wholesome into flitches during the prior to final sawing. The slow drying process adopted by sawmills, using thermal oil as the heating medium also improves the drying of Ramin.

4.2 Situation at Activity Completion as Compared to Pre-Activity Situation

Compared to the pre-activity situation, it is apparent that there is a better understanding of the Ramin sawmilling process in Peninsular Malaysia. The activity undertaken shows that recovery rate for Ramin sawn timber is in the range of 73%, while the wastage is relatively low at 27%. It must also be noted that the demand for Ramin wood, a light coloured material in the international market is very high, especially from Japan and Europe.

Figure 13: Graded Ramin sawn timber.

Figure 14: Ramin sawn timber bundles.

This report provides benchmark data on the recovery of Ramin saw-milling activity, both in terms of processing recovery and wastage rates. It must be recognized that these data would serve as the reference for future deliberation on the future of Ramin as a protected species, as it is the point of contention of the FDPM.

5.0 Assessment and Analysis

The following points reveal the major assessment and analysis of the activity undertaken:

i. The quality of the Ramin saw log is good, with minimal defects.

ii. The sawing of Ramin, using the modified saw-dry-rip (SDR) method improves the recovery of Ramin sawmilling activities significantly. Further, the slow drying processes employed to dry the material also minimizes the chances of drying defects on the wood material.

iii. The wastage in Ramin sawn timber production is minimal, as the saw mills maximizes their recovery by producing stills, poles, dowels and small dimension components that have application in other value-added products. Large off-cuts and slabs are also sold to the nearby particleboard mills, to be used as material stock.

Figure 15: Saw dust collection.

Despite these assessments, it must be emphasized that the study was grossly limited by the extent of Ramin sawmilling activities in Peninsular Malaysia. The inconsistent supply of Ramin saw logs and the rapid turn-around in processing to avoid biodegradation of the wood, somewhat affected the data collection and the ensuing analysis. Nevertheless, the activity undertaken has been able to achieve the specific objectives, by providing the necessary benchmark values for recovery and wastage in Ramin sawmilling operations.

6.0 Conclusions and Recommendations

Based on the activities undertaken, it can be concluded that Ramin recovery in the sawmilling operation is in the range of 73%, while the wastage is in the range of 27%.

It is recommended that, the processing of Ramin should be approached from the concept of full utilization, whereby mixed products are produced to ensure the highest possible recovery. Sawn timber production alone, will not provide high recovery rates, but the production of small dimension parts and component stocks will significantly improve the recovery of Ramin processing.

Figure 16: Ramin recovery strips.

It is also recommended that the processing of Ramin is best done using fully or semi-mechanized machines, as it will minimize the excessive sawing variations currently observed. It must be stated that the mills involved in this study, has machines and technologies which were manually operated and out-dated.

7.0 References

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Appendix

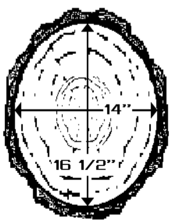
In order to calculate the recovery, volume of the log must be the first priority. The volume of logs will be determined using the formula below:

i. Gross Volume of Logs:

$V = 0.3927 \times (D^2 + d^2) \times L \times F$……..……..……………………………..…........(1)

V = Log volume in m^3
D = Average diameter of large end of log in cm
d = Average diameter of small end of log in cm
L = Length of log in m
F = Conversion factor 10^{-4}

In determining the average of each end, the largest and the smallest diameters at end of the log were taken. They were taken perpendicular to each other and passed through the centre (not necessarily the pith) of the log. To obtain the average at each end, the two diameters obtained were added and the sum is divided by two.



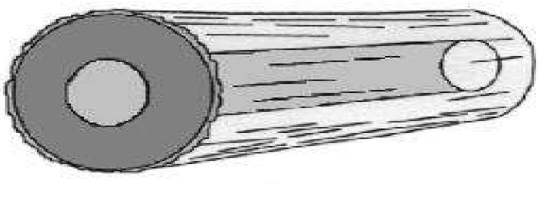
14" + 17" = 31"
31" / 2 = 15" diameter

Generally, processing of hardwoods is associated with wood defects. Defects of log such as split, knot, and hollow heart also must be recorded. Where the hollow heart was present and extended throughout the log, the volume of the decay was computed according to this formula:

ii. Volume of decay:

$Vd = 0.3927 \times (Dd^2+dd^2) \times L \times F$……………………..……...…………………(2)

Vd = Volume of decay in m^3
Dd = Average diameter if decay of large end in cm
dd = Average diameter of decay at small end in cm
L = Length of hollow heart in m
F = Conversion factor, 10^{-4}



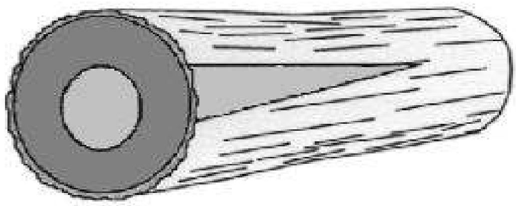
Cylindrical (round or oval)

If the hollow heart occurs only at one end of log and penetrates to only certain length, then the hollow heart is assumed to be conical in form and its volume will be determine using the following formula.

iii. Volume of decay:

$Vd = 0.2618 \times D^2 \times L \times F$………………………………………………………………. (3)

Vd = volume of decay in m^3
D = Average diameter of hollow heart in cm
L = Length of hollow heart in cm
F = Conversion factor 10^{-4}



Conical (round or oval)

After measuring the log, both end of the log will be marked with crayon for identifying through subsequent operations. The cutting pattern also will be observed during the study.

Timber volume is the cubic meter volume of green sawn timber that is produced during the sawing of each log. Every pieces of sawn timber produced will be measured and recorded with regards to actual width, thickness and length giving the gross recovery per log.

iv. Green volume of sawn timber will be calculated using this formula:

$Vg = L \times T \times W \times F$ ……………………..……………..……………………..…….(4)

Vg = Green volume of sawn timber
L = Length of sawn timber in m
T = Thickness of sawn timber in cm
W = Width of timber in cm
F = Conversion factor, 10^{-4}

Total sawn timber yield from each log is the sum of the green volume all pieces of sawn timber from each log. Then, we will calculate the percentage of recovery:

v. Recovery rate:

$\sum Vg / V \times 100$………………………...………...(5)

Vg = Volume of sawn timber in m3
V = Log volume in m3

To determine the volume of the saw dust when a saw a cut adjacent to each piece of sawn timber, the following formula will be used:

vi. Adjacent board kerfs volume:

$(W + (2K) + (2T)) \times K \times L \times F$……………………………………….…………….(6)

W = Rough green width of sawn timber in cm
T = Rough green thickness of sawn timber in cm
K = Saw kerf in cm
L = Length of log in m
F = Conversion factor 10^{-4}

vii. Total kerfs adjacent to edgings volume:

$[K / (T+K)] \times$ (Total edgings and adjacent kerfs volume)….………………....…...(7)

viii. Total edging and adjacent kerfs volume:

Total log volume - total sawn timber and adjacent board kerfs volume ………..……………………...……………………………………...…...………..(8)

ix. Total Volume saw dust:

Total adjacent board kerf volume + Total kerf adjacent of edging volume…………………….……………………..……………………… (9)

The total volume of coarse residues was calculated by subtracting the volume of sawn timber and saw dust from the gross volume of log.

x. Total volume of course residue:

Gross volume of log - total volume of sawn timber - total volume of saw dust………………………………………………………………….…….. (10)