Economy and Environment Program
for Southeast Asia
Tanglin PO Box 101
Singapore 912404
Phone: (65) 6831-6854
Fax: (65) 6235-1849
E-mail: eepsea@idrc.org.sg
Web site: www.eepsea.org

RESEARCH REPORT

NO. 2003-RR1

Responses of Timber Concessionaires to Selected Policy Instruments: The Case Of Peninsular Malaysia

Mohd. Shahwahid Haji Othman
Research Management Centre, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor D.E. Malaysia.
(msho@econ.upm.edu.my)

Awang Noor Abdul Ghani
Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor D.E. Malaysia.
(awang@forr.upm.edu.my)

This report investigates the characteristics and behaviour of logging concessionaires in Peninsular Malaysia. It highlights the aspects of these companies and their concessions that affect environmental performance. It finds that the companies are caught in a Catch-22 situation in which an increase in both harvesting rates and the number of trees left standing leads to more environmental damage in logging areas. The report suggests that the Malaysian government should introduce and encourage more environmental-friendly harvesting techniques, allow higher cutting intensities but with greater monitoring and control, and extend the cutting cycle to give the forests sufficient time to recuperate and regenerate.

Published by the Economy and Environment Program for Southeast Asia (EEPSEA)
Tanglin PO Box 101, Singapore 912404 (www.eepsea.org)
tel: +65-6235-1344, fax: +65-6235-1849, email: eepsea@idrc.org.sg

EEPSEA Research Reports are the outputs of research projects supported by the Economy and Environment Program for Southeast Asia. All have been peer reviewed and edited. In some cases, longer versions may be obtained from the author(s). The key findings of most *EEPSEA Research Reports* are condensed into *EEPSEA Policy Briefs*, available upon request. The Economy and Environment Program for Southeast Asia also publishes *EEPSEA Special Papers*, commissioned works with an emphasis on research methodology.

National Library of Canada cataloguing in publication data

Main entry under title:

Behavior of timber concessionaires in response to selected policy
instruments: case of Peninsular Malaysia

(Research Report, ISSN 1608-5434 ; 2003-RR1)
Co-published by the International Development Research Centre.
Includes bibliographical references.
ISBN 1-55250-033-0

1. Lumber trade – Malaysia – Terengganu.
2. Timber – Economic aspects – Malaysia – Terengganu.
3. Forests and forestry – Economic aspects – Malaysia – Terengganu.
I. Mohd. Shahwahid, Haji Othman.
II. Awang Noor, Abd. Ghani.
III. Economy and Environment Program for Southeast Asia.
IV. International Development Research Centre (Canada)
V. Title.
VI. Series: Research report (Economy and Environment Program for Southeast Asia) ; 2003-RR1.

HD9766.M4B43 2003 338. 1‘7498‘095951 C2003-980087-3

Responses of Timber Concessionaires to Selected Policy Instruments: The Case Of Peninsular Malaysia

Mohd. Shahwahid Haji Othman

and

Awang Noor Abdul Ghani

December, 2002

Comments should be sent to: Mohd. Shahwahid Haji Othman, Deputy Director, Research Management Centre, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor D.E. Malaysia. Tel: 603 – 89466185 Fax: 603 - 89426539

Email: msho@econ.upm.edu.my and

Awang Noor Abdul Ghani, Deputy Dean, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor D.E. Malaysia. Tel: 603 – 89467197

Email: awang@forr.upm.edu.my

EEPSEA was established in May 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Lao PDR, China, Papua New Guinea and Sri Lanka.

EEPSEA is supported by the International Development Research Centre (IDRC); the Swedish International Development Cooperation Agency (Sida); and the Canadian International Development Agency (CIDA).

EEPSEA publications are also available online at http://www.eepsea.org.

ACKNOWLEDGEMENTS

We would like to take this opportunity to thank David Glover, EEPSEA, for facilitating the approval of this grant; Jeff Vincent, as leader of an earlier report and for allowing the use of the model as a basis for application in this study; and the Terengganu State, and in particular, South Terengganu District Forestry Department for cooperation in the data collection.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

BEHAVIOR OF TIMBER CONCESSIONAIRES IN RESPONSE TO SELECTED POLICY INSTRUMENTS: THE CASE OF PENINSULAR MALAYSIA

Mohd. Shahwahid Haji Othman

and

Awang Noor Abdul Ghani

EXECUTIVE SUMMARY

The regulation and taxation of logging activities can, in principle, profoundly affect the preservation of both global and local environmental values associated with forests. These would appear to be strong policy levers affecting economic output and government revenue in forested countries. This project analyzes unique quasi-experimental data on logging from the District of South Terengganu in Peninsular Malaysia where the availability of pre- and post-felling forest inventories make it possible to disentangle the impacts of forest condition, logger characteristics, fiscal regime, and regulatory structures on harvesting decisions. The tasks of this research endeavor were (i) to analyze the performance of timber concessionaires with regards to extraction efficiency and adherence to quantifiable logging specifications using forest inventory data; (ii) to review the literature on usage of economic instruments in ensuring adherence to sound forest management practices; (iii) to formulate and refine the econometric approach for analyzing the role of selected economic instruments in influencing sound logging behavior; and (iv) to report and disseminate the findings.

The major findings of the study are highlighted below:

- Allocating forest compartments to long-term concessionaires can increase timber productivity but do not reduce logging damages.

- In terms of the use of fiscal measures to generate state revenue, raising the bidding or tendering of the area-based premiums, motivates higher harvesting rates.

- Raising harvesting rates would increase logging damages. However, without increasing productivity, concessionaire(s) may not have the incentive to comply with environmental regulations in forestry. Complying with good harvesting practices such as road specifications, increases production costs. Concessionaires have to find a source to compensate this loss.

This study was constrained by the availability of data that limited a wide coverage of sample points. Future studies should attempt to incorporate other districts to capture enough variability in factors influencing harvesting decisions and damage impacts.

1.0 INTRODUCTION

A decade ago, Repetto and Gillis (1988) attributed government policies for much of the economically inefficient and environmentally destructive use of tropical forests observed in developing countries. The book garnered considerable attention both inside and outside the research community. Emphasizing on timber concession policies, it argued that short and insecure concession agreements, combined with timber charges that are low, undifferentiated, and levied on extracted logs instead of standing timber, undermine incentives to minimize logging damage and maximize long-run timber values associated with sustainable forest management.

The book prompted a spate of studies that replicated and refined its analyses of ―rent capture": the ratio of government revenue to available resource rents. Several studies alluded that the logging compartment allocation system in South East Asia is attributed to low rent capture (Sulaiman 1977; Boado 1988; Gillis 1988; Vincent 1990; Vincent et al. 1993; Awang Noor et al. 1992). More recent notable studies along these lines included the works by the World Resources Institute in Suriname and Guyana (Sizer and Rice 1995; Sizer 1996). Arguments for longer concession agreements and increased rent capture were featured prominently in World Bank Forest Sector Assessments (World Bank 1991). Grut et al. (1991) advocated area-based premiums for concessions in Africa, to be determined at auctions. This recommendation was featured in the Bank's policy dialogue in the region. Gillis (1992) also advocated area-based premiums. The application of area-based premiums determined at auctions as against fixed premiums has raised the Government's ability to capture their fair share of the rent in Malaysia (Mohd Shahwahid and Awang Noor 1998). A recent report by Hyde et al. (1999) has warned against raising the forest royalties, which is a volume-based instrument whose success in raising rent capture is dependent in part on the elasticity of the marginal cost function. According to the authors, increases in the royalty are two-edged swords as even when government revenue collection is raised, the incentive to log illegally also rises. Volume-based instruments tend to discourage forest utilization and provide incentives for high grading. This further supports the use of area-based premiums.

However, the empirical base for these recommendations is very thin. Despite the abundant evidence of low rent capture, there is little empirical information on the behavioral impacts of changes in timber charges. There is still virtually no empirical evidence on which elements of a concession agreement—like its length, its renewability, how it allocates responsibilities between the concessionaire and the forestry department—has the greatest impact on concessionaire behavior. When one considers that the impacts of concession policies and regulations could well vary in forest types, market conditions, characteristics of the concessionaire, and the presence or absence of ‗informal' regulatory pressures from communities in and around the forest, our knowledge is even more limited than it seems.

The reason for this knowledge gap is that it is difficult and expensive to collect information on logger activities in remote forests. In many countries, agencies responsible for collecting this information are not able to do so. Furthermore, to analyze the impact of alternative policies requires that all other factors have to be constant. This is difficult to do in many countries, yet most countries have no internal variation in policies.

One approach to overcome this problem is to simulate policy impacts by coupling an economic model of logger behavior with an ecological model of forest growth. This is a promising approach because it allows assessment of a wide range of policies over multi-decade periods. Recently, Boscolo and Vincent (1997) presented findings that challenged some of the conventional wisdom. They found that long concession periods by themselves did not reduce forest damage; that minimum diameter limits on tree felling imposed significant opportunity costs in terms of forgone timber values, while yielding limited long-term environmental gains; and that very short-term concession periods, with renewal linked to observable performance indicators, may be preferable to performance bonds as a means of securing compliance with regulations. However, Walker and Smith (1993), using a stylized optimal stopping model, found that short-term renewability failed to secure compliance if discount rates were high.

Simulation approaches, however interesting, need to be validated against observations of actual behavior. It is for this reason that the proposed research is valuable, as it will exploit a unique quasi-experimental situation in Malaysia.

1.1 Malaysia as a Natural Experiment in Concession Policies

Malaysia provides a promising opportunity for conducting a rigorous empirical investigation of concession policy issues. The Malaysian constitution grants the 13 states of the Malaysian Federation considerable autonomy over forestry matters (Kumar 1986; Vincent et al. 1997). Although most states have ratified a common National Forestry Policy and National Forestry Act, they retained authority over the allocation of timber concessions and the establishment of concession terms, including timber charges. Some states allocate concessions by a closed-door administrative process, while others auction concession rights. In some states, most concession agreements amount to one-year harvesting licenses, while in others, agreements lasting several decades account for most of the areas licensed for logging. A few states with long-term agreements make the concessionaire responsible for certain forest management activities. The relative magnitudes of area charges (charges per hectare) and royalties (charges per cubic meter of extracted logs) vary across states. Royalties are relatively uniform across species in some states but sharply differentiated according to timber values in others. Monitoring and enforcement efforts by the State Forestry Offices (SFOs) also vary, due to differences in funding and staffing.

Within Malaysia, there is thus great variation in concession policies. Three other factors make Malaysia attractive for research on the impacts of concession policies. Firstly, much of the necessary data are available. The SFOs conduct inventories of individual concession compartments (annual cutting blocks) before and after logging. Data from inventories before logging (pre-felling, or pre-F inventories) enable one to control differences in forest characteristics, while data from inventories after logging (post-felling, or post-F inventories) enable one to infer differences in concessionaire behavior in terms of logging damage and compliance with logging regulations. Secondly, the logistics of data collection and interaction with relevant authorities are not unduly complex, especially if the study is limited to Peninsular Malaysia.

1.2 Relevance of the Malaysian Experience

While the Malaysian situation is not necessarily representative of logger behavior in all the tropical forests, it has direct relevance to the ecological and economic conditions prevailing in Southeast Asia, one of the world's main tropical forest areas and the source of most internationally traded tropical timber. This study illuminates the factors influencing logger behavior which will be of broad interest throughout the developing world.

1.3 Linkage of a Reduction in Logging Damage on Residual Trees to Environmental Benefits

Although the environmental impact of the logging behavior was not directly investigated in this study, it is well known that reduced logging damages to residual trees have a significant influence on various indicators of environmental disturbances. When damages to uncut trees is reduced, the remaining standing forest is healthier and provides more environmental services. Unfortunately data was unavailable for computation since it was not collected by the Forestry Department at the compartment level.

From the literature, it is known that environmental damage could be reduced by lower density logging which would indirectly decrease environmental impacts. Higher disturbance of the forest following unsupervised logging below the cutting limits increases erosion rates and accelerates surface runoff. This observation was verified when paired hydrological studies between unsupervised and supervised selective logging methods were conducted in Bukit Berembun, Negeri Sembilan in Malaysia (Baharuddin 1995; Zulkifli et al. 1990; Abdul Rahim et al. 1993). When standing trees extracted were reduced from 40% of stocking to 33%, and when buffer strips along rivers were set, there were evidences that the suspended solids and turbidity levels were less than that under unsupervised logging operations. Similarly, supervising logging operations along prescribed guidelines, including harvesting marked trees only, led to a decline in the number of trees harvested from 152 m^3/ha to 103 m^3/ha in Sabah. This decline in tree harvest led to the reduction in the proportion of area with soil disturbance (from 17% to 7%), skid trail density 199m/ha to 67m/ha, proportion of trees killed during logging (5-60 cm dbh) from 41% to 15% and increases in the density of undamaged Dipterocarp trees (5-20 cm dbh) from 49 to 104 (Pinard et al. 1995). All this information confirms the reduction in environmental damage from limiting harvest to prescribed marked trees only.

1.4 Forestry in Peninsular Malaysia

Investigating the behavior of concessionaires requires an understanding of the forestry management and trade in the country. Table 1 provides the basic statistics of the land area in Peninsular Malaysia. The total land area of Peninsular Malaysia is 13,162,314 ha, of which only 5,979,649 ha (45.4%) is forest. A large portion of the forest is further classified into a permanent forest reserve (PFR) that covers 4,837,500 or 80.9%. The rest of the forests is classified into Stateland, Wildlife Reserve and other reserve areas. The PFR is further classified into Productive forest for sustainable timber production, Protected forest and Amenity forest. A Stateland forest is a forestland earmarked for conversion into development projects.

Table 1. Land Area of Peninsular Malaysia, 2000

	Hectares
Land Area	13,162,314
Forested Area	5,979,649
-Permanent Forest Reserve	4,837,500
-Stateland	444,817
-Wildlife Reserve	650,302
-Other Reserved Area	47,030
Non-Forested Area	7,182,665

Source: Official files from the Forestry Department (2000)

One of the forest policies set in the country to promote sustainable timber production is the setting up of long-term agreement areas within each major forest resource state. In a long-term agreement area, the concessionaire would have a security of annual licensed compartment area for harvesting to be followed by rehabilitation activities if the forest is within the PFR to ensure a second cycle of harvesting in the next coupe some 30 to 35 years later. In the year 2000, the long-term agreement area was 1.3 million ha covering 21.7% of the total forestland. Within this agreement area, a total of 1.1 million ha or 86.3% was classified as PFR with the rest being Stateland (Table 2). The annual coupe for harvesting in this agreement area was 23,042 ha or 2% of the PFR portion of the agreement area, and 1,838 ha or 1% from the Stateland. At the end of 2000, 533,466 ha or 47.0% of the PFR portion of the agreement area had been harvested while 107,546 ha or 60.2%of the Stateland had been logged.

Table 2. The Status of Long-term Agreement Area, 2000

Forest Category	*PFR*	*SL*
Total Forest Area (ha)	1,134,768	178,533
Annual Coupe (ha)	23,042	1,838
Total Forest Logged (ha)	533,466	107,546

Source: Official files from the Forestry Department
Note: PFR = Permanent Forest Reserve
SL = Stateland

Table 3. The Status of Harvesting from Different Categories of Forest, 2000

Area Opened for Harvesting	*ha*
Permanent Reserved Forest	
1. Approved Annual Coupe	46,040
2. Harvested Annual Coupe Area	30,366
3. Development Purpose	2,684
4. Forest Plantation	762
5. Others	3,055
6. **Total** (2+3+4+5)	36,867
7. Stateland	47,193
8. Alienated Land*	35,804
Total Area Opened For Harvesting (6+7+8)	119,864

Source: Official files from the Forestry Department
* Alienated land is land owned by individuals

In the year 2000, the area opened for harvesting was 119,864 ha yielding on average 42.32m^3/ha. From this total area of forest opened, 30.7% were from the PFR, 39.4% from Stateland and 29.9% from Alienated land (Table 3). Within the PFR, a large portion of the forest area opened was from the annual coupe with minor contributions from areas opened for development purposes such as road construction, and forest plantations. An interesting observation is that the annual coupe was lower than the official approved annual coupe by 34%. This is part of the government‘s effort to compensate for excessive harvesting from PFR in previous decades particularly in the seventies and eighties.

Table 4 provides information on the trend of the annual coupe from the PFR. Annual coupes have been steadily declining in the Peninsular. This is part of the conservation strategy to ensure sustainable timber production.

Table 4. Annual Coupe in the Permanent Reserved Forests, Peninsular Malaysia

Malaysian Plan (MP)	*5th MP*	*6th MP*	*7th MP*
Period	1986-1990	1991-1995	1996-2000
Total (ha)	71,200	52,250	46,040

Source: Official files from the Forestry Department

The collection of forest revenues plays a dual function; as a source of State revenue and indirectly as an instrument to promote natural resource conservation. When the State is capable of raising sufficient revenue on a sustainable basis from conferring extraction rights to concessionaires and license holders, the State has more incentives to temporarily distribute forest openings and rehabilitate the forest to assure subsequent harvesting in future cycles. Forest revenues from timber harvesting were estimated to be MYR 293 million (USD 77.11 million) in the year 2000. State revenues from timber come in several forms: royalties or forest taxes, premium, silvicultural cess and penalties. The main source of State revenue was from forest premium, which was a kind of ‗lump sum sunk‘ cost to obtain the rights of log extraction. This premium generated 52.5% while royalties from log extraction provided another 22.6% (Table 5).

Table 5. Sources of State Revenue from Forestry, 2000

Royalties					
Sawlogs	*Others*	*Premium*	*Cess*	*Others*	*Total*
66,339 (22.6%)	11,712 (4.0%)	153,977 (52.5%)	36,341 (12.4%)	24,883 (8.5%)	293,252 (100.0%)

Source: Official files from the Forestry Department

Malaysian forest trees are predominantly from the family Dipterocarpaceae that contains various tree species. In the timber trade, timber is normally classified into two trade groups of Dipterocarps and Non-Dipterocarps. As there are a large number of tree species that vary in wood densities, these trees can be further classified into three wood density groups. Prices of log thus vary according to the different trade groups and wood densities. Table 6 provides a list of log prices by species in the year 2000. Depending on the quality of each forest stand, the average prices of logs would vary by the compartment and this may influence harvesting intensity.

Table 6. Log Prices by Species, 2000

Species	*MYR/m³*	*USD/ m³*
Balau	691	181.84
Balau Merah	634	166.84
Cengal	1,182	311.05
Merbau	723	190.26
Mixed Heavy Hardwood	407	107.11
Kempas	434	114.21
Keruing	545	143.42
Kapur	549	144.47
Mengkulang	599	157.63
Tualang	425	111.84
Mixed Medium Hardwood	402	105.79
Meranti Merah Tua	804	211.58
Meranti Merah Muda	732	192.63
Meranti Kuning	492	129.47
Meranti Putih	511	134.47
Meranti Merah	721	189.74
Mersawa	626	164.74
Sepetir	416	109.47
Nyatoh	647	170.26
Jelutong	579	152.37
Rubber/ *Hevea* Logs	89	23.42
Mixed Light Hardwood	402	105.79

Source: The Malaysian Timber Industry Board

When harvesting is from the PFR, felling is limited to prescribed tree diameter limits to ensure that only matured trees are harvested and advanced growth trees are left behind as residual stands to continue the cycle of timber production. Often the limits are in the range of 45 cm diameter at breast height (dbh) for Non-Dipterocarps while the Dipterocarps have a higher dbh cutting limit (ranging from 50 to 60 cm dbh depending on the tree stocks). Dipterocarps tend to be marked at a higher dbh limit because they have generally slower growth rates. Hence larger trees have to be left as residuals so that in the next cycle there will be sufficient stocks for harvesting. Foresters view sustainability in the context of continuity of timber supply rather than optimal present value benefits. There are situations where they incorporate economic considerations.

In the year 2000, the total log production in Peninsular Malaysia was 5.07 million m^3 of which 84% were from trees of diameter 45 cm and above (Table 7). Only a small proportion of trees were below this 45 cm diameter which was mainly from harvesting in Statelands and a few were from trees where the cutting limits may be set below 45 cm dbh in the PFR. However it is interesting to note that in Terengganu State, the study site, the proportion of trees belonging to log diameters less than 45 cm was 35% of the total (Table 7).

Table 7. Production of Logs by Diameter Class Size

Diameter of logs	*Cubic meters*	*Percentage*
National		
45 cm	4,260,062	84.0%
< 45 cm	812,088	16.0%
Total	5,072,150	
Terengganu		
45 cm	391,011	65.5%
< 45 cm	205,832	34.5%
Total	596,843	

Source: Official files from the Forestry Department

Table 8 shows that the peninsula-wide distribution of logs was mainly sourced from PFR and this trend is more prevalent in the state of Terengganu. This suggests that some portion of the logs harvested below 45 cm diameters were in fact from the PFR. The cutting limit is decided that the current cut would meet a certain targeted volume of commercial timber. In the event that the current coupe is poor in yield, the cutting limit can be lowered to accommodate a higher volume and an economic current harvest. This is one of the cases where economic consideration is incorporated in the system. The implication is then to delay the second cycle harvest for a longer period.

Table 8. Log Production by Forest Types, 2000

Forest Types	*Production Of Logs (Cubic meters)*	*Percentage* (%)
National		
Permanent Reserve Forest	2,957,880	58.4
Stateland	1,706,067	33.6
Alienated Land	408,203	8.0
Forest Plantation	-	-
Total	5,072,105	100.0
Terengganu		
Permanent Reserve Forest	385,750	64.6
Stateland	140,889	24.8
Alienated Land	70,204	11.8
Forest Plantation	-	-
Total	596,843	100.0

Source: Official files from the Forestry Department

Table 9 provides information on various wood products produced in Peninsular Malaysia. The total production of logs was estimated as 5 million m^3. Log export is banned. These logs together with log imports, produced 3.9 million m^3 of sawn timber, 0.2 million m^3 of veneer, 0.6 million m^3 of plywood, 0.4 million m^3 of wood mouldings and 9.5 thousand m^3 of block board. The external trade in wood products in Peninsular Malaysia was favorable with export earnings of MYR 3.657 million (USD 0.96 million) and imports of MYR 1,039 million (USD 273.42 million).

Tables 10, 11, 12 and 13 provide characteristics of the wood-based industry in Peninsular Malaysia. These tables describe the installed capacities, number of establishments, total investments and number of workers. This information is a good measure of the scale of operations of the mills utilizing the logs produced from the forest. They may be important explanatory variables to equations explaining the dependent variables of trees harvested or damaged.

Table 9. Timber Production from Peninsular Malaysia, 2000

	m^3
Production Logs	5,072,150
Sawn timber	3,928,657
Plywood	570,374
Veneer	187,710
Mouldings	416,955
Block board	9,458

Source: Official files from the Forestry Department

Table 10. Estimated Installed Capacity of Primary Wood-based Industries, 2000

Industry	*million m^3*
Sawmills	12.309
Plywood / Veneer Mills	1.955

Source: Official files from the Forestry Department

Table 11. Number of Major Wood-based Industries, 2000

Types of Mill	*Number*
Sawmills	667
Plywood / Veneer Mills	50
Mouldings Mills	157
Furniture, Wood Working & Joinery Factory	2,801
Blockboard Mills	12
Chipboard Mills	7
Moulded Particleboard Mills	5
Medium Density Fibreboard	7

Source: Official files from the Forestry Department

Table 12. Total Investment (Fixed Asset) of Selected Wood-based Industries, 2000

Wood-based Industries	*MYR('000)*	*USD('000)*
Sawmills	817,610	215,160.53
Plywood / Veneer Mills	569,916	149,977.89
Moulding Mills	392,267	103,228.16
Total	1,779,793	468,366.58

Source: Official files from the Forestry Department
Note: Fixed assets value at 31.12.1999

Table 13. Number of Workers in the Wood-based Industries

Wood-based Industries	*Number of Workers*
Sawmills	23,186
Plywood / Veneer Mills	9,464
Moulding Mills	7,168
Logging Industry	10,443
TOTAL	50,261

Source: Official files from the Forestry Department

2.0 RESEARCH OBJECTIVES

The objective of the proposed study is to investigate how regulatory and fiscal factors affect logging behavior in Peninsular Malaysia.

Within this framework, the principal hypotheses tested are:

- Area-based bidding or tender premiums will increase extraction rates and fiscal revenues but this may occur at the expense of damages to residual stand;
- Concession length has no effects on harvesting and damage rates;
- Higher royalties will reduce net incomes of concessionaires and decrease extraction rates, which may have the effects of either lowering or raising fiscal revenues; and
- Logging road specifications prescribed in the logging licenses can raise the cost of compliance, creating a strong incentive for non-compliance, and raise environmental degradation.

3.0 MODEL

The sections below on the model, data availability and econometric estimation issues are taken from Vincent et al. (1999).

The model focuses on timber harvest and logging damage in an individual concession compartment. The forest in the compartment is heterogeneous, with multiple species of trees in different diameter classes. The model assumes that the logger holds a one-year license for the right to harvest trees in the compartment. For this right, it has to pay a premium which is enforced either on a fixed area-based rate or based on an amount obtained through an auction. Furthermore, it assumes that the logger faces regulations that prohibit: (i) the harvesting of trees below specified minimum diameter cutting limits, and (ii) excessive logging damage. These regulations are, however, not implemented wholly for various reasons.

3.1 Variables and Functions in the Model

The $1 \times I$ vector $\mathbf{n}_k$ summarizes the structure of the forest in compartment k before logging. Each element in the vector, n_{ik}, gives the number of trees in class i, where class is defined on the basis of both species and diameter. For example, if there are five species and six diameter classes, then $I = 30$. The index i is defined such that $i = 1, \ldots, l$ represent classes below the minimum diameter cutting limit, while $i = l+1, \ldots, I$ represent classes above.

Similarly, $\mathbf{h}_k$ is a $1 \times I$ vector that gives the number of trees harvested in each class, h_{ik}; $\mathbf{p}_k$ is a $1 \times I$ vector that gives the market value of logs in an individual tree in each class, p_{ik}; and $\mathbf{r}_k$ is an $1 \times I$ vector that gives the royalties on logs in an individual tree, r_{ik}. Note that p_{ik} pertains to log price (price at the mill), not stumpage value (log price minus marginal logging cost). The logger‘s revenue net of timber fees is thus given by $(\mathbf{p}_k - \mathbf{r}_k)\mathbf{h}_k' - a_k$, where a_k is a scalar representing the premium (area-based fee). This expression ignores all taxes and fees other than royalties and premium. Other important charges (e.g., income tax) could be included via straightforward modifications of this expression and the profit expressions given below.

Total logging cost is a function of the number of trees harvested in different classes, $\mathbf{h}_k$; a scalar representing effort made by the logging company to minimize logging damage, θ_k; and a vector of exogenous variables, with uniform values across tree classes, related to characteristics of the compartment (e.g., average slope, forest road density, distance from mill) and the company (e.g., size, ownership), $\mathbf{x}_k^C$:

$$C(\mathbf{h}_k, \theta_k, \mathbf{x}_k^C)$$

$\partial C/\partial h_{ik} > 0$ and $\partial C/\partial \theta_k > 0$: cost is increasing in both harvest and effort to minimize logging damage. The effects of the variables in $\mathbf{x}_k^C$ vary.

An alternative specification would include logging damage directly in the cost function, analogous to models that include pollution as an unpriced factor of production in cost functions for industrial enterprises (Larson and Bluffstone 1997, p. 28). Denoting the number of trees damaged by logging by the $1 \times I$ vector $\mathbf{d}_k$, the cost function under this specification would be

$$C(\mathbf{h}_k, \mathbf{d}_k, \mathbf{x}_k^C)$$

where $\partial C/\partial d_{ik} < 0$. A cost function of this type directly indicates the costs to loggers of, say, regulations mandating reduced logging damage. Although this specification is attractive, we do not employ it, because very little data on logging costs are available in Peninsular Malaysia. The initial specification, $C(\mathbf{h}_k, \theta_k, \mathbf{x}_k^C)$, yields expressions that can be applied more readily to Peninsular Malaysian data.

The forestry department enforces two principal logging regulations. First, it penalizes the logger for violating the cutting limits. The size of the penalty is an increasing function of the number of trees harvested below the cutting limits:

$$Z^l(h_{1k}, \ldots, h_{lk})$$

where $\partial Z^l/\partial h_{ik} > 0$. The logging company perceives that its probability of being penalized is a function of not only the number of trees harvested below the cutting limits but also a vector of exogenous variables, again with uniform values across tree classes, related to characteristics of the compartment (e.g., terrain), the logging company (e.g., whether it is state-owned or private), and the SFO (e.g., the number of rangers per square kilometer of forest), $\mathbf{x}_k^l$:

$$\alpha^l(h_{1k}, \ldots, h_{lk}, \mathbf{x}_k^l)$$

where $\partial \alpha^l/\partial h_{ik} > 0$. The effects of the variables in $\mathbf{x}_k^l$ vary.

Secondly, the department penalizes the logger for damaging residual trees. The model is slightly more complicated than the model for cutting limit violations. The size of the penalty is an increasing function of the number of trees damaged, $\mathbf{d}_k$:

$$Z^d(\mathbf{d}_k)$$

where $\partial Z^d/\partial d_{ik} > 0$. The number of trees damaged in a given class is an increasing function of the number of trees harvested in all classes; an increasing function of the number of residual trees in the class in question; and a decreasing function of effort to minimize damage:

$$d_{ik} = d_{ik}(\mathbf{h}_k, n_{ik}-h_{ik}, \theta_k)$$

where $\partial d_{ik}/\partial h_{jk} > 0$ ($j = 1, \ldots, I$), $\partial d_{ik}/\partial(n_{ik}-h_{ik}) > 0$, and $\partial d_{ik}/\partial\theta_k < 0$. The perceived probability of being penalized is a function of the number of trees damaged and a vector of exogenous variables, $\mathbf{x}_k^d$, similar or identical to those for penalties related to the cutting limit:

$$\alpha^d(\mathbf{d}_k, \mathbf{x}_k^d),$$

where $\partial \alpha^d/\partial d_{ik} > 0$. The effects of the variables in $\mathbf{x}_k^d$ vary.

As indicated, damage in the model is defined solely in terms of damage to residual trees. Developing a broader ecological measure of damage would involve establishing relationships between tree cover and variables like fauna abundance, soil stability, etc.

3.1.1 Structural Equations for Harvest and Damage

The logging firm selects $\mathbf{h}_k$ and θ_k to maximize expected profit, which is the difference between revenue net of timber fees and the sum of logging costs plus expected penalties:

$$(\mathbf{p}_k - \mathbf{r}_k)\mathbf{h}_k' - a_k - C(\mathbf{h}_k, \theta_k, \mathbf{x}_k^C) - \alpha^l(h_{1k}, \ldots, h_{Ik}, \mathbf{x}_k^l)\, Z^l(h_{1k}, \ldots, h_{Ik}) - \alpha^d(\mathbf{d}_k, \mathbf{x}_k^d)\, Z^d(\mathbf{d}_k)$$

subject to:

$$d_{ik} = d_{ik}(\mathbf{h}_k, n_{ik} - h_{ik}, \theta_k)$$

$$h_{ik} + d_{ik} \leq n_{ik}$$

Following this, it is assumed that the second constraint is not binding: harvest decisions are interior solutions.[1] This might not be the case in practice. For example, loggers can be expected to harvest all commercial trees in larger diameter classes, and they would harvest more if more were available. We discuss the econometric implications of relaxing the assumption of an interior solution later.

The first-order condition for θ_k yields:

$$\partial C(\cdot)/\partial\theta_k = -\,\alpha^d(\cdot)\, \Sigma[\partial Z^d(\cdot)/\partial d_{jk}(\cdot)\ \partial d_{jk}(\cdot)/\partial\theta_k] - Z^d(\cdot)\, \Sigma[\partial\alpha^d(\cdot)/\partial d_{jk}(\cdot)\ \partial d_{jk}(\cdot)/\partial\theta_k]$$

where the sums are evaluated over $j = 1, \ldots, I$. Effort to minimize logging damage is optimized when the marginal cost of effort (the LHS) equals the marginal benefit (the RHS). The marginal benefit has two components. The first is the reduction in the penalty, while the second is the reduction in the probability of being penalized. This first-order condition implies that the structural equation for θ_k includes the following variables:

$$\theta_k = f^\theta(\mathbf{h}_k, \mathbf{n}_k - \mathbf{h}_k, \mathbf{x}_k^C, \mathbf{x}_k^d)$$

Note that we can substitute this into d_{ik} to obtain:

$$d_{ik} = f^d(\mathbf{h}_k, \mathbf{n}_k - \mathbf{h}_k, \mathbf{x}_k^C, \mathbf{x}_k^d)$$

This does not include p_{ik}, r_{ik}, or $\mathbf{x}_k^l$, whose effects are entirely captured by $\mathbf{h}_k$ (this will become clearer below). The fact that we do not observe θ_k thus does not prevent us from deriving an estimable specification for the equations predicting $\mathbf{d}_k$.

[1] Forestry regulations in Peninsular Malaysia permit interior solutions: loggers are allowed to leave standing up to 20% of the trees above the minimum diameter cutting limits. Some of these trees are reserved as mother trees to generate seeds for germination into new seedlings. Fruit trees are left behind to provide food for wildlife.

There are I first-order conditions for $\mathbf{h}_k$. The $I–l$ expressions for harvesting trees above the cutting limits have the form:

$i = l+1, \ldots, I$

$$p_{ik} = r_{ij} + \partial C(\cdot)/\partial h_{ik} + \alpha^d(\cdot)\sum[\partial Z^d(\cdot)/\partial d_{jk}(\cdot)\ \partial d_{jk}(\cdot)/\partial h_{ik}] + Z^d(\cdot)\ \sum[\partial\alpha^d(\cdot)/\partial d_{jk}(\cdot)\ \partial d_{ik}(\cdot)/\partial h_{jk}]$$

Again, the sums are evaluated over $j = 1, \ldots, I$. This expression implies:

$$h_{ik} = f^h(p_{ik}-r_{ik}, n_{ik}, \mathbf{h}_{k(j\neq i)}, \mathbf{n}_{\mathbf{k}(j\neq i)}-\mathbf{h}_{k(j\neq i)}, \mathbf{x}_k^C, \mathbf{x}_k^d, \theta_k)$$

Note that p_{ik} and r_{ik} enter this structural equation as $p_{ik}–r_{ik}$. Also note that the equation includes the harvesting of trees in classes other than i (i.e,, $\mathbf{h}_{k(j\neq i)}$) on the RHS.

For trees below the cutting limits, the l first-order conditions contain additional terms related to penalties for violating the cutting limits:

<u>$i = 1, \ldots, l$</u>

$$p_{ik} = r_{ij} + \partial C(\cdot)/\partial h_{ik} + \alpha^d(\cdot)\sum[\partial Z^d(\cdot)/\partial d_{jk}(\cdot)\ \partial d_{jk}(\cdot)/\partial h_{ik}] + Z^d(\cdot)\ \sum[\partial\alpha^d(\cdot)/\partial d_{jk}(\cdot)\ \partial d_{jk}(\cdot)/\partial h_{ik}]$$

$$+ \alpha^l(\cdot)\ \partial Z^l(\cdot)/\partial h_{ik} + Z^l(\cdot)\ \partial\alpha^l(\cdot)/\partial h_{ik}$$

which implies:

$$h_{ik} = f^h(p_{ik}-r_{ik}, n_{ik}, \mathbf{h}_{k(j\neq i)}, \mathbf{n}_{\mathbf{k}(j\neq i)}-\mathbf{h}_{k(j\neq i)}, \mathbf{x}_k^C, \mathbf{x}_k^d, \mathbf{x}_k^l, \theta_k)$$

This differs from the above by including $\mathbf{x}_{\boldsymbol{k}}^l$.

The structural equation for θ_k can be used to eliminate θ_k from the structural equations for number of trees harvested. This yields:

$$h_{ik} = f^h(p_{ik}-r_{ik}, n_{ik}, \mathbf{h}_{k(j\neq i)}, \mathbf{n}_{\boldsymbol{k}(j\neq i)}-\mathbf{h}_{k(j\neq i)}, \mathbf{x}_k^C, \mathbf{x}_k^d), \qquad \text{for } i = l+1, \ldots, I$$

$$h_{ik} = f^h(p_{ik}-r_{ik}, n_{ik}, \mathbf{h}_{k(j\neq i)}, \mathbf{n}_{\boldsymbol{k}(j\neq i)}-\mathbf{h}_{k(j\neq i)}, \mathbf{x}_k^C, \mathbf{x}_k^d, \mathbf{x}_k^l), \quad \text{for } i = 1, \ldots, l.$$

It is expected that $\partial h_{ik}/\partial(p_{ik}-r_{ik}) > 0$ and $\partial h_{ik}/\partial n_{ik} > 0$. There are no prior assumptions for the effects of changes in $\mathbf{h}_{k(j\neq i)}$ and $\mathbf{n}_{\boldsymbol{k}(j\neq i)}-\mathbf{h}_{k(j\neq i)}$ upon h_{ik}.

4.0 AVAILABLE DATA IN PENINSULAR MALAYSIA

According to the forest management code and procedure in many states, availability of data in Peninsular Malaysia should be adequate to apply the model developed above. However, after assessing the adequacy of these data on the ground, one of these procedures which is critical to the study was not recorded as mentioned. Data on post-felling inventory were not collected in the same format or detailed as in pre-felling inventory; hence an assessment of damage and harvesting was not possible. Information breakdown by diameter classes was not collected. Instead, a subjective reporting was given on the level of damage and the need for rehabilitation activities. No detailed data on trees belonging to the two categories, undamaged and damaged (including rotten trees) were available. However, throughout the country one district did collect this information in sufficient details for us to conduct the study. These data are described below and they are related to specific variables in the model.

4.1 Description of the Data

Data for individual compartments logged since the mid 1980s was compiled from the forest district of South Terengganu located on the east cost of the Peninsular. The study included forests managed under the Selective Management System (SMS), which covered mostly permanent forest reserve (PFR) logged since the mid-1980s. The status of the PFR has been reported in Tables 1-3.

Pre-F and post-F inventories provide most of the data needed for the study. Until the 1970s, most loggings in Peninsular Malaysia occurred in lowland forests. Logging shifted to hill forests as government agencies and private estates converted lowland forests to rubber and oil palm plantations. With the change in forest type, the Peninsular Malaysia Forestry Department switched its forest management system from the modified Malayan Uniform System (modified MUS) to the SMS. The SMS aims at creating a forest with two age classes and providing harvests every 25-30 years. It relies on medium-sized trees as the source of the next harvest and prescribes minimum diameter cutting limits that prohibit loggers from felling those trees. The pre-F inventories provide the data the Forestry Department needs to set minimum diameter cutting limits. The data include number of trees and basal area (total cross-sectional area of tree trunks) by species group and diameter class.

The Department conducts post-F inventories to determine the adequacy of stocking healthy trees after logging. The inventories record not only the number of live trees remaining in the compartment after logging (by species group and diameter class), but also damage, if any, to those trees. They also record the density of stocking of very young trees (seedlings and saplings) in sample plots within the compartment. The density of such trees is the most straightforward indicator of sustainability prospects (as those trees will form the future forest), and it is highly sensitive to the care taken during logging to minimize damage to standing trees and the disturbance of forest soils.

The pre- F and post-F inventories are the source of data on dependent variables included in the regression analysis. The dependent variables of interest are measures of trees harvested and trees damaged from the harvesting. The post-F inventories provide information on the number of residual trees by species group and diameter class. While the pre-F inventories provide information on the number of trees available by species group and diameter class prior to harvesting. Deducting this number of trees above the diameter class-cutting limit from the pre-F inventories by the number of trees from the post-F inventories of similar diameter classes can provide us with the information of trees harvested. Similarly deducting the number of trees below the diameter class cutting limit from the pre-F inventories by the number of trees from the post-F inventories of similar diameter classes can provide us with the information of trees damaged. It should be noted that the post-F inventories contain two species groups in this case (Dipterocarps and Non-Dipterocarps).

The license agreements for the concessions provided much of the data on the independent variables, but other sources were also consulted (e.g. the closing reports that are evaluation records of harvesting performance prepared by the SFOs at the conclusion of logging, and general records of the SFOs and the Forestry Department Headquarters). Some independent variables were different by compartment while others varied over time.

4.1.1 Pre-F and Post-F Data

The pre-F and post-F inventories were the source of data on n_k, h_k, and d_k. The SFOs conduct pre-F inventories one to two years before a compartment is logged. The inventories are based on a 10% systematic linear sampling system: temporary, 20 m (50 m sample plots equivalent in toto to 10% of compartment area are laid out in a rectangular grid (the distance between plots on a given sampling line is 100 m, and the distance between lines is 50 m). Inventory crews record the species and diameter at breast height (dbh; 1.5 m above the forest floor) of every live tree with a dbh of 15 cm or more. The Forestry Department Headquarters uses this information to calculate mean (per hectare) values of the number of trees, basal area, and timber volume by species and diameter class in the compartment.

The SFOs conduct post-F inventories 2-5 years after logging. These inventories are also based on a systematic linear sampling system, but the sampling intensity is lower. The inventory provides four types of data:

1. It gives the number and basal area of trees above 15 cm dbh remaining in the compartment after logging by 15 cm dbh classes (unrestricted for dbh > 90 cm). It divides these trees into two broad species groups, commercial and non-commercial. The Forestry Department maintains the list of species with commercial value. Currently, it includes 53 preferred species and 54 acceptable species. In comparison with the pre-F inventory, the post-F inventory provides additional subjective information on logging damage, but it offers less detail on species group and diameter class.

2. The post-F inventory provides similar data for pole-sized trees, i.e. trees in the 5-15 cm dbh class.

3. It provides data on the average number of undamaged saplings and seedlings per sample plot.

4. It divides them into commercial and non-commercial groups. The stocking density of poles, saplings, and seedlings is the most straightforward indicator of sustainability, as these smaller trees will form the future forest. It is highly sensitive to the care taken during logging to minimize damage.

Both the pre-F and post-F inventories provide data on trees with dbh > 15 cm, but the post-F data contain fewer categories. The pre-F data must therefore be aggregated across both species and diameter classes to yield a structure comparable to the post-F data. This aggregation yields twelve tree classes (i = 12): six diameter classes (15-30, 30-45, 45-60, 60-75, 75-90, and 90+ cm) and two species groups (commercial and non-commercial). The pre-F data on number of trees in these aggregate classes provide the data for n_k. The post-F data on number of damaged trees with dbh > 15 cm are only subjectively reported, hence the data for $\mathbf{d}_k$. is not available. What is available is the number of standing trees after felling. The number of harvested trees, $\mathbf{h}_k$, can then be imputed by the expression,

$$\mathbf{h}_k = \mathbf{n}_k - \text{Post-F data on number of undamaged trees.}$$

In principle, values of $\mathbf{h}_k$ calculated by this approach should always be non-negative. This might not be the case in practice, given that the data on the RHS are based on sampling and come from different pre-F and post-F sample plots. For the same reason, it is conceivable that some of the values in $\mathbf{h}_k$ could exceed corresponding values in $\mathbf{n}_k$.

Trees with dbh < 15 cm are too small to have commercial value in Peninsular Malaysia, so the post-F data on them should not be used in estimating $\mathbf{h}_k$. This is not possible anyway, as the pre-F inventories do not collect data on such trees; hence, data for $\mathbf{n}_k$ are not available. The damage function in the analytical model of logger behavior, which is for trees of commercial size but below the cutting limit, has the form

$$d_{ik} = f^d(\mathbf{h}_k, \mathbf{n}_k - \mathbf{h}_k, \mathbf{x}_k^C, \mathbf{x}_k^d)$$

where $\mathbf{h}_k$ and $\mathbf{n}_k$ pertain to trees with dbh > 15 cm.

The pre-F inventories will be the source of data on minimum diameter cutting limits. Cutting limits vary from compartment to compartment. They also frequently vary within a compartment between trees in the family Dipterocarpaceae, which includes many of the most valuable species in the Peninsular Malaysian forests, and trees in other plant families. They typically range from 45 to 60 cm. The dependent variable for the damaged function can be proxied or alternatively measured by the difference on the number of trees $\mathbf{n}_k$ with dbh below the cutting limits obtainable from pre-F and post-F inventories. A decline in the number of trees below the cutting limit suggests damages occurring during the logging operations on trees not marked for harvesting. Theoretically, this decline in the number of trees with diameters below the cutting limits could be caused by illegal felling. However, this is unlikely, since these trees are not marked trees or tagged trees. Logs extracted from the forests must have matching marked-tree tags.

As a move to avoid misspecifications of variables to measure the harvested and damaged trees, we used only number of trees rather than tree basal area or volume. From interviews with foresters and forest officers, the potential sources of error during inventory were mainly tree identification by species not by species groups, and scale measurements of tree diameters and heights. Relying on number of trees would reduce this problem.

4.1.2 Data on Prices and Timber Fees

In addition to data on $\mathbf{n}_k$, $\mathbf{h}_k$, and $\mathbf{d}_k$, the model requires data on $\mathbf{p}_k$, $\mathbf{r}_k$, a_k, $\mathbf{x}_k^C$, $\mathbf{x}_k^d$, and $\mathbf{x}_k^l$. A monthly publication of the Malaysian Timber Industries Board (MTIB), ‗Maskayu‘, includes regional data on log prices in the Peninsular. Log prices vary considerably across species, and they have fluctuated considerably over time.

The disaggregated price data can be combined with the pre-F data on timber volumes by species and diameter class to calculate weighted-average prices, (;) $\mathbf{p}_k$, for the aggregate classes in $\mathbf{n}_k$. Differences in forest composition will cause these weighted-average prices to vary across compartments.

The Forestry Department Headquarters periodically publishes information on royalty and premium rates. This information is also available from the license agreements for individual compartments, which are filed in the SFOs. Revenue shares for royalties and other volume-based fees[2] ranged from 19% to 52%. In Terengganu and other states, the area-based fee can either be imposed on a fixed premium or determined at auction (tender). License agreements give the tender price for compartments that are auctioned. As in the case of log prices, royalty rates by species can be combined with pre-F data on timber volumes by species and diameter class to calculate weighted-average royalties; $\mathbf{r}_k$, for the aggregate classes in $\mathbf{n}_k$.

4.1.3 Data on Factors Affecting Logging Costs

Numerous factors affect logging costs. Information on basic ‗forest characteristics‘ like forest type and average slope, is available for individual compartments from the pre-F inventories. Information on ‗market characteristics‘ that affect hauling costs is available for individual compartments from SFO maps (for example, distance to nearest major road).

Information on ‗characteristics of the license-holder‘ (concessionaire)—for example, whether the license-holder is a private or public enterprise (or individual), conducts the logging operations itself or hires a logging contractor, and uses labor-intensive or heavily mechanized logging techniques—is available from the license agreement. Information on ‗formal regulatory factors‘ like the length of the license agreement (license-holders with longer agreements may be more likely to build higher quality roads), the concession allocation mechanism (competitively allocated logging rights might ―squeeze out" less efficient operators), and the allocation of forest management responsibilities (allocating more responsibilities to the license-holder raises his costs) is also available for individual compartments from the license agreement.

Additional information on whether the concessionaires own any other businesses related to timber production can also be collected from the District Forest Office that have records on owners of wood-related industrial licenses. This is to ensure that the

[2] For example, in addition to royalties, all states collect a silvicultural cess that is earmarked for forest management. Its rate is low compared to royalty rates.

concessionaires are part of a vertically or horizontally integrated company that may be harvesting data for reasons other than maximizing profits from the unit.

Although direct data on logging costs are not available, inclusion of these factors in the harvest equations as $\mathbf{x}_k^C$ should capture most of the factors responsible for differences in logging costs across compartments and over time.

4.1.4 Data on Factors Affecting Probability of Being Penalized

Information on license-holder characteristics (politically connected concessionaires are less likely to be penalized) and formal regulatory factors (penalties are more likely to be assessed if more forest rangers are on the ground) is available from the SFOs. SFO staffing levels are relatively proportionate to forest management responsibilities and these differ considerably among states. However, since the data available was from one district only, the number of forest rangers is constant. Furthermore, a check on the closing reports that were prepared within a year after completion of timber harvesting all showed that no penalty was imposed for damages upon residual stands, Hence no information is available to describe the penalty variable.

4.1.5 Data on the Compartment

Data describing the characteristics of the compartment are available from the license and from records of the District Forest Office. These include compartment area, altitude, slope, distance from nearest public road, and length of forest roads and status of the compartment whether they are ‗virgin' or ‗logged'. The length of forest roads within a compartment that the concessionaire is allowed to build is a logging specification earmarked in the forest licenses, hence is a policy variable that may have an influence on logger's behavior.

5.0 DATA COLLECTION

The criteria for the selection of district for data collection are as follows:

- a district where both short-term and long-term concessions were allocated
- a district where data on pre- and post-felling inventories, closing report and compartment report were available and accessible.
- a district where the District Forest Administration is cooperative.

These criteria were more demanding than we had initially expected. Despite traveling round the country, only the administration of the District Forest of South Terengganu could fulfill the above criteria. The fact that many international agency sponsored research projects were conducted here makes the record keeping in this district more reliable. Data were collected from 40 forest compartments covering Cherul Forest Reserves, Sungai Nipah Forest Reserve, Jengai Forest Reserve, Jerangau Forest Reserve, Rasau Kertih, and Pasir Raja Selatan Forest Reserve. Despite the preparation of the various reports, only 18 compartments have all the reports simultaneously intact. The other 20 compartments have at least one of the necessary reports misplaced. It should be noted that data collected were not regularly referred after the forest operations were completed. Other than for making decisions on post-felling forest rehabilitation activities, much of the data collected were seldom utilized. The up-keep of the records was not satisfactory.

6.0 CONSTRAINTS OF DATA AVAILABILITY ON THE EMPIRICAL MODEL ESTIMATION

Field investigations provided important feedbacks on data actually collected. The Pre-F Inventory data on number of trees in accordance with aggregate diameter classes from sapling sizes were available and provided the data for $\mathbf{n_k}$. A critical omission occurred in the Post-F Inventory. In theory, the Post-F Inventory should have collected data on the number of damaged trees with dbh > 15 cm. This would have contributed the data for $\mathbf{d}_k$. These data were not available. Instead the Post-F Inventory provided number of undamaged trees only ($\mathbf{ud}_k$).

But these undamaged trees ($\mathbf{ud}_k$) not only referred to survival of residual trees but a small component could be marked trees remaining unfelled. The occurrence of illegal felling of trees below the cutting limits was not verifiable. Theoretically, information on illegally felled trees with dbh below the cutting limit would be reported in the closing report for which penalties would be imposed. From the 40 compartments, only one compartment reported the occurrence of such illegal operation. Instead, many trees were left unfelled if they belonged either to species fetching low prices or if assessed to be damaged or with hollow logs. Previously, the loss in royalty collections was assessed and charged. The Forestry Department has done away with this practice with the argument that it would be favorable to the State if the trees remained standing and that there will be more trees left for subsequent harvesting. Nevertheless, given that licensees have made advanced premium payments, it was more likely that very few marked trees remained unfelled and it can be concluded that $\mathbf{ud}_k$ in most cases are survived residual trees.

Nevertheless, information on the number of damaged trees for trees $\mathbf{d}_k$ within the classes‘ 15cm dbh and the cutting limits can be estimated from

$$\mathbf{d}_k = \mathbf{n_k} - \mathbf{ud}_k + \mathbf{f}\ \mathbf{ud}_k$$

where f is the logging damage factor upon residual trees with diameters below the cutting limits. During harvesting, residual trees may be damaged either in its natural form such as hollow trunk or knots, or from the impact of falling trees. A tree is considered damaged if it sustains moderate to severe stem and or crown damages. A stem damage tree may range from mere natural pre-logging damage to severe damage from inclined stems pushed by falling trees with barks ripped off. While a crown damage ranges from a small diameter branch broken off to severe crown damage with all branches broken off. Stem and crown damage factor increases with rising diameter classes. Several studies on logging damages have been conducted in Malaysia. Studies by Yong (1990) at Gunung Tebu Forest Reserve indicated that the overall logging damage increased from 40.75%, to 41.75% and 49.12% for trees in diameter classes 5-15cm, 15-30cm and 30-45cm respectively. Similar trends were observed by Chung (1992) who observed logging damage percentages ranging from 41% to 47% for diameter classes from 5 cm to 45 cm; Canonizado (1978) who estimated 64% damage for trees from 30-50 cm diameter classes at Jengka. Studies by Fox (1968) reported a logging damage of 68-75% for the lowland Dipterocarp forest in Sabah. Liew and Ong (1986) obtained an overall logging damage of 68-72% for the mixed Dipterocarp forests in Sarawak. In this study, a logging damage factor (f) of 41.75%, 49.12% and 60% for trees in diameter classes 15-30cm, 30-45cm and > 45cm were used respectively.

Information on harvested trees is available from the following:

$$\mathbf{h}_k = \mathbf{n}_k - \mathbf{d}_k - \mathbf{ud}_k$$

$\mathbf{n_k}$ is obtained from the Pre-F Inventory data on number of trees for diameter classes above the cutting limits at each compartment. $\mathbf{ud}_k$ is obtained from the Post-F Inventory data on number of undamaged trees at each compartment. As mentioned, the Post-F Inventory does not record the number and volume of damaged trees above the cutting limit ($\mathbf{d}_k$). The number of damaged trees can be indirectly assessed in two ways.

One is from the difference of the number of undamaged trees ($\mathbf{ud}_k$) above cutting from the rule of thumb of 32 residual healthy marketable trees. In the production forest reserves within the PFR where logging is permitted, selective logging based on the Selective Management System (SMS) is practiced. This system attempts to prescribe cutting regimes that yield an economically viable harvest volume while leaving sufficient residual trees of advanced regeneration to ensure future harvests at intervals ranging from 30 to 35 years. In practice, the SMS is implemented by setting minimum-diameter cutting limits for Dipterocarp and Non-Dipterocarp trees and by analyzing data from Pre-F inventories. Cutting limits typically are no lower than 50 cm dbh for Dipterocarps and 45 cm dbh for Non-Dipterocarp timber species. Minimum residual stocking is also required, which should not be less than 32 marketable trees of good quality from diameter class 30 to 45 cm or its equivalent per ha.

The disadvantage of using the 32 trees marketable residual tree convention, is that loggers could have taken a strategic decision of not harvesting trees not deemed unprofitable to fell. Yet, these unfelled trees could have been assessed as being among the 32 marketable residual trees.

The second way is to assess the logging damage upon residual trees by relying upon logging damage percentages from the literature. This is the approach adopted in this study. Information on the number of damaged trees ($\mathbf{d}_k$) can be computed for those classes above the cutting limits from

$$\mathbf{d}_k = \mathbf{f}\ \mathbf{ud}_k$$

where f is the logging damage factor upon residual trees with diameters at and above the cutting limits

As expected, trees with dbh < 15 cm are available from the Pre-F Inventory but not from Post-F Inventory data. Hence, econometric estimation will focus only on the harvest and damage equations for trees above and below the cutting limits, not for poles, saplings, or seedlings. Owing to the limited data points from the 18 compartments, only aggregated damage and harvest equations were estimated. This leads to the estimation for only one damage equation for trees below the cutting limit and a harvest equation for trees above the cutting limits.

7.0 EMPIRICAL HARVEST AND DAMAGE FUNCTIONS

The empirical harvest function [$h_k = f^h(p_{ik}-r_{ik}, n_{ik}, \mathbf{h}_{k(j\neq i)}, \mathbf{n}_{k(j\neq i)}-\mathbf{h}_{k(j\neq i)}, \mathbf{x}_k^C, \mathbf{x}_k^d)$] and damage function [$d_{ik} = f^d(\mathbf{h}_k, \mathbf{n}_k-\mathbf{h}_k, \mathbf{x}_k^C, \mathbf{x}_k^d)$] to be estimated are subjected to availability of data. Even when the data of these variables are available, they may be highly correlated since one can be a linear transformation of another. Hence, the empirical model may have a smaller number of independent variables.

The variables are not categorized into diameter classes as described in the theoretical model. This is done to avoid situations where data on number of trees in the post-felling inventories exceeding the data on number of trees from the pre-felling inventories. The post-felling inventories are done several years after the pre-felling inventories enabling some trees from a lower diameter class to enter a higher diameter class. The number of trees harvested variable is computed by deducting the number of trees available from the post-felling inventories from that of the pre-felling inventories. Hence this variable can be negative. Aggregating across diameter classes, avoids this situation.

7.1 Harvesting Function

The empirical harvesting function is

$$h_{mk} = f^h(p_{mk}-r_{mk}, n_{mk}, h_{k(n\neq m)}, n_{k(n\neq m)}-h_{k(n\neq m)}, prem_k, alt_k, slp_k, secrd_k, dur_k, dist_k, ltc_k, spgrp_m)$$

where

h_{mk} is the number of trees from species group m (Dipterocarp or Non-Dipterocarp) harvested per ha from compartment k;

n_{mk} is the number of trees available standing per ha prior to harvesting operations above the cutting limit for each of the Dipterocarp and Non-Dipterocarp group m from compartment k;

$h_{k(n\neq m)}$ is the number of trees above the cutting limit harvested except for the trees from species group m from the compartment;

$n_{k(n\neq m)}-h_{k(n\neq m)}$ is the number of trees not felled that becomes the residual stand;

$p_{mk}-r_{mk}$ is the net value of species group m from compartment k to the concessionaire. It is computed as log price of species minus royalty payments;

$prem_k$ is the premium payments for compartment k;

alt_k is the altitude of compartment k;

slp_k is the slope of compartment k;

$secrd_k$ is the length of the secondary road in the compartment per ha;

dur_k is the duration of the harvesting operation at the compartment;

$dist_k$ is the distance from compartment k to the mill;

ltc_k is a dummy variable signifying that the licensee is a long term concessionaire;

$spgrp_m$ is a dummy variable signifying species group (1=Dipterocarp and 0=Non-Dipterocarp).

The coefficient for n_{mk} is expected to be positive. The number of trees harvested is dependent on the available number of trees from that species group in the compartment.

To know the sign of the coefficients for the variables $h_{k(n \neq m)}$ and $n_{k(n\neq m)}-h_{k(n\neq m)}$ would require an understanding of the significance of these variables in the context of the forest management system adopted. When a logging concessionaire or his contractor has freedom of selection of trees to fell, he may have to consider other trees he has already felled. Economically, he has to consider the marketability of the current tree to be felled vis-a-vis those already cut down. In this respect, as more trees are felled, the incremental incentives to fell are diminished. But under the current practiced forest management, trees above the cutting limit have been pre-marked for felling and the logging crew or the contractor is obliged to carry out the felling task to avoid being penalized. Hence, as more marked trees are available, the higher will be the harvesting rate. It can be expected that the coefficient of the variable $h_{k(n \neq m)}$ is positive.

In the case of $n_{k(n\neq m)}-h_{k(n\neq m)}$ which is the number of trees not felled that become the residual stand, the consideration is relatively clear cut. A larger residual stand indirectly required a smaller number of trees marked for harvesting. Hence, the larger the residual stand density, the lower would be the harvesting rate. The coefficient of $n_{k(n\neq m)}-h_{k(n\neq m)}$ is expected to be negative analogous to a stock externality.

The coefficient of the net value of species group m ($p_{mk}-r_{mk}$) from compartment k to the concessionaire is expected to be positive. This single variable represents several influential factors of harvesting namely, prices of logs, and any variable cost of felling including payments of government taxes like royalties. Harvesting and the extraction of timber from Malaysian forests require a permit and a transfer right. To obtain these, concessionaires pay a forest premium for the extraction rights, a royalty as a tax and a silvicultural cess for eventual use by the Forestry Department to rehabilitate the degraded forest. But premium payments are not deducted in the computation of $val_{ik.}$ When val_{ik} rises, the sources for this increment can be due to an increase in log prices or a decline in any variable costs including royalties and silvicultural cess. As $p_{mk}-r_{mk}$ is raised, the profitability of harvesting an additional tree rises. This serves as an important incentive for concessionaires through their contractors to fell more trees.

Premium payments for acquiring the rights to harvest the compartment k ($prem_k$) are advanced lump sum payments, which are determined either through a tender process or in some cases at an administered rate. Either case, premiums are paid in advance. It is in the interest of contractors to extract as many marked-trees as possible having made payments. Hence, it is anticipated that the coefficient for this variable would be positive.

Concessionaires through their contractors have an interest to extract those timbers whose stumpage value exceeded the marginal cost of extraction. The potential impact of both these forms of payment upon timber extraction, works in opposite directions. A premium is anticipated to raise timber extraction while a royalty theoretically makes contractors more selective in their extraction. However, since the current royalty rates only vary slightly among species and their rates only take up a small proportion of timber prices (<10%), extractions are rarely selective.

Harvesting is influenced by the characteristic of the compartment. Important characteristics of the compartment that have a direct effect on harvesting productivity and harvesting techniques are the altitude and slope. High altitudes especially at hill ridges are normally dense with trees but tree density declines at the slopes of the compartment. Hence the coefficient of the compartment altitude is expected to be positive. Slope can influence forest management in two ways. Harvesting in sloping areas may (i) cause more damage to residual trees and (ii) lead to less road construction owing to the technical difficulty. Hence, with access limited to more sloping areas under current harvesting system, number of trees harvested would be curtailed from that compartment. It is anticipated that the coefficient for the compartment slope would be negative.

Road construction is an essential operation during harvesting as it determines access to the timber for extraction. Two main roads are constructed in a compartment: (i) main road for access within the compartment and (ii) secondary road to facilitate skidding of logs from the stumps. It is conjectured that the longer the main road and the greater the secondary road, the higher is the access to trees for extraction and skidding. On the other hand, with more roads built, the risk of damages to residual trees is greater. It is anticipated that the coefficient for the proxy variable for road, the length of the secondary road in the compartment, would be positive.

Another important factor that could influence tree harvesting is the duration of the harvesting operation. The longer the period, the greater is the opportunity for contractors to extract the timber. But it is the interest of the contractors to reduce field duration to cut costs on food allowances and loan services. The coefficient of this variable is expected to be positive.

The distance from the compartment to the mill could influence the quantity of trees harvested. There is a certain threshold distance beyond which certain trees are not economically harvested. The coefficient of this variable is expected to be negative.

The characteristics of the concessionaire have an influence on logging behavior. A long-term concessionaire has a large block of forest to manage. This long-term concessionaire is required to manage the forest on a sustainable basis. There is no incentive to “cut and run” to another harvesting site or compartment and if this is attempted it would be penalized. This means harvesting operations have to abide with approved management practices during harvesting and after felling rehabilitation practices. Hence, a long-term concessionaire is more secure in terms of harvesting areas and would practice good harvesting husbandry to prevent incurring excessive post-felling management costs. He would have the interest to practice selective felling to ensure sufficient residual timber trees for the next harvesting cycle. The concessionaire would have a long-term view and would be planning for an assured long-run profit. Hence, it is anticipated that the variable long-term concessionaire would have a negative coefficient.

7.2 Damage Function

The empirical damage function to be estimated is

$$d_{mk} = f^{d}(h_k, n_k – h_k, prem_k, alt_k, slp_k, secrd_k, dur_k, ltc_k, spgrp_m)$$

where

d_{mk} is the number of trees damaged due to harvesting belonging to species group m (Dipterocarp and Non-Dipterocarp) from compartment k;

h_k is the total number of trees harvested from compartment k;

$n_k – h_k$ is the number of residual trees from all dbh class (both above and below the cutting limits) from the compartment.

The number of damaged trees is very much influenced by the number of trees harvested from the compartment. To know the coefficient for the variable h_k requires an understanding of the significance of this variable. Every time a large tree is felled, other trees whose crowns are entangled with it would also be pulled down. Trees are entangled at the crown level and climbers and creepers enmeshed at the branches of these trees together make it more difficult for felling. When several trees are pulled down, they will drag along neighboring trees, saplings and seedlings. Many other standing trees would incur broken branches or other injury. Hence, it is anticipated that the coefficient for h_k would be positive.

The number of trees damaged is also dependent on the density of residual trees, $n_k – h_k$ (i.e. the number of trees not harvested). The higher the density of the residual stand, the greater will be the number of trees that are damaged or injured by trees felled. Hence, it is expected that the coefficient of the number of residual tree variable would also be positive.

The role of the premium variable on number of trees damaged relates to the premium being an advanced payment. As long as profitability is the sole motive of harvesting and the premium is pre-paid, contractors would take efforts to extract as much timber as possible with the least amount of expenditures. This implies that contractors would, as far as possible, not indulge in precautionary or prescribed harvesting operations, like observing directional felling and pre-felling or cutting of climbers and creepers, which delay felling operational time. In reducing costs and raising profitability, there will be more damage to residual stand. This will happen especially if the concessionaire takes a short-term view of the harvesting operation. Any extra conservation effort and expenditure would not guarantee the concessionaire an automatic license in the future. However, if the concessionaire takes a long-term view, the situation would be reversed. Hence, it is expected that the coefficient for the variable $prem_k$ would be positive.

Tree damage is also influenced by the characteristics of the compartment. The important characteristics of the compartment that have a direct effect on tree damages are altitude and slope. Hill ridges at high altitudes are normally dense with trees. Attempts to fell these trees and transport them out would require a network of forest road construction. The high density of roads in the compartment will result in more losses of un-marked trees for harvesting. Hence the coefficient of the compartment altitude is expected to be positive.

The status of tree damages at sloping areas is not perfectly clear. In sloping areas where road construction and felling are hampered, damage is minimal. This would likely occur in very high slopes. However, in areas where the slopes are manageable, the harvesting intensities would lead to rising numbers of damages to residual trees. It is anticipated that the coefficient for the compartment slope would be positive.

Under the current harvesting system, the intensity of road construction can determine harvesting productivity and damages to residual stands. As mentioned earlier, roads are constructed at two levels: (i) main road for access within the compartment and (ii) secondary road to facilitate skidding of logs from the stumps. As more roads are built, there is a greater risk of damages to residual trees. It is anticipated that the coefficient for the length of road in the compartment would be positive.

Another important factor that could influence logging damages is the duration of the harvesting operation. If the forest is opened to harvesting operations for longer periods, the physical contact of the forest with logging equipments and crew will be greater. There is a greater risk that the compartment will be degraded. When harvesting operations get extended into the wet season, the logging roads get very muddy requiring detours that would damage more forest areas. The coefficient of this variable is expected to be positive.

The characteristics of the concessionaire have an influence on logging damage. A long-term concessionaire has a long-term view of harvesting, extending into future cycles. As mentioned earlier, the long-term concessionaire is required to manage the forest on a sustainable basis. The long-term concessionaire has an incentive to practice good harvesting husbandry and to prevent incurring excessive post-felling activities. He would have the interest to practice selective felling to ensure sufficient healthy residual timber trees for the next harvesting cycle. Hence, it is anticipated that the variable long-term concessionaire would have a negative coefficient.

8.0 RESULTS

8.1 Descriptive Statistics of the Variables Used in the Analysis

8.1.1 Harvesting Function

Table 14 provides the descriptive statistics of the variables used in estimating the harvesting function.

Table 14. Mean and Standard Deviation of Variables in Harvesting Function

Variables	*Mean*	*Std. Deviation*
h_{mk} (number of trees)	6.89	5.35
n_{mk}(number of trees)	9.57	5.32
$h_{k(n \neq m)}$(number of trees)	6.41	4.90
$n_{k(n \neq m)} - h_{k(n \neq m)}$, (number of trees)	88.47	52.90
$p_{mk} - r_{mk}$ (MYR/m^3)	149.07	67.01
alt_k(m)	162.03	70.94
slp_k (degree)	20.94	7.03
$secrd_k$ (m/ha)	89.09	70.87
dur_k (days)	444.76	265.26
$dist_k$ (km)	53.31	43.39
$prem_k$(MYR/ha)	118.07	138.73

Note: The mean compartment area was 306 ha
3.8 MYR = 1 USD

The number of trees actually harvested per compartment depends on the cutting limit set for the compartment and the number of trees available prior to felling (n_{mk}). The cutting limits by compartment vary, depending on stand densities of Dipterocarps and Non-Dipterocarps prior to felling. Cutting limits are set to ensure sufficient residual trees to continue future harvesting cycles while requiring a minimal economic cut that is attained at current harvesting. Since, on an average the annual growth rates of Dipterocarps are smaller than Non-Dipterocarps, there is a gap in the cutting limits between these two timber categories with the limit slightly higher for Dipterocarps than Non-Dipterocarps. The cutting limits for the compartments selected range from the following:

- 50 cm dbh for commercial Dipterocarps and 45 cm dbh for Non-Dipterocarps
- 55 cm dbh for commercial Dipterocarps and 45 cm dbh for Non-Dipterocarps
- 55 cm dbh for commercial Dipterocarps and 55 cm dbh for Non-Dipterocarps
- 60 cm dbh for commercial Dipterocarps and 45 cm dbh for Non-Dipterocarps
- 60 cm dbh for commercial Dipterocarps and 50 cm dbh for Non-Dipterocarps
- 60 cm dbh for commercial Dipterocarps and 55 cm dbh for Non-Dipterocarps

8.1.2 Logging Damage Function

Logging damage function is conducted on data of forest stand below the cutting limits. Table 15 provides the descriptive statistics of the variables used in estimating the logging damage function.

Table 15. Mean and Standard Deviation of Variables in Logging Damage Function

Variables	*Mean*	*Std. Deviation*
d_{mk} (number of trees)	30.60	36.63
h_k(number of trees)	20.86	11.42
n_k–h_k (number of trees)	93.63	56.70
alt_k(m)	162.03	70.94
slp_k (degree)	20.94	7.03
$secrd_k$ (m/ha)	89.09	70.87
dur_k (days)	444.76	265.26
$prem_k$(MYR/ha)	118.07	138.73

Note: The mean compartment area was 306 ha
3.8 MYR = 1 USD

8.2 Estimates of the Harvesting and Logging Damage Function

8.2.1 Harvesting

A logarithmic function was estimated as the coefficient would directly provide us with elasticity figures. This function was first estimated using ordinary least squares estimation method. A plot of the residual errors and the predicted values of the number of trees harvested showed a distribution with a potential heteroschedasticity problem (Appendices I and II). A weighted least squares estimation was attempted using the reciprocal of the natural logarithm of the number of standing trees above the cutting limit per ha for each of the Dipterocarp and Non-Dipterocarp group m from compartment k (log n_{mk}) as weights to correct for the suspected heteroschedasticity problem. Initially all the independent variables mentioned in the empirical model were nested. Variables that were not statistically significant at the 10% level and were found to be highly correlated were dropped. Nevertheless, variables that were deemed to have policy relevance were retained to at least provide information on their level of influence upon the variation in the level of harvesting rates. The total number of samples was 34 (i.e. 17 compartments split into Dipterocarp and Non-Dipterocarp species group).

Table 16 provides the estimates of the harvesting function for forest compartments in the district of South Terengganu, Malaysia. The specification selected did provide a reasonable good fit with several significant coefficients, significant F statistic that measures the overall fit, and high R^2 that indicates the independent variables, provided substantial variations of the dependent variable. The Durbin Watson (D.W.) test statistic for the OLS estimates did fall within the lower and upper bounds of the 5% points of the Durbin-Watson Test Statistic of $d_L = 1.15$ and $d_U = 1.81$ for the number of elements of the parameter vector that includes the constant term, K>6 and the number of samples, n=34. Hence, the hypothesis of no first order serial correlation was rejected. Data used in this analysis were obtained from compartments opened during the eighties and early nineties with certain years having more compartments than other years. The D.W. test statistics for the WLS estimates did not fall within the above limits and the hypothesis of no serial correlation can be accepted.

Seven independent variables; the number of standing trees above the cutting limit per ha for each of the Dipterocarp and Non-Dipterocarp group m from compartment k (n_{mk}); the number of harvested trees above the cutting limit except for the trees from species group m from the compartment ($h_{k(n\neq m)}$); length of the secondary road in the compartment per ha ($secrd_k$); duration of the harvesting operation at the compartment (dur_k); premium payments for compartment k ($prem_k$); dummy variable signifying whether the licensee was a long term concessionaire (ltc_k); and dummy variable signifying species group ($spgrp_m$) were found to be statistically significant in explaining the rate of harvesting (h_{mk}) at various levels of statistical significance for the WLS estimated function. This estimated function was able to explain some 97% of the variation of harvesting rates. The function suggested that many factors could influence the total number of trees harvested.

Harvesting rate was influenced at the 1% level of significance by the overall stock density prior to harvesting, the number of other trees above the cutting limit harvested, status of owning a long-term concession, and forest premiums paid. Other influential factors included the duration of harvesting activities and the density of the secondary road in the compartment. Empirically, the variable $n_k - h_k$ that measured the residual stand did not contribute to explaining harvesting decisions and was dropped. No matter how dense the residual stand, felling decision was limited to the trees above the cutting limit.

The coefficients obtained from the logarithmic functional form provided us directly with the information on harvesting elasticity with respect to the variables. The estimate of the harvesting elasticity with respect to pre-felling tree density of 0.95, suggests that for every 1% increase in the mean tree density above the cutting limit, there would be an increase of 0.95% in the harvesting rate. Another way to look at it is, if there were an extra tree to harvest, that tree would necessarily be felled. Failure to do so would lead to a penalty. If the trees harvested were measured in terms of volume basis, then this coefficient could also be interpreted in this light. If there is 1 m^3 of tree marked for harvesting, 95% or 0.95m^3 of that tree could be utilized with 5% or 0.05 m^3 being wasted due to damages during harvesting.

Table 16. Estimation of a Harvesting Function of a Forest Compartment for Trees above the Cutting Limit

Variable	*OLS Coefficient*	*WLS Coefficient*
Constant	-3.812 (-3.65)***	-3.447 (-3.62)***
Natural logarithm of the net value of species group m [log $p_{mk}-r_{mk}$]	0.294 (1.34)	0.159 (0.96)
Natural logarithm of number of trees of species group m prior to harvesting [log n_{mk}]	0.778 (6.17)***	0.949 (7.27)***
Natural logarithm of number of trees harvested except from species group m [log $h_{k(n\neq m)}$]	0.095 (0.85)	0.264 (2.91)***
Natural logarithm of premium payment [log $prem_k$]	0.330 (2.98)***	0.251 (2.58)***
Natural logarithm of length of the secondary road [log $secrd_k$]	0.177 (1.86)*	0.166 (1.75)*
Natural logarithm of duration of harvest [log dur_k]	0.564 (2.29)**	0.291 (2.08)**
Dummy variable for long term concession licensee [ltc_k]	-1.548 (-3.73)***	-.473 (-3.57)***
Dummy variable for species group m [$spgrp_m$]	.181 (1.19)	.163 (1.86)**
N	34	34
F statistics	26.82***	114.67***
R^2	0.89	0.97
Adj R^2	0.86	0.96
D.W.	1.51	1.95

Figures in brackets are the t statistics
***,** and * at 1%, 5% and 10% significant levels

This finding underestimated the level of wastage due to breakages and bucking. Griffin and Caprata (1977) estimated 6.5-8.0% waste level and even this was a low estimate of overall wastage to gross timber. The reason is that no consideration was made of trees not harvested on account of hollow trunk, a situation quite common in the larger dbh classes. Furthermore, our estimate is based on a ‗per tree basis' while that of Griffin and Caprata (1977) was based on actual volume loss.

The goal of the proposed study is to investigate how regulatory and fiscal factors affect logging behavior in Peninsular Malaysia. Relevant hypotheses that can be tested relate to the role of concession length, volume-based royalties, area-based forest premium and logging road specifications on harvesting rates. Since the variable net value of species group m from compartment k ($p_{mk}-r_{mk}$) was not statistically significant, it can be concluded that changes in royalty rates that can affect the net return per cubic meter of extraction, would not influence harvesting rates. This is especially so given that royalty rates in Peninsular Malaysia is a small proportion of prices ranging from 1% to 12% depending on species groups. This small contribution of royalty fee makes changes in net returns not large and variable enough to influence harvesting decisions. The licensees and contractors are obtaining a large surplus (price subtracting harvesting cost, not including pre-paid premiums) with a mean of 43% (ranging from 30%-80%) of prices. On the grounds, felling teams who are paid on commissions based on volume extracted, make harvesting decisions based on trees marked by the Forestry Department who will conduct post-felling checking.

Premium variable ($prem_k$) is statistically significant with the expected positive signs.

Having paid in advance, contractors have the motivation to extract as much marked-trees as possible. This variable is useful as a policy tool and can be used to directly relate area-based close bidding or tender for extraction rights to ensure marked trees are felled and as fiscal revenues. An elasticity of 0.25 suggests that an increase in 1% premium rate would raise the harvesting rates by 0.25% only. The elasticity falls within the inelastic range. State Governments may use this close tender premium as a tool to raise revenue while expecting contractors to fell all marked trees and obtain further revenue from royalty and silvicultural cess that charged on a volume extracted basis.

The statistically significant negative coefficient for the long-term concessionaire variable implies that a long term concessionaire is more conservative in its felling operation and may have a longer term view of its operation by leaving sufficient residual trees to continue the second cycle harvesting. This augurs well with the government policy of providing 21.7% of the total forest land or 86.3% of the classified PFR as long-term agreement areas to the long-term concessionaires to harvest and manage.

The statistically significant positive coefficient for the variable time duration of completing harvesting activities suggests that a longer period would provide a greater opportunity for contractors to complete their jobs and harvest all marked trees. Current practice requires that each contractor requests for an extension to complete the job.

The positive coefficient obtained for the variable length of the secondary road in the compartment per ha ($secrd_k$) suggests that high road densities make it easy in getting to tree stumps and for skidding out logs. But logging contractors are also required to abide by logging road construction specifications which would only raise their production cost since their net returns would be reduced. An investigation conducted by an International Tropical Timber Organization (ITTO)-Forest Research Institute of Malaysia (FRIM) at the study site found that requiring logging contractors to follow road construction specifications could lead to an increase in road construction cost about 6.5 times and an overall economic harvesting cost by 69%.

The low elasticity estimates obtained for the variable premium payments for compartment k ($prem_k$) and the variable length of the secondary road in the compartment per ha ($secrd_k$) suggests that attempts by the government to institute or modify existing regulations to promote forest sustainability, environmental conservation and raise revenue may have a relative small impact on the rate of harvesting. But this may not necessarily be discouraging. It can be used gainfully. The fact that raising taxes through an increase in premium and enforcing strict environmental regulations that would reduce road densities may not adversely restrict log production, is a useful situation since the economic incentives of compliance may not be affected. Such low elasticities are obtained for only these two variables. Fortunately it is not rampant in all policy variables, such as whether the licensee is a long-term concessionaire (ltc). Otherwise, there is a trade-off. If all elasticities are very low, then logging contractors are not responsive to government policy and the government cannot use such policies very effectively to change behavior.

In the context of environmental management, the intention to use economic instruments like forest taxation through raising premium rates and enforcement of environmental friendly specifications on road construction may not curb production. Concessionaires may still be in a position to capture their share of the rent, if the log market is sensitive to rising overall cost of production and that market prices of logs keep track with the trend. They may go for productivity improvements by harvesting all marked trees and by reducing wastages. The positive link between production cost and prices for logs has been established during buoyant timber trading in another study conducted during the eighties and nineties (Mohd Shahwahid 1995). The log market in Malaysia is basically a suppliers market due to the declining areas opened for harvesting. Higher cost leads to higher domestic market prices. In Peninsular Malaysia, log exportation was totally banned two decades ago and yet there is a supply deficit.

8.2.2 Logging Damage

A logarithmic function was again estimated for the logging damage function. This function was first estimated using ordinary least squares estimation method. A plot of the residual errors and the predicted values of the number of trees harvested indicate a positive trend and a potential heteroschedasticity problem (Appendixes III and IV). A weighted least squares estimation was attempted using the reciprocal of the natural logarithm of the number of residual trees from all dbh class (n_k-h_k) as weights to correct for the heteroschedasticity problem. As in the harvesting function, initially all the independent variables mentioned in the empirical model were nested. Variables that are not statistically significant at the 10% level and were found to be highly correlated were dropped. Nevertheless, variables that are deemed to have policy relevance are retained to provide information that they do not influence the description of the variation in the level of logging damage. The total number of samples was 30 (i.e. 15 compartments split into Dipterocarp and Non-Dipterocarp species group).

Table 17 provides the estimates of the damage function for forest compartments in the district of South Terengganu, Malaysia. The specification selected did provide a reasonable good fit with several significant coefficients; significant F statistic that measures the overall fit, high R^2 that indicates the independent variables did provide substantial variations of the dependent variable. The D.W. test statistic did not fall within lower and upper bounds of the 5% points of the Durbin-Watson Test Statistic of $d_L = 2.17$ and $d_U = 2.82$ for the number of elements of the parameter vector that includes the constant term, K>6 and the number of samples, n=30. Hence, the hypothesis of no first order serial correlation can be accepted. Furthermore the data collected are not strictly time series, rather more cross-sectional occurring between the years 1980 to mid-1990s.

Only three independent variables, number of harvested trees from the compartment (h_k), number of residual trees from all dbh class (n_k-h_k) and dummy variable signifying species group ($spgrp_m$), were found to be statistically significant in explaining the rate of harvesting damage (d_{mk}) at 1% significant level. Nevertheless, this estimated function was able to explain some 83% of the variation of logging damage. However, none of the coefficients obtained for the policy relevant variables were statistically significant. The function suggests that the major sources of logging damage are the total number of trees harvested and the total number of residual trees, and that damage is more prevalent among the Non-Dipterocarp species group.

As explained in the theoretical model, logging damage is related to the intensity of harvesting and the density of residual stand. These coefficients obtained are also the estimates of the elasticity of logging damage with respect to the residual stand density and the harvesting rates. The damage elasticity for n_k - h_k of the residual stand density was estimated at 1.2 that can be considered as being elastic. This implies that for every 1% increase in the residual stands density that a 1.2% rise in logging damage can be expected using current harvesting technology. The damage elasticity for the number of residual trees (n_k - h_k) of the residual stand was estimated at 1.2 that can be considered as being elastic, h_k was 0.68, which implies that, for every 1% increase in the harvesting rate, the logging damage would increase by 0.68%. These findings work in opposite directions. Raising harvesting productivity through exploiting more trees per ha would raise logging damages. Yet if fewer trees were harvested, it would raise the residual stand which would also lead to rising logging damage. This is the dilemma facing logging business.

Prior to harvesting, the tropical natural forest is undisturbed, as they are exposed to only non-disruptive methods of harvesting non-wood forest products. The matured trees are large with canopies intertwined by rattan and other climbers. Felling these matured trees is bound to produce an impact upon other trees. As long as there are attempts to harvest these trees, together with the heavy machinery and road system involved, and pulling forces of the climbers, logging damages are bound to rise especially if the residual stand densities are rich.

Table 17. Estimation of a Logging Damage Function of a Forest Compartment for Trees below the Cutting Limit

Variable	*OLS Coefficient*	*WLS Coefficient*
Constant	-1.611 (-0.68)	-2.422 (-1.01)
Natural logarithm of number of trees harvested [log h_k]	0.559 (2.26)**	0.679 (2.77)***
Natural logarithm of the number of residual trees [log n_k–h_k]	1.065 (5.71)***	1.224 (7.21)***
Natural logarithm of premium payment [log $prem_k$]	0.131 (0.78)	.119 (0.66)
Natural logarithm of duration of harvest [log dur_k]	-0.179 (-0.80)	-.283 (-1.19)
Natural logarithm of length of total road density [log $troad_k$]	-0.097 (-0.29)	-0.011 (-0.03)
Dummy variable for long term concession licensee [ltc_k]	-0.116 (-0.26)	-0.021 (-0.20)
Dummy variable for species group m [$spgrp_m$]	-1.711 (-7.78)***	-0.386 (7.63)***
N	*30*	*30*
F statistics = 18.65	*15.45****	*10.62****
R^2	*0.83*	*0.77*
Adj R^2	*0.77*	*0.70*
D.W.	*2.21*	*2.15*

Figures in brackets are the t statistics
***,** and * at 1%, 5% and 10% significant levels

The findings from this study should be treated as preliminary, until and when more data are available in other districts. Nevertheless, given the current state of affairs, at least in this district, several implications on forest management are worth pondering upon. Possible implications to forest management are that any planning that raises the residual stand density such as setting high cutting limit dbh classes or quotas upon minimum economic cut with the intention of maintaining a high residual stand, while well-intended may not be able to meet its long-term objective of sustainable management. If the findings of this study are proven right when more data is available, harvesting activities under current system would only have the effects of increasing logging damages and wastages. The government may want to take heed and to introduce more environmental-friendly harvesting techniques including one where pre-felling climber cuttings and directional felling are implemented and closely supervised.

This issue has an economic consideration as well. Planners may want to consider lowering the cutting limits that can result in a higher current harvesting intensity and present value benefits with the effect of opening fewer areas annually in line with meeting the annual timber requirements. Otherwise, much of the residual stand would be put to waste owing to logging. However, it should be noted that this circumstance refers to existing logging technology. With the application of less damaging harvesting methods such as helicopter logging and incorporation of reduced impact specifications, damages could be much reduced. The application of helicopter logging is not unrealistic, as Malaysia has already experimented with this technique in Sarawak, another state.

Lowering the cutting limits will require modifications to the current regulations in forest management practices. With a thinner residual stand density, the next cutting cycle will have to be delayed from the current range of 25 to 30 years. This _bi-cyclic' cutting cycle where harvesting can be done twice within a rotation of 60 years may no longer be feasible. Instead a single cutting cycle of once in every 50-60 years may have to be implemented.

The above observations cannot be verified in this paper. It is not possible to apply an intertemporal forest model in this study. All licensees are given 1-year licenses to harvest their allotted compartments. This is applicable in long-term concessionaires. The only difference is that these concessionaires are operating in their own concessions and their annual harvesting compartments can be planned ahead. For those non-concessionaires, it is very difficult to link company decisions to compartment data. It is not certain why this one-year license constraint is applied to long-term concessionaires. Personal interviews with Forestry officials suggest that the one-year license provides a control mechanism on the harvesting operations whereby Forestry officials can monitor and supervise harvesting operations, at least in theory. Leaving unconstrained harvesting decisions in terms of annual area opened to concessionaires would encourage early harvesting of the whole concession area. While this makes financial sense in terms of present value gains, it may distort forest conservation goals of sustainable forest management.

Ideally, a simulation study can be conducted by making a comparative study between two harvesting options practicing different cutting limits over several cutting cycles. To be holistic, non-timber impacts include non-wood forest products and environmental services have to be incorporated. The net present values between the two options could be computed and compared. But much of the environmental services of forests have not been quantified that will still limit the simulations.

The insignificant coefficient on long-term concessionaire is contrary to the hypothesis that concession length does have the effects on reducing logging damage rates. A possible explanation relates to the issue of the length of the harvesting licenses mentioned earlier. While it is true that long-term concessionaires are assured of harvesting areas, their harvesting activities do not differ from that of short-term licensees. The sub-contracting of harvesting jobs is still widely practiced and long-term concessionaires are not directly involved in felling and transporting out the logs. In some cases, because long-term concessionaires are government interests, the Forestry Department tends to delegate some of the activities and monitoring to the concessionaires. Errant concessionaires may fail to conduct their duties and to supervise contracted fellers to observe harvesting specifications stated in the harvesting contract.

The coefficient for logging roads was not statistically significant. This prevents testing the role of logging road specifications as prescribed in the logging licenses in raising environmental degradation and logging damages. Another goal of the proposed study is to investigate how area-based bidding or tender of premiums can increase extraction rates and fiscal revenues at the expense of damages to residual stand. The premium variable while significant in influencing harvesting behavior has indicated otherwise in the damage function.

9.0 CONCLUSION AND POLICY IMPLICATIONS

The Malaysian Government has adopted a forest conservation policy of reducing the annual logging coupe while relying on forest taxation as an important source of State revenue. It is committed to complying with international conventions of sustainable forest management in producing forest reserves. The annual logging coupes have been reduced distinctly in Peninsular Malaysia since the late eighties. This was done with the intention of sustaining timber production and State revenue in the long-term.

This study highlights the following findings that have policy implications:

1) Allocating forest compartments to concessionaires integrated with a processing mill is found to raise timber productivity since they have reasons to be more productive in harvesting and to be able to absorb the material abandoned in the forest. Previously, many integrated timber organizations suffer from problems of low capacity rates. There are many reasons to explain this problem. One important reason is poor financial management in integrated timber organizations. The sales made could barely break even with the large operating and maintenance cost incurred due to inappropriate equipment. The high operating cost was also caused by inexperienced management, problems of overstaffing in public enterprises, lack of incentives for higher productivity and in some cases, political interference and social issues. Many of these organizations sold their logs to private mills to cover their costs. Hence, capacity utilization was low and some proposed processing facilities were never constructed. Due to problems of management and equipment, as well as incomplete facilities, recovery rates were low and wastage in the forest and the mills remained high. With forest compartments getting scarcer and

competition getting stiffer, many of these problems are now being resolved.

2) A long-term concession holder has a long-term view on forest management as the concession is under its management care for subsequent cycles. Apart from harvesting, it is also responsible for pre and post-logging activities. This study has shown that the concessionaire behavior supported this hypothesis with respect to harvesting. Cutting limits set upon trees to harvest were observed with the intention of reserving enough residual trees for the next cycle. In spite of this, there are no indications that damages were lower under long-term concession holders. This may reflect that an over reliance on the sub-contracting system to harvesting could be the root cause of the problem. Under this system, concessionaires were unable to exert control over the harvesting teams employed by contractors. Harvesting teams were reluctant to observe specified harvesting regulations on road construction and directional felling. Hence the government may have to ponder over this issue of control over the harvesting system currently adopted and increase field supervision.

3) Fiscal measures to generate State revenue are already in place. The taxation system involves area-based premium payments which can either be set administratively or through biddings or tenders, royalty payments proportional to the level of extraction and a silvicultural cess to finance forest rehabilitation activities.

The findings of this study have shown that the harvesting elasticities on the variables amenable to fiscal measures (premium) are quite inelastic. This implies that the government can enact or raise fiscal and regulatory measures without having to worry seriously about production levels. Fortunately such low elasticities are not rampant in all policy variables such as in the dummy variable for long-term concessionaire (ltc). Otherwise, there is a trade-off. If all elasticities are very low, then logging contractors are not responsive to government policy and the government cannot use such policies very effectively to change behavior.

4) It was found that raising harvesting rates would increase logging damages. Yet without raising productivity, concessionaire may not have the incentive to comply with environmental regulations in forestry. Compliance costs money and concessionaires have to find a source to compensate this loss. This study is preliminary and has to be expanded for more meaningful policy discussions. One possible avenue to permit rising productivity in compliance with logging prescriptions is to lower cutting limits. But this will decrease current residual stocks that would not achieve the economic cut in the next cycle. Lowering the cutting limit followed by extending the cutting cycle will give the residual stand sufficient time to recuperate and regenerate. This will require modifications to the current regulations in forest management practices.

The followings are some policy implications.

Policy Implications on Fiscal Measures

With supply areas curtailed but demand for logs not following suit, it is expected that the rate of forest utilization would increase if the prices of logs are raised in anticipation of continued demand improvements. It should be noted that the reduction in logging areas also provides incentives for contractors to be involved in illegal activities. With this reduction in forest land available for logging, there is a need to identify supply responses that can encourage further extraction of currently under-utilized or partially marketed species from the forest that otherwise would have been left standing. If prices are raised high enough, this will overcome contractors‘ unwillingness to extract low value trees, which are not high enough to pay for the cost of felling, transportation and taxes. This will provide sufficient profit margins. The findings of statistically insignificant coefficient for the net return variable (price deducting royalties) made are unable to find a link to relevant policy implications.

There are statistical significant relationships between the premium variable and harvesting rates. The government has instruments open for use to raise revenue. With the elasticity on premium being low, raising the premium rate will not affect harvesting rates due to the structure of the saw log market which is a seller‘s market.

State governments in Peninsular Malaysia will have a strong interest in evaluating the fiscal and environmental impacts of logging taxation and regulation. Although the environmental impacts were not directly investigated, it is a known fact that reduced logging damage to residual trees has a significant influence on lessening environmental disturbances.

Policy Implications on Duration of Concession

When left unguided and unsupervised, short-term concessionaire and their contractors tend to have a myopic viewpoint and preclude forward-looking behavior. Insecure concession tenure is said to be one of the main reasons. The State usually grants compartments with duration of a year with an opportunity of extension on application. There is no guarantee that a successful applicant will have repeated success of getting another compartment upon completion unless he is a long-term concessionaire. Each compartment granted is just a harvesting license with the State Forestry Offices responsible for post-logging management activities. These licenses do not have any real option to determine whether to harvest in the present period or to delay the period. They either harvest the timber in the compartment before the end of the period (contract), or they lose it. They have little incentives to minimize damage to the residual stand, as they have no reason to expect that they would receive the same concession again when it is due for a second harvest several decades later. It is not surprising that rates of logging damage are high, with consequent negative impacts on regeneration possibly in the next cutting cycle.

The above expected behavior of loggers should be an indicator for the State government to offer concessions to integrated and long-term concessionaires so that the onus and accountability of managing the concessions would be brought to the beneficiary.

Policy Implications on Environmental Management

The government has acceded to comply with the International Tropical Timber Organization‘s (ITTO) Year 2000 Objective and its _Criteria and Indicators‘ (C&I) for sustainable forest management. The National Committee on Sustainable Forest Management has adopted the Malaysian Criteria and Indicators (MC&I) that is based on the ITTO Guidelines on Sustainable Forest Management. In implementing this MC & I at the forest management unit (FMU), several additional activities have to be conducted. One important requirement is to comply with road construction in designated mapped locations and to limit road densities to prescribed lengths. For instance, the lengths of primary and secondary roads are not to exceed 40m/ha and 200m/ha respectively.

On the other hand, complying with the MC & I, which among others, require greater compliance to various forest management criteria and indicators would raise logging costs and marginal cost of harvesting, causing profitable levels of production to slide down (Mohd Shahwahid et al. 1999).

Future Studies

This study is constrained by the availability of data that limits a wide coverage of sample points. Future studies should attempt to incorporate other districts to capture enough variability in factors explaining harvesting rates and logging damage. To do this would require the cooperation of the Forestry Department as part of the study team and would require the collection of data from current compartments where its planning can be instilled.

REFERENCES

Abdul Rahim N., Zulkifli Y. and Baharuddin K. 1993. Effectiveness of Conservation Measures in Selective Logging Practices. 1993. Paper presented at the Conference on Forestry and Forest Products Research, FRIM, Kepong.

Awang Noor Abd. Ghani; Jeffrey R. Vincent and Yusuf Hadi. 1992. Comparative Economic Analysis of Forest Revenue Systems in Peninsular Malaysia. Final Report Submitted to Osborn Center Forestry Policy Grants Program. World Wide Fund for Nature, Washington, D.C.

Baharuddin, K. 1995. Effects of Logging on Sediment Yield in a Hill Dipterocarp Forest in Peninsular Malaysia. Journal of Tropical Forest Science 1(3): pp.1-15

Boado, E. L. 1988. Incentive Policies and Forest Use in the Philippines. ed. Repetto, R. and Gillis, M. *In* Public Policies and the Misuse of Forest Resources. Cambridge University Press. Cambridge. pp. 165-198.

Boscolo, M. and Jeffrey R. Vincent. 1997. Promoting Better Logging Practices in Tropical Forests. Policy Research Working Paper No.1971. Development Research Group, The World Bank, Washington, D.C.

Canonizado, J.A. 1978. Simulation of Selective Forest Management Regime. Malayan Forester 41. pp.171-175.

Chung, K.S. 1992. A Case Study on the Effects of Silviculture Treatments in Tropical Rainforests in Malaysia. In proc. of the Symposium on Harvesting and Silviculture for Sustainable Forestry in the Tropics, Kuala Lumpur, Malaysia. pp. 15-23.

Forestry Department Headquarters, Peninsular Malaysia, (n.d.) Perangkaan Perhutanan Semenanjung Malaysia 1996 [Forestry Statistics Peninsular Malaysia 1996], Kuala Lumpur.

Fox, J.E.D. 1968. Logging Damage and the Influence of Climber Cutting prior to Logging in the Lowland Dipterocarp Forest of Sabah. Malayan Forester 31. pp. 326-347.

Gillis, M. 1988. Indonesia Public Policies, Resource Management and the Tropical Forest. *In* Public Policies and the Misuse of Forest Resources. ed. Repetto, R. and Gillis, M. Cambridge University Press, Cambridge. pp. 43-105.

Gillis, M. 1992. Forest Concession Management and Revenue Policies. Narendra P. Sharma, ed *In* Managing the World's Forests: Looking for the Balance between Conservation and Development. Kendall-Hunt, Dubuque, Iowa.

Griffin, M. and Caprata, M. 1977. Determination of Cutting Regimes under Selective Management System. ASEAN Seminar on Tropical Rainforest Management, Kuantan, Pahang, Malaysia.

Grut, M.; J. A. Gray and N. Egli. 1991. Forest Pricing and Concession Policies: Managing the High Forests of West and Central Africa. *In* World Bank Technical Paper No. 143. Africa Technical Department Series, World Bank, Washington, D.C.

Hyde, William. F.; Hariadi Kartodihardjo; Azis Khan and Erwinsyah. 1999. OED Forest Policy Review: Indonesia Case Study. (Draft Report).

Kumar, R. 1986. The Forest Resources of Malaysia. Oxford University Press, Singapore.

Larson, Bruce A., and R. Bluffstone. 1997. Controlling Pollution in Transition Economies: Introduction to the Book and Overview of Economic Concepts. ed Bluffstone, R. and Larson, Bruce A. *In* Controlling Pollution in Transition Economies. Edward-Elgar, Cheltenham, U.K.

Liew, T.F. and C.C.Ong. 1986. Logging Damage in the Mixed Dipterocarp Forests of Sarawak. Information Paper for the Ninth Malaysian Forestry Conference. pp. 13-20 Logging and Crown Liberation. Forest Ecology and Management 81. pp. 85-94.

Mohd Shahwahid, H.O. 1995. Forest Conservation and Its Effects on Peninsular Malaysian Log Supply. ASEAN Economic Bulletin 11(3): pp. 320-334.

Mohd Shahwahid, H.O. and Awang Noor, A.G .1998. Economic Rent from Hardwood Timber Extraction in the West Coast of Peninsular Malaysia. Malaysian Journal of Agricultural Economics (MJAE) Vol 12. pp. 1-15.

Mohd Shahwahid, H.O.; Abdul Rahim, N.; Awang Noor, A.G.; Ahmad Fauzi, P.; Salleh, M.; Muhammad Farid, A.R.; and Mohammad Azmi, M.I. 1999. Incremental Cost of Meeting Criteria and Indicators for Achieving Sustainable Forest Management. International Conference on the Application of Reduced Impact Logging to Advance Sustainable Forest Management: Constraints, Challenges and Opportunities. Environment & Development Second International Conference. 26 February to 1 March 2001. Organized by the Asia Pacific Forestry Commission (APFC). Kuching, Sarawak, Malaysia.

Pinard, M.; Putz, F.E.; J. Tay; and T. E. Sullivan. 1995. Creating Timber Harvest Guidelines for a Reduced Impact Logging Project in Malaysia. Journal of Forestry October 1995. pp. 42-45.

Repetto, R. and M. Gillis. 1988. Public Policies and the Misuse of Forest Resources. Cambridge University Press, New York.

Sizer, N. and R. Rice. 1995. Backs to the Wall in Suriname: Forest Policy in a Country in Crisis. World Resources Institute, Washington, D.C.

Sizer, N. 1996. Profit without Plunder. World Resources Institute, Washington, D.C.

Sulaiman, H. N. 1977. A Method of Forest Revenue Assessment based on Inventory Data. Malaysian Forester 40(3). pp. 144-159.

Vincent, R. V. 1990. Rent Capture and the Feasibility of Tropical Forest Management. Land Economics 6 (2). pp. 212-23.

Vincent, J. R.; Awang Nor, A. G.; and Yusuf, H. 1993. Economics of Tropical Timber Fees and Logging in Tropical Forest Concessions. Unpublished report. p.70

Vincent, Jeffrey R.; Rozali bin Mohamed Ali and Associates. 1997. *In* Environment and Development in a Resource-Rich Economy: Malaysia under the New Economic Policy. Harvard Studies in International Development. Harvard University Press, Cambridge, Massachusetts.

Vincent, J.R.; K.M. Chomitz; Mohd Shahwahid, H.O.; and Awang Noor, A.G. 1999. Using Inventory Data to Analyze Logging Behavior in Tropical Forests. Report submitted to the World Bank.

Walker, R. and Tony, E. Smith. 1993. Tropical Deforestation and Forest Management under the System of Concession Logging: A Decision-theoretic Analysis. Journal of Regional Science 33(3). pp. 387-418.

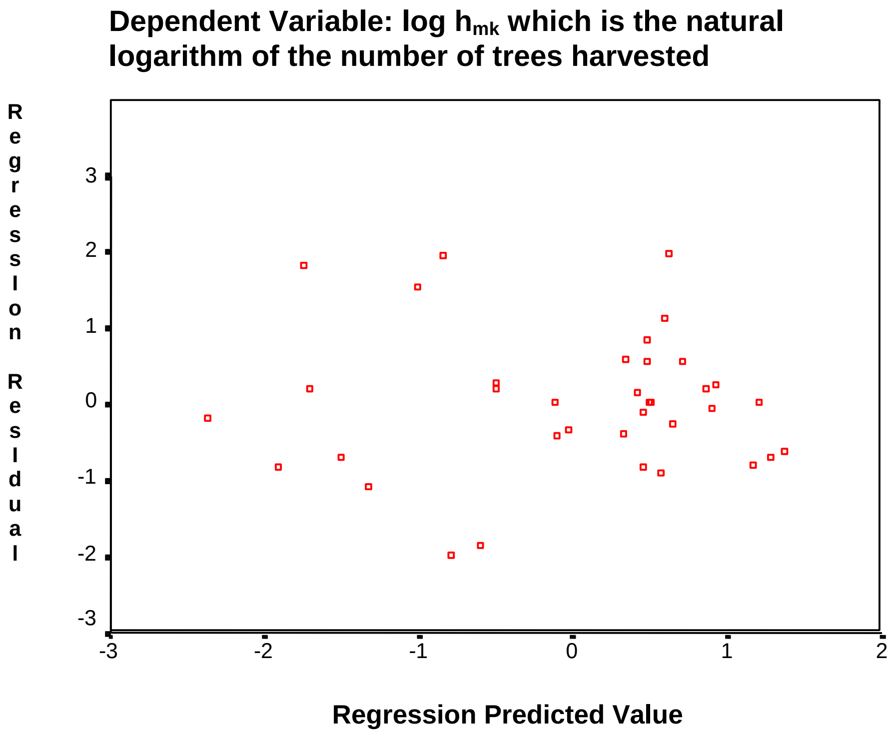
World Bank. 1991. The Forest Sector: A World Bank Policy Paper. Washington, D.C. p. 46.

Yong, T.K. 1990. Growth and Yield of a Mixed Dipterocarp Forest of Peninsular Malaysia. ASEAN Institute of Forest Management. Kuala Lumpur, Malaysia. pp.160

Zulkifli, Yusop; Anhar Suki; and Baharuddin Kasran. 1990. Post-Logging Effects on Suspended Solids and Turbidity – Five-Year Observation. Paper presented at the (Workshop on Watershed Development and Management). 19-23 February 1990, Kuala Lumpur. p. 34 .

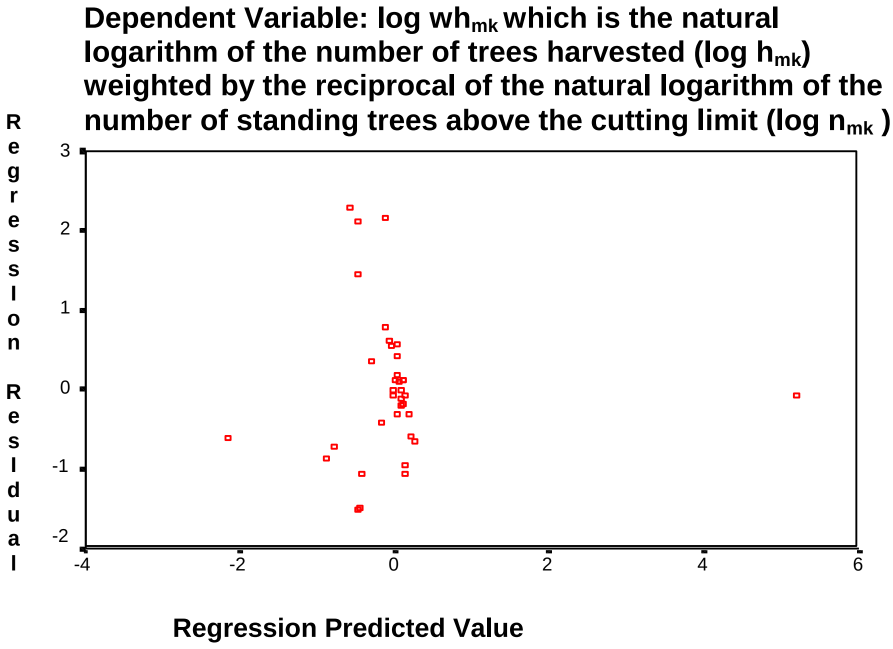
Appendix 1

A Scatter Plot of Regression Standardized Residual with the Regression Standardized Predicted Value for the Ordinary Least Squares (OLS) Harvest Function



Appendix 2

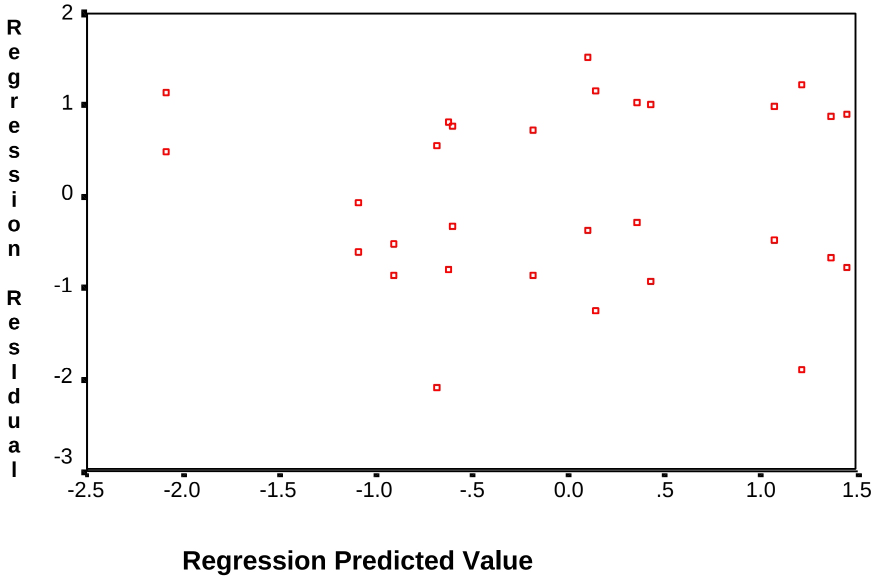
A Scatter Plot of Regression Standardized Residual with the Regression Standardized Predicted Value for the Weighted Least Squares (WLS) Harvest Function



Appendix 3

A Scatter Plot of Regression Standardized Residual with the Regression Standardized Predicted Value for the Ordinary Least Squares (OLS) Damage Function

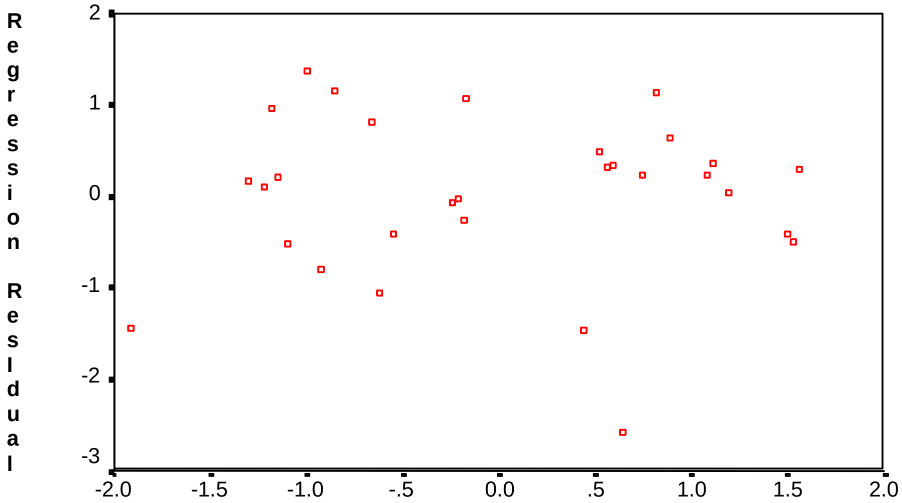
Dependent Variable: log d_{mk} which is the natural logarithm of the number of trees damaged



Appendix 4

A Scatter Plot of Regression Standardized Residual with the Regression Standardized Predicted Value for the Weighted Least Squares (WLS) Damage Function

Dependent Variable: log wd_{mk} which is the natural logarithm of the number of trees damaged weighted by the reciprocal of the natural logarithm of the number of residual trees from all dbh class ($logn_k$-h_k)



Regression Predicted Value