FOREST OPERATIONS FOR SUSTAINABLE FORESTRY IN THE TROPICS

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Edited by

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Preface

Forest harvesting and transportation operations are an essential component of sustainable forestry. Recognition of this fact is consistent with the theme of the XX IUFRO World Congress, "Caring for the Forest: Research in a Changing World." The symposium summarised in this volume was organised at the World Congress in Tampere in order to provide a forum for discussion of new techniques for planning, implementing, and controlling forest operations in ways that promote the sustainable management of tropical forests. Because of the large number of papers presented at the Congress it was not feasible for IUFRO itself to publish all of the papers. The task of doing so for this symposium has thus been carried out by IUFRO Subject Group S3.05-00, "Forest Operations in the Tropics," now redesignated as Research Group 3.05.00 in the new IUFRO structure. Nine of the 12 authors who made presentations during the symposium agreed to prepare formal papers for inclusion in these Proceedings. The remaining three papers are not included in this volume because they have been published elsewhere. Although the papers have been reformatted to ensure consistency and have been checked for completeness, they remain essentially as presented by the authors and any opinions expressed are those of the authors themselves with no implied endorsement by either IUFRO or CIFOR.

Acknowledgements

In addition to the IUFRO volunteers who helped with the S3.05-00 symposium during the World Congress in Tampere, two individuals in particular have assisted greatly in the preparation of this volume for publication. **Mrs. Nani Djoko,** assistant to the Deputy Director General for Research at CIFOR, assisted in the organisation of the symposium by maintaining correspondence with the authors and other participants, and by ensuring that the necessary logistical arrangements were made. She also typed several of the contributions and reformatted others. **Mrs. Rita Mustikasari,** IUFRO Liaison Officer at CIFOR, did most of the page layout and scanning of figures for this volume, and also corresponded with the authors as necessary to ensure that revisions were properly incorporated.

Finally, financial and administrative assistance provided by CIFOR permitted this volume to be published, and this is also gratefully acknowledged.

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Tropical Forest Soil Compaction: Effects of Multiple Log Skidding Tractor Passes on Surface Soil Bulk Density at Sao Hill, Tanzania

George A. Migunga

Abstract

Forest soil compaction by log skidding tractors was studied by measuring changes in the surface soil bulk densities in three forest sites where clearfelling operations were being undertaken.

The forest surface soil bulk densities in major skid trails after 5 and 10 passes of log skidding tractors were compared with those of undisturbed forest soils. Mean surface soil bulk density of the 0 - 15 cm depth surface of plantation forest soils which was 0.87 g/cm^3 was increased to 1.16 g/cm^3 after 5, and to 1.36 after 10 passes of log skidding by a farm tractor, and from 0.87 g/cm^3 to 1.53 g/cm^3 after 5 passes and to 1.58 g/cm^3 after 10 passes of log skidding by an articulated skidder.

Results indicated that multiple log skidding tractor passes on the forest soils produced significant increases in surface soil bulk densities. The results further indicated that the initial 5 passes on the same route produced most of the soil compaction.

Key words: Tropical soils, logging, tractors, bulk density.

Introduction

Log skidding in the forest stand occurs on the soil that at the same time is used as a growth substrate. In Tanzania, forest plantations harvesting is either done manually or by tractors, such as farm tractors mounted with one or two drum winches, crawler tractors and articulated rubber tired skidders with winch (Ole-Meiludie and Njau 1989). There have been increased timber harvesting activities from thinnings and clearcuts. This has resulted in increased entries into forests by log skidding tractors. These increased entries definitely result in increased machine traffic on the forest soils, which will destroy the ground vegetation, damage tree roots and compact the soil to a degree where tree roots have difficulties to re-occupy a former territory. The increase in log skidding operations in plantation forests could result in increased damage to residual trees in thinnings, reduced site productivity, and future tree growth.

It has been reported that under unfavorable conditions, vehicular traffic causes compaction in soils (Greaten and Sands 1980; Braunack 1986; Wasterlund 1992). Studies on the effect of vehicular traffic on forest soils have been reported widely (Greaten and Sands 1980; Braunack 1986), while few studies are reported on tropical soils (Maganga and Chamshama 1984; Ole-Meiludie and Njau 1989; Malmer and Grip 1990). The operation of logging machines in forests have been documented to cause short and long term effects on forest soil physical, mechanical and hydrological properties, site productivity and damage to residual trees (Froehlich 1979, Greaten and Sands 1980, Wasterlund 199 1, 1992).

Soil compaction has been measured by several methods. The most direct measure of soil compaction is by monitoring changes in the surface soil bulk density (Greaten and Sands 1980, Ole-Meiludie and Njau 1989).

Relatively little attention has been paid to the effects of logging machines on tropical forest soils and residual trees (Greaten and Sands 1980; Malmer and Grip 1990). Though few basic studies have been undertaken in Tanzania on forest soil compaction by log skidding tractors, there is evidence that soil compaction occurs (Maganga and Chamshama 1984, Ole-Meiludie and Njau 1989). Studies on the impacts of log skidding in plantations to fully understand the phenomenon of plantation forest soil compaction are necessary.

Traffic of log skidding tractors in tropical forest plantations will cause soil compaction which might affect future soil productivity and tree growth.

This study analyses the effects of log skidding on surface soil bulk density in one of the forest plantations in Tanzania. The main objective was to measure the changes on surface soil bulk density resulting from multiple log skidding tractor passes on forest soils.

Methodology

The study area

The study was carried out at Sao Hill Forest Plantations in Iringa between January 1988 and December 1990. The plantations are located in the southern highlands of Tanzania between altitudes 1400 and 2000 m above sea level. The soils are derived from the basement complex rocks; the parent material is pre-Cambrian granites with Ndebere Usagara gneiss. They are predominantly kaolinitic with low base exchange capacity and pH varying from 4.0 to 5.8. The plantations were established in some areas which had previously been under agricultural production. The climate is characterized by a rainy season from November to April and a long dry season from May to October. Mean annual rainfall is 1300 mm but ranges from 725 to 1400 mm. Temperatures are fairly cool; mean monthly minimum ranges from 10 to 18 degrees Celsius and mean monthly maximum ranges from 23 to 28 degrees Celsius. Main species planted in the plantations are *Pinus patula, Pinus elliotti,* and some *Eucalyptus.* To date about 43,700 hectares have been planted.

Data collection

Data were collected on three stands of *Pinus* **patula** that were being clearcut at 25 years of age. The compartments are referred to as site 1, 2, and 3. Terrain was fairly easy with slopes ranging from -7%

to +8%. Data were collected during the dry season between May and October.

Two types of tractors were studied. A farm tractor fitted with two drum winches for logging purposes and an articulated rubber tire skidder were used to skid logs to a roadside landing. The technical data for both machines are presented in Table 1.

Table 1. Technical data for the skidding machines.

	Unit	Farm tractor	Articulated skidder
Model		Ford 66 10 (1980)	Timberjack 225A (1982)
Power			
-maximum	kW	60.00	69.00
-flywheel	kW	57.40	65.00
Mass			
-front axle	kg	2030.00	4311.00
-rear axle	kg	2440.00	2425 .00
Tire dimensions			
-front	mm	60.96 x31.50	152.4x42.93
-rear	mm	43.18	152.4x42.93
-length	m	2.71	5.69
-width	m	1.96	2.39
-number		4.00	4.00
Ground pressure			
-front	kPa	51.85	64.64
-rear	kPa	64.56	36.36
Load capacity	kg	3418.00	5952.00

Three levels of treatment were adopted. TO = undisturbed forest plantatibn soil, T5 = five tractor passes on the same route, TIO= ten tractor passes on the same route. The operator was instructed to follow the same route during log skidding to the landing and when returning to the stump area. Soil sampling by the soil core sampler was performed along each route before and after the tractor passes. Thirty intact soil core samples of mineral soil were taken along the route at the center of the wheel rut for T5 and TlO respectively, and on undisturbed soils 2 m on adjacent areas at a depth 0 - 15 cm below the soil surface for bulk density and moisture content determination.

Cylindrical soil core samplers with core sample rings of 53 mm x 50 mm x 5 mm with a volume 100 cm^3 were used to collect soil samples. The samples were then oven dried at 104 degrees Celsius. After this they were -weighed and the soil moisture content and surface soil bulk density determined.

Data analysis

Analysis of variance was used to test for significant differences between undisturbed and treated soils. Statistical computations were made to compare the effect of multiple tractor passes on surface soil bulk density.

Forest soil samples from the sites were analyzed to determine the particle size distribution by the hydrometer method (Juo 1978). The textural classes for the sites are presented as Table 2.

Table 2. Soil textural classes of soils studied.

Particle size, mm	Site 1	Site 2	Site 3
0.02 - 0.002% sand	51	52	29
0.002 - 0.02% silt	5	18	40
<0.002% clay	44	40	31
Textural class	sandy clay	sandy loam	clay loam
Moisture content %	28	26	25

Results and Discussion

Mean values of surface soil bulk density for the different sites and treatments are presented in Tables 3 and 4. Table 3 summarizes statistics for the measured soil bulk density for the farm tractor. Table 4 presents summary statistics for the articulated skidder studies.

Notes:
s.d. = standard deviation
n = number of samples

Table 3. Surface soil bulk density statistics for the farm tractor.

		Soil bulk density, g/cm^3				
Site	Number of passes	mini-mum	maxi-mum	mean	s.d.	n
	0	0.68	0.95	0.84	0.062	30
1	5	0.95	1.31	1.13	0.079	30
	10	0.89	1.51	1.19	0.159	30
	0	0.79	1.08	0.91	0.063	30
2	5	1.01	1.41	1.21	0.106	30
	10	1.11	1.81	1.44	0.151	30
	0	0.78	1.01	0.88	0.056	30
3	5	0.95	1.35	1.15	0.090	30
	10	1.25	1.61	1.45	0.100	30

Significant differences in the O-15 cm surface soil bulk density occur between undisturbed forest soils and skid tracks after the machines have made 5 or 10 passes. The analysis further indicated that there was a significant increase in surface soil bulk density with an increasing number of skidding machine passes. The results were similar to those reported by other researchers (Braunack 1986; Wbterlund 1991; Malmer and Grip 1990; Rollerson 1990). This increase indicates that soil compaction results from multiple passes by log skidding tractors.

Table 4: Surface soil bulk density statistics for the articulated skidder.

		Soil bulk density, g/cm³				
Site	Number of passes	minimum	maximum	mean	s.d.	n
	0	0.68	0.95	0.84	0.062	30
1	5	1.12	1.91	1.37	0.154	30
	10	1.35	1.71	1.51	0.084	30
	0	0.79	1.08	0.91	0.063	30
2	5	1.41	1.90	1.68	0.133	30
	10	1.25	1.95	1.59	1.190	30
	0	0.78	1.01	0.88	0.056	30
3	5	1.23	1.84	1.55	0.148	30
	10	1.02	1.90	1.64	0.214	30

However, the increase in surface soil bulk density was more significant after 5 passes. It increased from 0.87 g/cm^3 to 1.16 g/cm^3, an increase of 33% above the undisturbed soils. The additional increase was 17% after 10 passes by the farm tractor. For the articulated skidder the soil bulk density increased from 0.87 g/cm^3 to 1.53 g/cm^3 after 5 passes, an increase of 88% above that for undisturbed soils, with an additional increase after 10 passes of only 3% above that after 5 passes. These results indicate that the first five tractor passes cause much more significant surface soil compaction than the subsequent passes.

The passage of log skidding machines on undisturbed soils caused increased surface soil bulk densities on all sites. Surface soil densities greater than 1.30 g/cm^3 have been reported to inhibit root penetration and thus result in impeded tree growth (Shetron *et al.* 1988, Wästerlund 1992). The results therefore suggest that the increased soil bulk density can impede tree growth or regeneration on the compacted soils unless amelioration steps are taken.

Conclusion

The study indicated that operation of skidding tractors on a tropical forest plantation soil resulted in significant increases in surface soil bulk density. The increase in surface bulk density was influenced by the type of log skidding tractor used. Therefore, there is a need for proper planning and organization of log skidding operations in order to minimize soil compaction in plantation soils. The increase caused by the tractors would likely inhibit tree seedling growth in the skidtrails.

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Use of Oxen in Logging Operations in Rural Areas of Costa Rica

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Abstract

The main objective of this paper is to present a general overview on the use of oxen in logging operations in rural areas of Costa Rica. Details on the actual use, limitations and potential of oxen as a low-impact logging system for Costa Rica and Central America are provided. Information is also included on conditions that must exist to obtain the best benefits from oxen logging. Oxen and crawler tractors are compared based on production rates, logging costs, and environmental impact on soils and residual trees.

The social and economic advantages of using oxen for harvesting tropical forests are discussed, keeping in mind the limitations present in some of these forests due to the large size of the trees and steepness of the terrain.

Besides the lower production costs that could be obtained with oxen logging and their lower environmental impact, a major potential social benefit is being a labor intensive method. Almost 83% of the total hourly cost of oxen logging accrue to labor, as compared to only 20% for the crawler tractor. A key element for the successful utilization of oxen in logging operations is to recognize their limitations and advantages and to use them only where it is appropriate. As any other skidding method there is a range of conditions under which the system should be used, and more attention to this matter must be paid when working with oxen since they are more sensitive than machines to adverse site conditions. On the other hand, their low environmental impact, simplicity, low capital requirements, compatibility with different load sizes and products, and the necessity of less infrastructure, are reasons to promote their use whenever is possible.

Oxen logging must therefore be seriously considered as the best alternative for many community development projects. For better results, promotional activities must be undertaken to help people understand the benefits that this logging alternative can provide.

Key-words: low-impact logging, tropical forests, draft animals. Costa Rica.

1. Introduction

Costa Rica is a tropical country of 5 1,359 km*, located in Central America at a latitude between 8 and 11 degrees north of the Equator. Although small, Costa Rica has great diversity of topography, forest cover types, and climates.

Costa Rica has had over the years a long tradition on the use of draft animals, mainly oxen. They have been used for transportation, logging, and agriculture, and continue to be used despite the availability of equipment such as farm and crawler tractors.

In general, oxen are used in small logging operations which are accessible year-round and therefore do not require a more productive method that would extract the yearly production over a short period of 3 to 4 months (during the dry season).

Oxen are the main extraction method when the logs skidded are to be used at local level, for example, within the same farm or property.

Oxen are not regularly used for "industrial" harvesting of natural forests, since these operations generally use crawler tractors as the main skidding method. Oxen have been used in natural forests to harvest residual timber left by the tractor-based traditional harvesting operations. Given the lower cost per hour, oxen can skid damaged, smaller, or lower value trees whose extraction using a tractor would not be economically feasible. In some experiences, this combination has contributed to better utilization of forests (up to 50%), reducing the amount of logs or trees that have been cut or damaged and still are not harvested.

On the other hand, oxen are commonly used in harvesting forest plantations. Their use is favored under these conditions, since plantations are smaller in surface and the smaller trees make work easier. In larger plantations or difficult terrain conditions, they have been used in combination with farm tractors.

In this particular case the logging operation is completed in two stages. First, oxen are used to skid the logs from the stump to an intermediate landing or the side of the road (prebunching). The prebunching operation skidding is commonly done over short distances (50 to 200 m). Second, once in the landing, road or skid trail, the farm tractor is used with or without a trailer, over longer distances to complete the skidding to the loading yard.

Under this scheme, less damage is caused to the plantation, and the tractor can skid or transport larger loads, achieving better productivity.

Two skidding methods are used with oxen. In the traditional method, the logs or trees are skidded directly on the ground, held to the joke by a steel chain. This method is more appropriate for short distances (less than 125 m), and small trees. This alternative is simpler and requires the least investment, but it is the most limiting on the oxen since the skidding resistance is larger.

The other skidding method involves the use of a sulky (a metal logging arch with rubber tires) that is used to reduce the friction between the log and the ground. This accessory has contributed to increase the oxen carrying capacity up to 1200 kg, allowing their use over longer skidding distances and reducing road density. Cordero (1988) includes a detailed description on how to build and use a sulky for oxen logging.

The information presented in this paper is the result of different studies and evaluations carried out in Costa Rica. During different periods of time, funding and other types of support have been received from the following organizations: International Foundation for Science (IFS Sweden), World Wildlife Fund (WWF USA), Food and Agriculture Organization of the United Nations (FAO), University of British Columbia (UBC Canada), Institute of Technology of Costa Rica (ITCR), and Project for Sustainable Forest Management (BOLFOR, Bolivia).

2. Advantages of Using Oxen

In the following sections the advantages of using oxen are discussed, considering environmental effects, simplicity for their use, capital costs, adaptability, use of labor, and infrastructure.

2.1. Environmental Disturbance

Considering that skid trails are narrow and rudimentarily built, with minimal soil removal, the alteration caused is minimal. The slow speed at which animals move reduces damage to the residual trees, which is especially important for selective logging or thinning operations in forest plantations.

Tables 1 and 2 and Figures 1 and 2 summarize results of a study that compared the damage caused by logging with oxen and with a crawler tractor (Caterpillar D4), while selectively harvesting a tropical rainforest in southern Costa Rica. During the trials, an average of 30% of the volume trees larger than 50 cm in DBH was harvested (an average of 6.66 trees/ha). The following damage classes are used (adapted from: Jonkers 1987; Uhl and Guimaraes 1989):

1	harvested
2	very severe injury or killed by logging
3	severe injury
4	minor injury
5	no injury
21	killed not logging cause
31	severely damaged not logging cause
41	slightly damaged not logging cause

Most of the damage occurred on the smaller trees (less than 30 cm DBH). For the oxen the main effect was caused by the construction (clearing of vegetation) of the skid trails. A chi-square test ($p < 0.001$) did indicate a significant difference between the damage caused by oxen and tractor (comparing classes 2, 3, and 4). This difference was also significant when classes 21, 31, and 41 were compared. In both cases oxen caused less impact.

These data on damage to the residual vegetation include the impacts of felling, skid trails, and the skidding operation.

Besides the damage caused to the residual trees, logging also alters the soil. Soil damage is expressed in terms of soil compaction, soil surface disturbance, and soil removal.

Table 1. Number of trees per diameter and damage class after logging with oxen.

Damage Classes	Diameter Classes (cm)											Total	%
	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	+110		
2	33.33	13.33	3.67	3.00	1.00	0.33	0.00	0.00	0.00	0.00	0.00	54.67	11.85
3	3.33	10.00	0.67	0.00	0.33	0.33	0.33	0.00	0.00	0.00	0.00	15.00	3.25
4	16.67	23.33	6.00	3.33	5.33	1.33	0.67	0.33	0.00	0.00	0.00	57.00	12.36
21	3.33	0.00	0.67	0.00	0.00	0.33	0.33	0.33	0.00	0.00	0.33	5.33	1.16
31	3.33	0.00	0.67	0.33	0.33	0.00	0.00	0.33	0.00	0.00	0.00	5.00	1.08
41	0.00	0.00	0.33	1.00	0.33	0.33	0.00	0.33	0.00	0.00	0.00	2.33	0.51
Subtotal	60.00	46.67	12.00	7.67	7.33	2.67	1.33	1.33	0.00	0.00	0.33	139.33	
%	13.01	10.12	2.60	1.66	1.59	0.58	0.29	0.29	0.00	0.00	0.07		30.20
1	0.00	0.00	0.00	0.00	0.33	0.67	1.33	1.33	1.00	0.33	1.00	6.00	1.30
5	200.00	53.33	19.00	18.33	11.00	10.00	2.33	1.00	0.00	0.33	0.67	316.00	68.50
Subtotal	200.00	53.33	19.00	18.33	11.33	10.67	3.67	2.33	1.00	0.67	1.67	322.00	
%	43.35	11.56	4.12	3.97	2.46	2.31	0.79	0.51	0.22	0.14	0.36		69.80
Total	260.00	100.00	31.00	26.00	18.67	13.33	5.00	3.67	1.00	0.67	2.00	461.33	
%	56.36	21.68	6.72	5.64	4.05	2.89	1.08	0.79	0.22	0.14	0.43		100.00

Table 2. Number of trees per diameter and damage class after logging with tractor.

Damage Class	Diameter Classes (cm)											Total	%
	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	+110		
2	46.67	16.67	5.00	2.33	1.33	1.00	0.33	0.00	0.33	0.33	0.00	74.00	19.15
3	0.00	0.00	1.67	0.67	0.67	0.00	0.00	0.00	0.00	0.33	0.00	3.33	0.86
4	23.33	6.67	7.67	4.33	4.67	4.00	1.67	1.33	0.00	0.33	0.33	54.33	14.06
21	6.67	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	7.00	1.81
31	6.67	3.33	0.67	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	11.00	2.85
41	0.00	0.00	0.00	0.33	0.67	0.67	0.67	0.00	0.00	0.00	0.00	2.33	0.60
Subtotal	83.33	26.67	15.00	7.67	7.67	6.00	2.67	1.33	0.33	1.00	0.33	152.00	
%	21.57	6.90	3.88	1.98	1.98	1.55	0.69	0.35	0.09	0.26	0.09		39.34
1	0.00	0.00	0.00	0.33	0.67	0.33	0.33	1.67	2.00	1.00	1.00	7.33	4.82
5	133.33	36.67	22.67	13.67	8.67	5.00	4.00	2.33	0.67	0.00	0.00	227.00	149.34
Subtotal	133.33	36.67	22.67	14.00	9.33	5.33	4.33	4.00	2.67	1.00	1.00	234.33	
%	34.51	9.49	5.87	3.62	2.42	1.38	1.12	1.04	0.69	0.26	0.26		60.66
Total	216.67	63.33	37.67	21.67	17.00	11.33	7.00	5.33	3.00	2.00	1.33	386.33	
%	56.08	16.39	9.75	5.61	4.40	2.93	1.81	1.38	0.78	0.52	0.35		100.00

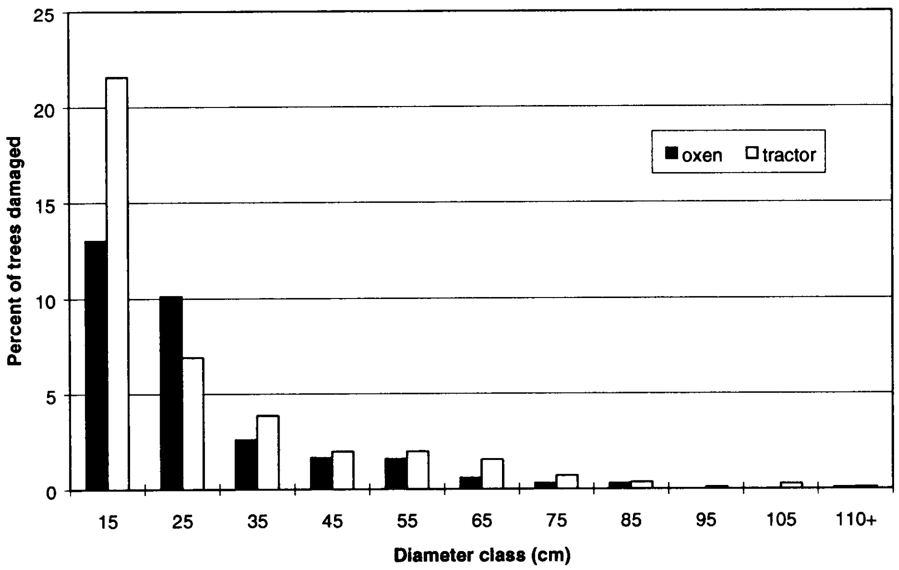

Figure 1. Percentages of trees damaged by oxen and tractor logging. Labels along the x-axis represent midpoints of the 10-cm-wide diameter classes shown in Tables 1 and 2.

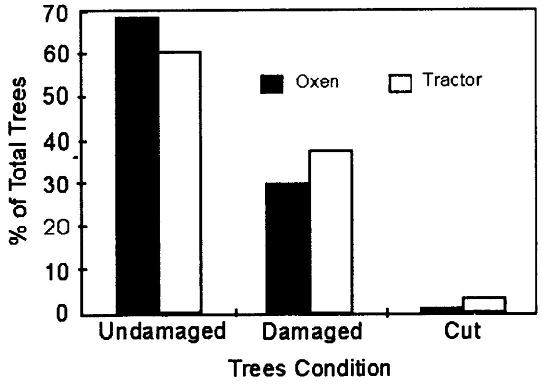

Figure 2. Percentage of total trees undamaged, damaged, or harvested in the oxen and tractor

In a case study to evaluate the compaction effects of oxen, it was determined that highest compaction occurred in the main skid trail, close to the landing where at least 110 skidding cycles were completed (or a total of 220 trips). In this particular case bulk density increased (with respect to an undisturbed site) 54%, from 0.526 g/cm^3 to 0.81 g/cm^3. In the rest of the main skid trail the increments remained between 14% and 30%. In neither case were bulk densities equal or greater than 1.2 g/cm^3, which is considered undesirable due to negative effects on trees and soil (Dyrness 1965 and 1972).

Table 3 includes the results of another evaluation, in a site where a mature forest plantation was clear cut and extraction with oxen was undertaken. It should be noted that in this case, only the landing had apparent densities of 1.2 g/cm^3.

Table 3. Average bulk density of the soil (g/cm^3) in places of a forest plantation logged with oxen.

Site	Bulk Density (g/cm^3)	Increase in Relation to an Undisturbed Site (%)
Main skid trail	0.93	9
Secondary trail	0.92	8
Landing	1.20	41
Undisturbed site	0.85	-

The extension of soil damage depends also on how much soil is removed as a consequence of roads or skid trails construction. Table 4 includes the total length of skid trails constructed to complete harvesting with oxen and with the tractor. A regular t-test was used and there was no significant difference on the amount of trails used by oxen and the tractor, but there was a significant difference when the volumes of soil removed were compared.

Table 4. Length (m) and earth moved (m^3) on skid trails used by oxen and crawler tractor.

Site	Oxen		Tractor	
	m	m^3	m	m^3
Block 1	404.85	121.46	488.50	935.20
Block 2	402.50	138.75	285.20	719.55
Block 3	592.40	283.60	390.00	618.00
Average	466.58	181.27	387.9	757.50

As can be seen in Figure 3 the tractor removed up to 4 times more soil than the oxen. Oxen skid trails are often built by hand and therefore soil removal is kept to a minimum. On the other hand, just the circulation of the tractor causes more soil removal than the oxen and the rubber-tired sulky.

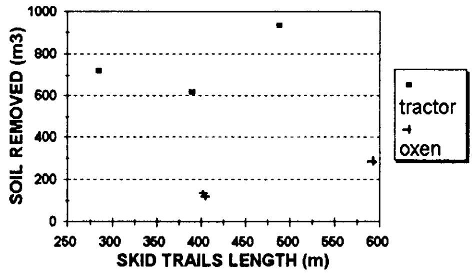

Figure 3. Length and soil removed on skid trails used by oxen and tractor

As can be seen oxen tend to cause less damage. Some other aspects like water pollution have not been evaluated, but if soil disturbance is reduced, there is less chance for water quality to be negatively affected. To reduce the environmental effects of tractor logging it is very important to reduce the amount of soil that is removed during road and skid trail construction.

2.2. Fixed and Variable Costs

In Costa Rica, the investment needed to own a well trained and equipped pair of oxen is close to 5% of the investment needed to purchase a small, 50 to 70 kW crawler tractor. The lower costs make the animal logging system available to a larger number of people.

Table 5 summarizes costs for owning and using a pair of oxen in a logging operation, including all the necessary accessories like the sulky, a steel chain, the yoke, etc. These costs consider 200 working days per year, 4 effective hours of work per day, and a utilization factor of 50%.

Table 5. Costs per year and effective hour for a pair of oxen.

Cost Component	US$/yr	US$/effective hr
Fixed Costs		
Amortization	139.40	0.174
Capital cost	336.50	0.421
Feeding	421.40	0.526
Veterinary	16.90	0.020
Variable Cost		
Tools	14.85	0.018
Maintenance	19.46	0.024
Labor	4512.00	5.640
Total	5459.70	6.823

The effective hourly costs (65% utilization factor) of owning and operating a small crawler tractor can be summarized as follows (US$):

Fixed Cost	16.72
Variable Costs	17.54
Labor	8.58
Total	42.84

The other consideration in relation with costs, is the structure or distribution of the costs in terms of fixed, variable and labor (Plot 4). As can be seen, most of the oxen cost is labor (83%) compared to 20% for the tractor. Therefore, when labor is available, the cost of it is low, and there is a need to provide employment to local people, conditions frequently found in developing countries, then the use of animals in logging operations must be promoted.

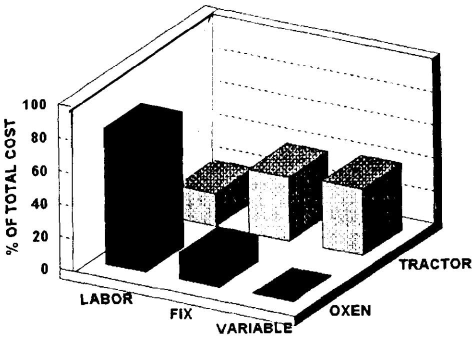

Figure 4. Cost distribution in % for oxen and tractor

2.3. Other Advantages

Another advantage of oxen is that the construction, use, and maintenance of equipment is easy. This makes oxen logging available to unskilled persons, and also, the simplicity of the working methods make them easy to understand and they can be almost immediately applied.

Oxen logging allows economical skidding of forest products, of different dimensions varying from large to small logs, posts of all sizes, and firewood. Machines tend to be more specialized, and one machine would hardly allow such flexibility in the size of products. In the case of machines, as the size of the product decreases, the operation costs remain almost constant, while the production decreases drastically.

Oxen are very versatile. With a few adaptations they can work in other activities such as agriculture and transportation, allowing the use of the oxen during most of the year.

3. Limitations for Using Oxen

As with any harvesting alternative, the use of oxen has some disadvantages or limitations that should be well understood to be able to obtain the most benefits out of their use.

Considering the cost information provided above, it must be noticed that most of the operation costs are fixed costs, since the oxen must be fed and need care even when they are not working.

The hourly production of oxen is low, compared to other mechanized methods such as tractors. Although production can increase by augmenting the number of teams, generally the use of animals adapts itself better to small operations.

Animals are better adapted to carrying logs with diameters smaller than 70 cm, and best results are obtained with logs between 40 and 50 cm. The use of the sulky has contributed to overcome this disadvantage. Also, larger logs have been skidded after they are split, or partially sawn in the forest.

Although their use is simple, workers must be able to establish a good relationship with the animals. They have to be well treated in order for the method to work. Machines can be abused and still work for a while, but if animals are abused the method does not function at all.

Finally, as a labor intensive method, it requires more physical effort on the part of the ox-driver and his helper, than if they were driving a tractor. However, there are no associated problems of noise, vibration or fumes.

4. Costs and Production

As mentioned before the use of the sulky has contributed to increase oxen production rates, as well to allow their use over longer distances and with larger loads. However, the use of the sulky is limited in terrain with slopes greater than 20%, and the operation becomes more difficult for the driver and his helper. Generally speaking it is not advisable to use the sulky on slopes greater than 30%.

In rugged terrain, the best solution is to use the oxen and chain to skid the logs downhill to a previously built skid trail, and from here use the oxen and the sulky to complete the skidding operation.

The sulky requires more labor, since loading and unloading is difficult for just one person, and an investment of about US$400 that, although low, is much higher than just buying the steel chain.

Table 6 includes information on the production (m^3/scheduled hour) obtained while extracting logs with a pair of adult oxen and a sulky from a 40 year-old forest plantation of *Cupressus lusitanica*. Most of the skidding was done using rudimentary skid trails, previously built, and whenever possible whole stems were skidded. Work was undertaken on an average 10% favorable slope.

Table 6. Production in m³/scheduled hour for a pair of oxen and a sulky skidding logs from a forest plantation.

Skidding Distance (m)	Production (m³/scheduled hour)
100	2.88
200	2.31
300	1.98
400	1.74
500	1.55
600	1.40
700	1.27
800	1.16
900	1.06
1000	0.97

In general, the daily production of a pair of oxen is equivalent to the hourly production of a small crawler tractor (equivalent to a Cat D4). This relationship has been observed during the harvesting of mature forest plantations of *Alnus acuminata* and *Cupressus lusitanica*, where the daily production (4 effective hours) of the oxen was an average of 19 m³, and the tractor had an average production of 13 m³ per scheduled hour. The average skidding distance was 250 meters.

A comparison between both methods in a natural tropical forest, resulted in an oxen average production of 7.35 m³ per 8-hour day, and the tractor produced an average of 10.48 m³/scheduled hour. The conditions of this type of forest, with large trees (up to 1.3 m DBH), and adverse slopes averaging 15%, are difficult for working with oxen.

The following table presents a summary of costs and production for the oxen and the crawler tractor working in forest plantations and natural tropical forests.

Table 7. Cost (US$/m³) and production (m³/scheduled hour) for oxen and tractor.

	Tractor	Oxen
Production		
Plantation	13.00	2.37
Natural Forest	10.48	0.92
Hourly Cost (US$/sch hr)	27.85	3.41
Cost of Skid Trails/m³		
Plantation	0.27	0.05
Natural Forest	0.67	0.15
Skidding Cost/m³		
Plantation	2.14	1.43
Natural Forest	2.66	3.70
Total Cost/m³		
Plantation	2.41	1.48
Natural Forest	3.33	3.85

These costs reflect the effects of terrain and forest conditions on the performance of the skidding system, and especially the influence of difficult conditions on oxen performance. The trees extracted had 60 to 85 cm in DBH, and wood specific densities between 0.7 and 1.1, which in combination are out of the normal range for optimal results with oxen.

5. Site Conditions for the Use of Oxen in Logging Operations

Following is a description of the conditions under which the oxen worked better and produced better results in terms of production, considering also the health and the safety of the animals. As far as possible animals should be used within the range of conditions indicated, but for specific reasons and during shorter periods of time they can also work under more difficult conditions.

5.1. Load Size

In general, and especially when comparing the animals to skidding methods based on the use of equipment, the oxen are better adapted to work with small logs. A pair of oxen equipped with a sulky can skid logs of up to 70 cm in diameter with a load of about 1 m³ or approximately 1000 kg. The best results are obtained with trees whose diameters vary between 40 and 50 cm (loads around 600 to 700 kg), conditions frequently found with forest plantations. Smaller trees require less effort from the animals, and also will be easier for the workers to prepare, hook and load.

In forest plantations the size of the trees is not a problem, since trees are smaller than in the natural forest and, on the other hand, there is a wide range of product sizes. Thus the good adaptability of the animals becomes an advantage.

When working in tropical forests where large trees are found (diameters above 1 m and up to 2 m) the animals have more limitations. In this case, the combined use of animals and equipment (crawler or farm tractors or rubber tired skidders) is the best alternative. With such combinations, the machines can build the skid trails and skid the larger pieces and the animals be used to skid all other material.

If large trees or logs have to be skidded with animals, they can be cut into shorter pieces or split, but in general this is an expensive operation.

During different field trials different loads per skidding cycle were used, and the larger the load the higher is the time per cycle, but also the larger is the production per hour. There should be a load that is so large that the time consumed is also extremely large and the production drops, but during the trials, even though loads of up to 2850 kg were skidded, this upper limit on load transported was not identified.

5.2. Skidding Distances

Skidding distances are directly related with road density and hourly costs. In general, forest plantations have more roads than natural forests, and considering that animals are better adapted to work over short distances, they find better work conditions on forest plantations.

The lower the operation costs, and especially the labor costs, the larger the distance that can be used with animals economically.

Animals are slow and therefore the distances over which they can be used more efficiently are short. If the load is being skidded directly over the ground, the longest skidding distance that should be used is around 200 meters. When the sulky is used, the skidding distance can be up to 2000 meters when working downhill. In average conditions the sulky can provide good results when used over a distance of up to 500 meters.

5.3. Terrain Slope

Skidding uphill (adverse slopes) has an important negative effect on the hourly production of animals. An adverse slope of only 15 to 20% can produce a reduction of 50% on the hourly production. Therefore, roads and skid trails, as well as the logging operation in general, must be well planned in such a way that skidding is done downhill as often as possible. Adverse slopes can be as high as 30 or 40% but over only short distances (5 to 10 m), and if the adverse slope is lower, the distance can be increased.

Favorable slopes may also have a negative effect if they are high, since the possibility of accidents increases. In general, the sulky should not be used on slopes greater than 30%. If skidding is done with a chain or a skidding pan the slopes can be as high as 60%, but the risk of injuring the animals is very high since the load can slide and hit them.

On steep terrain (slopes greater than 30%) a combination of chain and sulky was used. The chain was used to skid the logs to a previously established skid trail along which the sulky was employed. The slope of the skid trail can be easily controlled by constructing it across the slope.

5.4. Soil Type

The type, condition, and moisture content of the soil affects the production rate of the animals since the skidding resistance increases or decreases accordingly.

The poorest conditions for oxen skidding are found when working on stony soils since the skidding resistance is greater and also because the feet of the animals are more liable to be injured.

High moisture content and low soil bearing capacity (swamps, inundated flat areas) can considerably limit the use of mechanical skidding methods. Oxen and especially water buffaloes, are less sensitive to these extreme conditions and they usually can work on sites where it is almost impossible to skid logs with a crawler or farm tractor.

5.5. Harvested Volumes

Animal skidding is a harvesting method with low production output and therefore is better adapted to small scale harvesting operations. The total production of the harvesting operation can be increased by increasing the number of animals, but when the number of animals is larger than 20 some logistical problems may arise in order to provide the animals with food and appropriate care. This is more critical when working in forests or forest plantations where pasture is not abundant.

Another alternative to increase production is to combine animals with a mechanical system or to reduce the skidding distances. The combination of oxen with the use of farm tractors to harvest forest plantations is an excellent alternative to increase the total production of the harvesting operation.

5.6. Environmental Concerns

The use of animals to harvest products from sensitive areas is probably the best alternative since they have such a low environmental impact. For example, when skidding trees that have been thinned from a forest plantation, too much compaction or soil removal will have a negative effect on the residual trees and therefore a low impact method is needed. Also, the skid trails needed by the animals are much simpler than those needed by mechanical methods, and if the visual impact of the logging operations needs to be reduced, the animals are more likely to be the best alternative.

6. Conclusions

1. In order to obtain the best results in terms of costs, production, and animal health, and to facilitate the acceptance of animal based working methods, they must be used only under field conditions for which they are better adapted.

2. Working under the appropriate range of conditions, oxen can be as competitive as mechanized methods.

3. The main advantages of animal based logging methods when compared to mechanized methods are: low environmental impact, use of local inputs, low capital inputs, and use of more labor.

4. The main disadvantages of animal based logging when compared to mechanized methods are: its limitation in working with large trees, its limitation in skidding logs uphill, and its low hourly production.
5. Forest plantations can be economically and easily harvested with oxen in Costa Rica, and with low impact on the environment.

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A Case Study on Forest Harvesting Damages, Structure and Composition Dynamic Changes in the Residual Stand for Dipterocarp Forest in East Kalimantan, Indonesia

Elias

Abstract

This research was conducted in the forest concession areas of PT. Narkata Rimba (NR) and PT. Kiani Lestari (KL), East Kalimantan, Indonesia. They consist of 4 permanent plots at NR and. 8 at KL. The size of each plot is 100x100 m. The research was started in 1992. Observations and analysis were made on the effects of forest harvesting with the Indonesian Selection Cutting and Planting (TPTI) system on the residual stand of dipterocarp forest and its relation to the damages, structure and composition dynamic changes, natality, mortality, growth and the sustainability of the logged over forest.

The results indicated that the levels of residual stand damages positively correlate to the logging intensity, and most of the damaged trees were heavily injured. Harvesting caused loss of some species, but did not change the stand structure and composition of the species groups. The high tree mortality occurred immediately after harvest and afterwards, and drastically decreased in the third year. This opens up the possibility of developing measures to control the level of damages.

Key words: harvesting, damage, dynamic changes, sustainability

1. Introduction

Among the millions of hectares of tropical rain forests in the world, Indonesia has about 144 million hectares. About 94 million hectares of these forest areas are production forest. Currently, there are about 585 forest concession holders operating in the production forest. For the management of the natural tropical rain forest, almost all the forest concession holders use the TPTI system. The cutting cycle is 35 years. The TPTI system is a system in which commercial trees with diameter above 50 cm are removed from a site and leaving a minimum of 25 young commercial and healthy trees per hectare distributed uniformly in the area.

An important criterion for the judgment of wood harvesting, particularly from the TPTI system view point, is the condition of the residual stand after harvesting, like damage, structure and composition dynamic changes, natality and mortality. The damage to the residual stand can lead to infection by wood destroying fungi and can reduce growth and quality of the stand in the next cutting cycle.

The objective of this paper is to describe the actual situation of the residual stand of dipterocarp forest in East Kalimantan, after wood harvesting with the TPTI system.

2. Design and Measurements

The research was carried out on forest concession areas of NR and KL, in the province of East Kalimantan, Indonesia. The research plots consist of

- 4 permanent plots at NR, namely:
  Plot I: Plot before and after wood harvesting with slope O-15%.
  Plot II: Plot before and after wood harvesting with slope 16-25%.
  Plot III: Plot before and after wood harvesting with slope > 25%.
  Plot IV: Plot control or virgin forest

- 8 permanent plots at KL, namely:
  Plot I: Plot before and after wood harvesting with slope O-15%.
  Plot II: Plot before and after wood harvesting with slope 16-25%.
  Plot III: Plot before and after wood harvesting with slope 25%.
  Plot IV: Plot 4 years after wood harvesting.
  Plot V: Plot 9 years after wood harvesting.
  Plot VI: Plot 13 years after wood harvesting.
  Plot VII: Plot 17 years after wood harvesting.
  Plot VIII: Control plot of unharvested natural forest ("virgin forest")

The size of each plot is 100x100 m. Figure 1 shows the design of the plot and Figure 2 shows the design of strip 2 and 4 for vegetation analysis.

Beside permanent plots, survey on the logged over forest and virgin forest have been done. The design of the survey plots is the same as the design of subplots for vegetation analysis in permanent plots. For this purpose, l-3 linear plots 20x500 m, divided into continuous strip sampling 20x20 m, were used on each survey area.

The research was started in 1992 and repeated measurements were conducted annually on the following information:

1. Wood Harvesting System
2. Tree Mapping
3. Vegetation Analysis
4. Stand Profile/Structure
5. Residual Stand Damage
6. Natality
7. Mortality
8. Growth

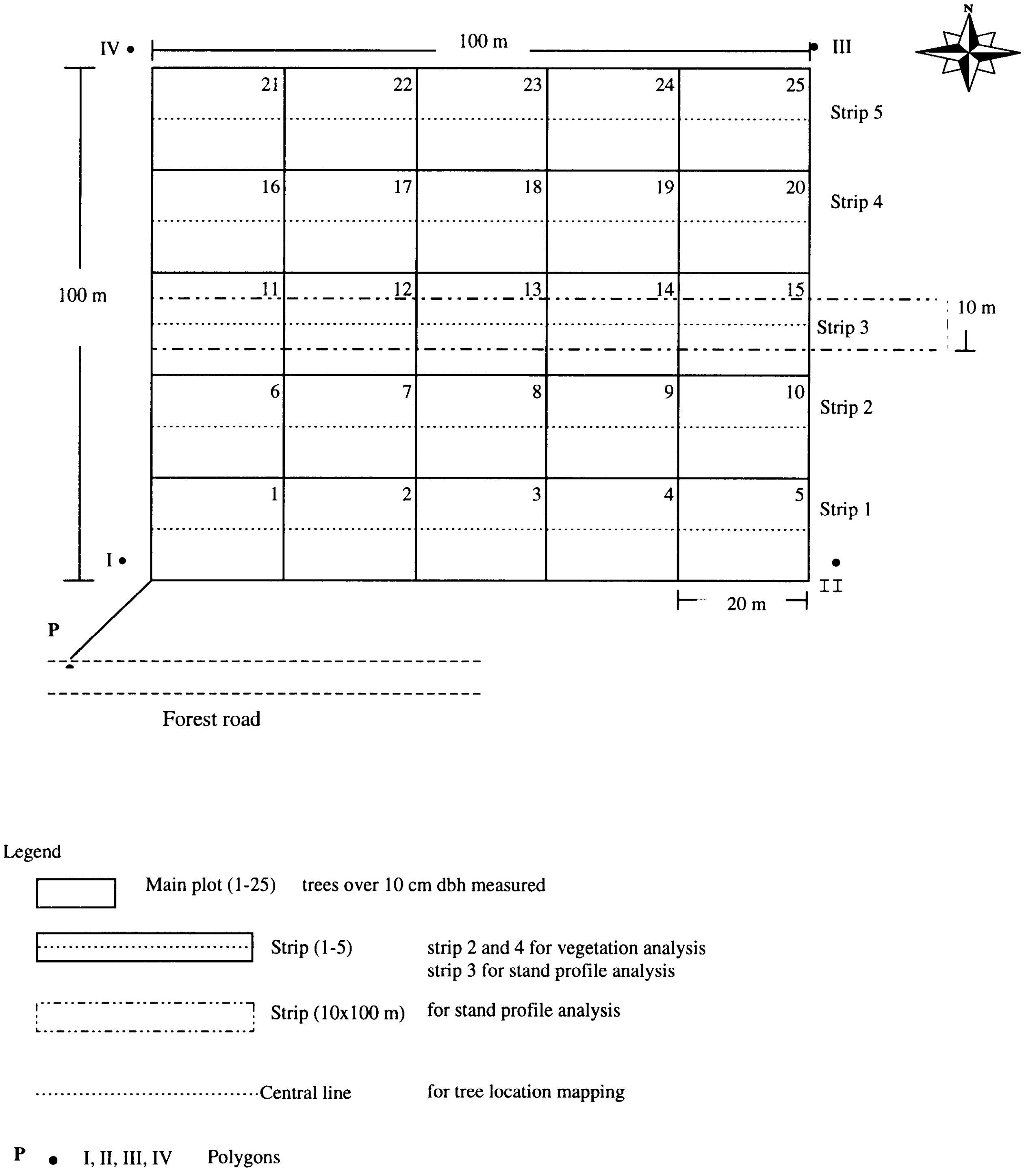
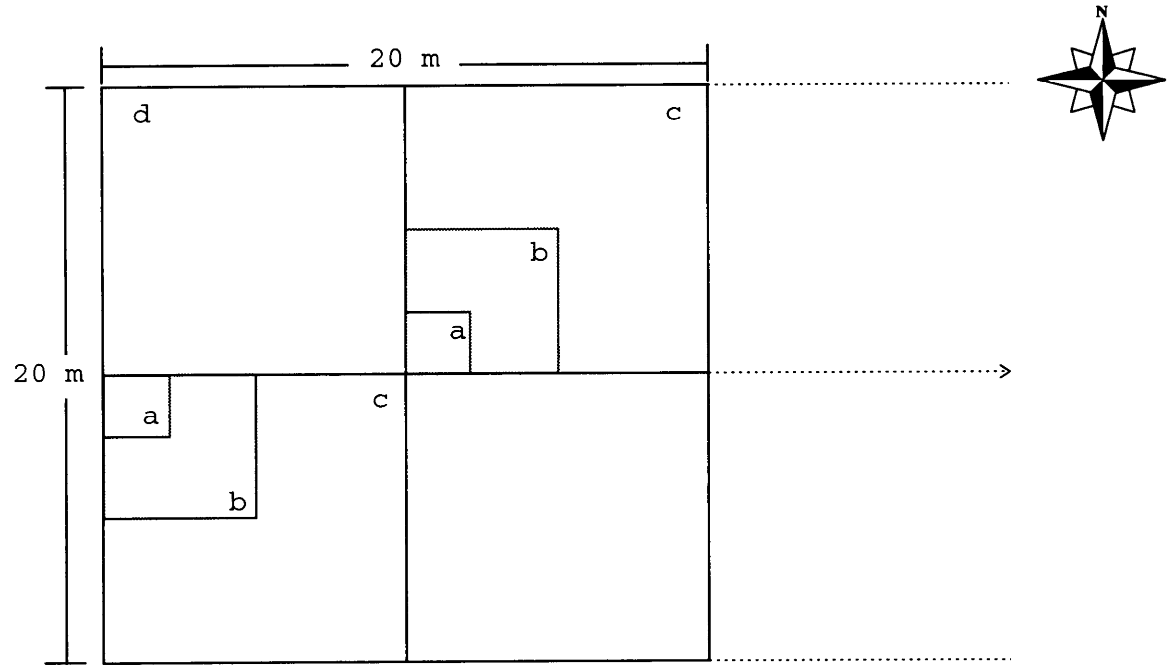


Figure 1. Permanent plot design.



a Seedlings (height < 1.5 m) measured on subplots 2x2 m
b Saplings (height ≥ 1.5 m, dbh < 10 cm) measured on subplots 5x5 m
c Poles (dbh ≥ 10 - 19 cm) measured on subplots 10x10 m
d Trees over 20 cm dbh measured on subplots 20x20 m

Figure 2. Design of subplots for vegetation analysis.

3. Results

Wood Harvesting System

The wood harvesting system used in the research area was as follows:

- Felling with heavy chainsaw (10-12 kg)
- Skidding with crawler tractor (160 kW) equipped with winch
- Bucking in landing with heavy chainsaw
- Debarking with crowbar
- Loading with wheel loader (220 kW)
- Hauling with truck trailer (225 kW)
- Unloading in log yard with wheel loader (220 kW)

The Degree of Residual Stand Damages

The degree of residual stand damages based on tree population and the stage of vegetation development were found as follows:

	For NR	For KL
for seedlings	30.02%	38.20%
for saplings	27.17%	43.40%
for poles	24.60%	33.26%
for trees	-	12.62%

Table 1 presents the data on the degree of the tree damages (diameter 10 cm and up) based on the logging intensity. The result indicated that the higher intensity of logging causes bigger damages to residual stand.

Table 1. Degree of residual stand damages based on logging intensity.

Permanent Plot	Trees Before Logging (Ø≥10cm)	Logging Intensity (Trees/ha)	Trees Damages (Ø≥10cm)	Degree of Damage (%)
In PT. Narkata Rimba				
I	620	2	58	9.39
II	697	6	146	21.13
III	748	17	259	35.43
In PT. Kiani Lestari				
I	565	8	218	38.60
II	487	9	225	46.20
III	480	8	221	46.82

Most of the damaged trees were of small sizes, e.g., in NR 65.23% damaged trees with diameter of 10-19 cm and 21.18% with diameter of 20-29 cm. Table 2 shows the diameter classes of the damaged trees in KL.

Table 2. Diameter classes of the damaged trees in PT. Kiani Lestari.

Diameter Classes	Percent of Damages
10 - 19 cm	28.01-33.47
20 - 29 cm	6.46-8.48
30 - 39 cm	1.26-2.97
40 - 49 cm	1.06-1.46
50 - 59 cm	0.54-0.64
≥ 60 cm	0.21-1.80

Based on the size injury of each individual trees, the degrees of the tree damages caused by wood harvesting were as follows:

	For NR	For KL
trees with heavy injury	82.12%	83.29%
trees with medium injury	13.19%	6.15%
trees with light injury	4.58%	10.56%

An analysis of the effects of diameter and height of trees and slopes on residual stand damages shows that the effects on the residual stand damages were not significant.

Types of Tree Damage

The tree damages or injuries consist of (see figures in annex 1):

- Crown damage
- Bark and stem injury
- Fallen tree
- Broken stem
- Root or buttress injury

These tree damages are generally caused by the felling and skidding activities. Table 3 shows the types of tree damages caused by felling and skidding activities in NR and KL. The damages caused by skidding were higher than by felling (75%:25%).

Opened area

The degree of opening in the residual stand caused by felling and skidding depends largely on the logging intensity, mainly the openings caused by felling. The higher intensity of logging causes a larger opened area of the residual stand. Table 4 shows the size of opened area caused by felling and skidding activities based on logging intensity. The size of the opened area caused by harvesting of one tree ranged between 285 and 512 m^2 or 396 m^2 on average.

Table 4. Opened area of residual stand caused by felling and skidding activities based on logging intensity.

Concession Area	Permanent Plot	Logging Intensity (trees/ha)	Opened Area (m^2) Caused by		Total (m^2)
			Felling	Skidding	
PT. Narkata Rimba	I	2	92	596	688
	II	6	808	2008	2816
	III	17	2512	2324	4836
PT. Kiani Lestari	I	8	2079	1501	3080
	II	9	3277	2077	4611
	III	8	1761	1624	3070

Table 3. Types of tree damage caused by felling and skidding activities in PT. Narkata Rimba and PT. Kiani Lestari.

Concession Area	Permanent Plot	Logging Intensity (trees/ha)	Types of Tree Damage					Total (%)
			Fallen Trees (%)	Broken Stems (%)	Crown Damage (%)	Bark & Stem Injury (%)	Root & Buttress Injury (%)	
PT. Narkata Rimba	I	2	5.50	0.97	2.5	–	0.32	9.38
	II	6	17.80	0.87	1.5	0.58	0.29	21.13
	III	17	21.89	3.83	8.0	1.64	–	35.43
PT. Kiani Lestari	I	8	24.24	5.39	5.3	3.23	0.36	38.60
	II	9	29.30	7.11	6.2	2.51	1.05	46.20
	III	8	30.30	5.86	7.6	1.91	1.06	46.82

The types of damage in NR caused by **felling** are:

- Crown damages: 49.45%
- Broken stem: 23.08%
- Fallen tree: 19.23%
- Stem injury: 8.24%

and caused by **skidding** are:

- Fallen tree: 88.32%
- Leaning tree: 4.47%
- Stem injury: 4.47%
- Crown and buttress damages and broken stem: 2.74%

Natality, Mortality and Tree Growth

Knowledge of natality, mortality and tree growth in the residual stand is important in order to improve the tropical forest management. This ensures the forest quality in the next cutting cycles.

Table 5 shows the natality and mortality of seedlings one and two years after wood harvesting in NR. The mortality and natality of seedlings were irregular. Generally, the seedling mortality of dipterocarp species occurred on meranti kuning (*Shorea gibbosa*), meranti merah (*Shorea leprosula* Miq.), and tengkawang (*Shorea* spp.), and the natality of dipterocarp species occurred on bangkirai (*Shorea laevifolia*) and melapi (*Hopea sangal* Korth).

The total number of seedlings of commercial Dipterocarpaceae species one and two years after wood harvesting are as presented in Table 6.

Table 5. The natality and mortality of seedlings one (Et+1) and two (Et+2) years after wood harvesting in PT. Narkata Rimba.

Permanent Plot	Species Groups	Natality (%)		Mortality (%)	
		Et+1	Et+2	Et+1	Et+2
I	A Commercial				
	1. Dipterocarpaceae			30.4	38.7
	2. Non Dipterocarpaceae	157.1	19.1		
	B Non Commercial	157.1			30.3
II	A Commercial				
	1. Dipterocarpaceae	190.6	122.6		
	2. Non Dipterocarpaceae	266.7	427.3		
	B Non Commercial	114.3	603.3		
III	A Commercial				
	1. Dipterocarpaceae			55.2	17.6
	2. Non Dipterocarpaceae	78.9			55.6
	B Non Commercial	135.2			69.0
IV	A Commercial				
(Virgin Forest)	1. Dipterocarpaceae	11.7	12.1		
	2. Non Dipterocarpaceae		5,000.0	50.0	
	B Non Commercial		17,000.0	50.0	

Table 6. The total seedlings of commercial Dipterocarpaceae species after wood harvesting (Et-0), (Et+1), and (Et+2).

Permanent Plot	Et - 0 (Seedlings /ha)	Et + 1 (Seedlings /ha)	Et + 2 (Seedlings /ha)
I	28,000	21,000	12,875
II	4,250	11,625	25,875
III	13,625	13,500	11,125
IV (Virgin forest)		22,750	25,500

The total number of seedlings of commercial Dipterocarpaceae species, both in logged over forest and virgin forest, was more than the minimum of 1,000 per hectare or 40 percent stocking as required by the regulation contained in the TPTI system.

Table 7 shows the mortality of trees with diameter ≥ 10 cm, during wood harvesting (Et-0), (Et+1), and (Et+2). In general, the dead trees consisted of small trees with diameter 10-39 cm. The mortality occurred during the wood harvesting year was 6.0-26.6% and one year after harvesting was 2.0-13.6%. These figures decreased drastically in the second year after harvesting (0.7-3.6%). It seems that higher damage occurring in residual stands causes the higher tree mortality. The mortality of trees in virgin forest was about. 0.9-2.4% per year which is 1.1% on average.

Table 7. Mortality of trees with diameter 10 cm and above in the residual stand and virgin forest in PT. Narkata Rimba.

Permanent Plot	Diameter Class (cm)	Mortality (%)		
		Et - 0	Et + 1	Et + 2
I	10 - 19	7.0	2.9	0.6
	20 - 29	4.5	1.0	0.0
	30 - 39	2.5	1.3	1.3
	40 - 49	4.2	0.0	4.3
	50 - 59	15.4	0.0	0.0
	≥ 60	0.0	0.0	0.0
	Total	6.0	2.0	0.7
II	10 - 19	20.2	16.1	3.9
	20 - 29	16.1	9.9	3.9
	30 - 39	7.8	13.6	2.0
	40 - 49	9.1	5.0	5.3
	50 - 59	0.0	12.5	0.0
	≥ 60	0.0	5.6	0.0
	Total	17.0	13.6	3.6
III	10 - 19	22.3	14.6	0.6
	20 - 29	19.6	10.8	2.0
	30 - 39	22.5	9.1	0.0
	40 - 49	14.8	8.7	0.0
	50 - 59	7.1	0.0	0.0
	≥ 60	15.4	4.5	0.0
	Total	26.6	12.5	0.8
IV	10 - 19	1.2	3.2	1.2
	20 - 29	1.9	0.0	0.0
	30 - 39	0.0	4.8	2.5
	40 - 49	9.5	0.0	0.0
	50 - 59	7.1	0.0	0.0
	≥ 60	0.0	0.0	0.0
	Total	1.6	2.4	0.9

Diameter measurements of tree species with diameter greater than 10 cm have recorded for three consecutive years (1992, 1993 and 1994) in NR within the permanent plots of logged-over forests. The diameter growths of trees after wood harvesting were as shown in Table 8 and 9.

Table 8. Diameter growth of trees one (Et+1) and two (Et+2) years after harvesting.

	Et+1	Et+2
Commercial species of Dipterocarpaceae	0.80-1.25 cm	0.86-0.39 cm
Commercial species of Non Dipterocarpaceae	0.55-1.13 cm	0.30-0.57 cm
Non Commercial species	0.62-1.01 cm	0.38-1.35 cm
On average	0.66-1.05 cm	0.41-1.04 cm

Table 9. Diameter growth of some commercial species of Dipterocarpaceae after wood harvesting.

	Et+1 (cm)	Et+2 (cm)
Meranti merah (*Shorea leprosula* Miq.)	1.07	0.44
Meranti putih (*Shorea parrifolia* Dyer)	0.90	0.80
Meranti kuning (*Shorea gibbosa*)	1.60	0.50
Bangkirai (*Shorea laevifolia*)	0.80	0.61
Tengkawang (*Shorea* spp.)	0.98	0.83
Mata kucing (*Shorea* spp.)	0.89	0.61
Markabang (*Shorea* spp.)	0.72	0.23
Melapi (*Hopea sangal* Korth)	0.97	0.28
Mersawa (*Anisoptera* spp.)	0.69	0.79

Table 10 shows the diameter growth and volume of 25 nucleus trees per hectare in NR. The average growth of diameter and volume one and two years after wood harvesting were 0.92 and 0.50 cm/year and 1.832 and 0.901 m^3/ha/year.

Table 10. The diameter growth and volume of 25 nucleus trees per hectare in PT. Narkata Rimba.

Permanent Plot	Et + 1		Et + 2	
	Diameter (cm/year)	Volume (m^3/ha/ year)	Diameter (cm/year)	Volume (m^3/ha/ year)
I	0.89	1.794	0.46	0.819
II	1.10	1.670	0.58	0.923
III	0.76	2.033	0.45	0.961
Average	0.92	1.832	0.50	0.901

Table 11 shows the diameter growth of trees with diameter over 10 cm in KL. The diameter growth of trees one year after wood harvesting were greater than 4, 9, 13 and 17 years after harvesting. The diameter growth of trees after wood harvesting were about 0.80-0.95 cm/year and after 4, 9, 13 and 17 years were about 0.47-0.69 cm/year. The diameter growth of trees in virgin forest were about 0.51-0.74 cm/year.

Table 11. The diameter growth of trees with diameter over 10 cm in PT. Kiani Lestari.

Permanent Plot	Logged Over Forest (year after wood harvesting)	Growth of Diameter (cm/year)			
		Com. Dipt.	Com. Non Dipt.	Non Com.	Average
I - III	1 year	0.87	0.80	0.95	0.87
IV	4 years	0.51	0.49	0.45	0.48
V	9 years	0.50	0.47	0.69	0.54
VI	13 years	0.68	0.51	0.52	0.57
VII	17 years	0.47	0.68	0.50	0.55
Logged over forests in average		0.68	0.65	0.72	0.69
VIII	Virgin Forest	0.55	0.51	0.74	0.60

The results showed that the diameter growth of trees at one year age was greater than 2, 4, 9, 13 and 17 years after wood harvesting. Based on the linear regression equation of logged over forest in KL, the average growth of commercial trees with diameter ≥ 10 cm was found 2.97 m^3/ha/year.

Dynamic Changes of Structure, Composition and Biodiversity

Wood harvesting with the TPTI system is equivalent to gap formation caused by natural treefall in the forest. Within such gaps (opened areas caused by felling and skidding) dynamic changes occurred through light stimulation, residual stand damages, natality, mortality and competition of some species. Table 12 shows the dynamic changes of the stand structure and composition before and after wood harvesting (Et-0, Et+1 and Et+2) in NR.

Wood harvesting with the TPTI system reduced the tree population about 10-37% by felling and skidding. One year after wood harvesting, the tree population decreased again by 8-25%, which was caused by mortality of damaged trees and tree position in the opened areas. Two years after harvesting, the mortality of the trees decreased drastically, and the tree population increased about 2-10%. The changes of the tree population in the virgin forest varied continually (but < 10% annually). The composition of the species groups (commercial Dipterocarpaceae, commercial non-Dipterocarpaceae and non-commercial), distribution of the tree diameter, and the relative positions of canopy or crown strata, before and after wood harvesting did not change, although the decrease in tree population and opened areas caused by harvesting had occurred. Figures 3-6 (see Annex) show the dynamic changes of the stand structure and composition before and after (Et-0, Et+1 and Et+2) wood harvesting.

Table 12. The number of tree species before and after wood harvesting (Et-0 and Et+1) in PT. Narkata Rimba.

Stages of Trees	Amount of Species in Permanent Plot										
	I			II			III			Virgin Forest	
	A	B	C	A	B	C	A	B	C	A 1993	A 1994
Seedling	20	17	28	20	20	22	22	17	22	5	6
Sapling	36	32	32	34	34	32	50	45	36	29	28
Poles	28	25	26	29	27	26	28	26	21	21	23
Trees	43	39	38	40	38	33	45	42	45	40	37
All stages of trees	64	59	63	60	59	59	124	110	112	58	58

A: Before wood harvesting
B: After wood harvesting (Et-0)
C: One year after wood harvesting (Et+1)

The numbers of trees species found in NR in Permanent Plots I, II, III and IV were 124, 64, 60 and 58 species.

The wood harvesting caused a decrease in the tree species around 1.7-11.29%, but about 14 years after wood harvesting the condition is predicted will return to normal. as shown in Table 13.

Table 13. The development of the sum of tree species with diameter 10 cm and up in logged over forest in PT. Kiani Lestari.

Permanent Plot	Logged over forest	Amount of Tree Species
I - III	After wood harvesting	34
IV	5 years after wood harvesting	39
V	9 years after wood harvesting	45
VI	13 years after wood harvesting	50
VII	17 years after wood harvesting	46
VIII	Virgin Forest	50

4. Conclusions

1. The degree of residual stand damages ranged between 28-45% and the incidence of damages to small trees was greater (about 80%). Most of the damaged trees were heavily injured (about 85%) and had little chance to recover since their growth was affected by the damage.
2. The degree of residual stand damages was found correlated to the intensity of logging. This opens up the possibility to develop measures to control the level of damage.
3. The mortality rate of young trees left after wood harvesting was between 6.0-26.6%. During the first year 2.0-13.6% and during the second year the mortality decreased drastically to 0.7-3.6%.
4. The total number of species on permanent plots (100 x 100 m) ranged between 58 and 124 species. Wood harvesting caused loss of some species (1-14 species or 1.7-11.29% of total number of species), but after about 14 years of harvesting it would recover.
5. The stand structure and composition of the species group before and after wood harvesting were almost the same, although a decrease of tree population and opened areas caused by wood harvesting has occurred.
6. The average growth of trees with diameter greater than 10 cm of the residual stand one year after wood harvesting was initially 0.55-1.25 cm/year and after that it decreased to 0.41-1.04 cm/year.
7. The average diameter growth and volume of 25 nucleus trees per hectare, one and two years after wood harvesting were respectfully 0.92 and 0.50 cm/year and 1.832 and 0.901 m^3/ha/year.

Acknowledgments

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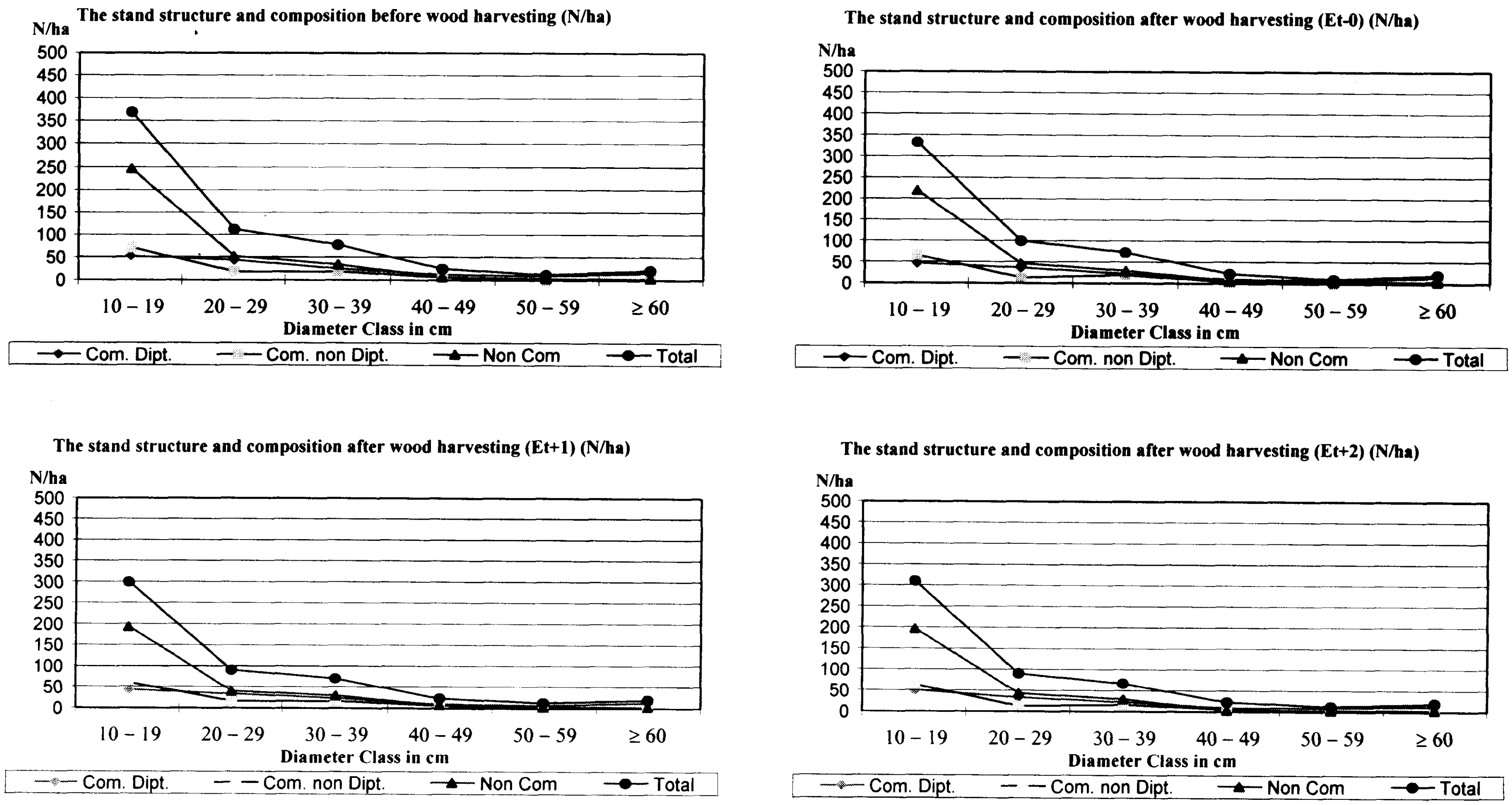
Annex (following pages):

Figures 3-6 show the dynamic changes of the stand structure and composition before and after (Et-O, Et+1 and Et+2) wood harvesting.

Figures 7-16 illustrate the condition of the forest in the permanent plots after harvesting.

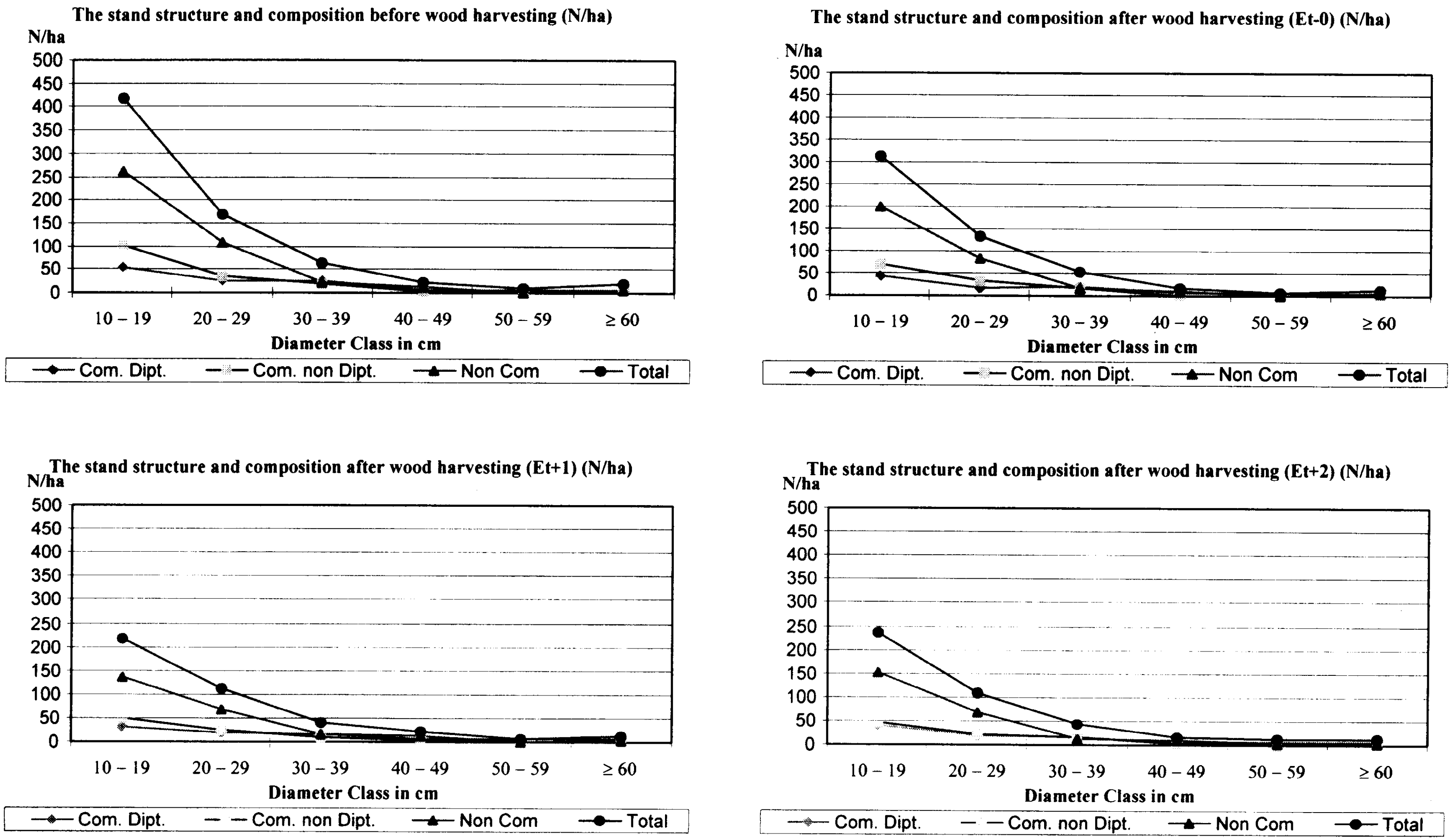

The stand structure and composition before wood harvesting (N/ha)

The stand structure and composition after wood harvesting (Et-0) (N/ha)

The stand structure and composition after wood harvesting (Et+1) (N/ha)

The stand structure and composition after wood harvesting (Et+2) (N/ha)

Figure 3. The dynamic changes of the stand structure and composition before and after wood harvesting in permanent plot I, in PT. Narkata Rimba.



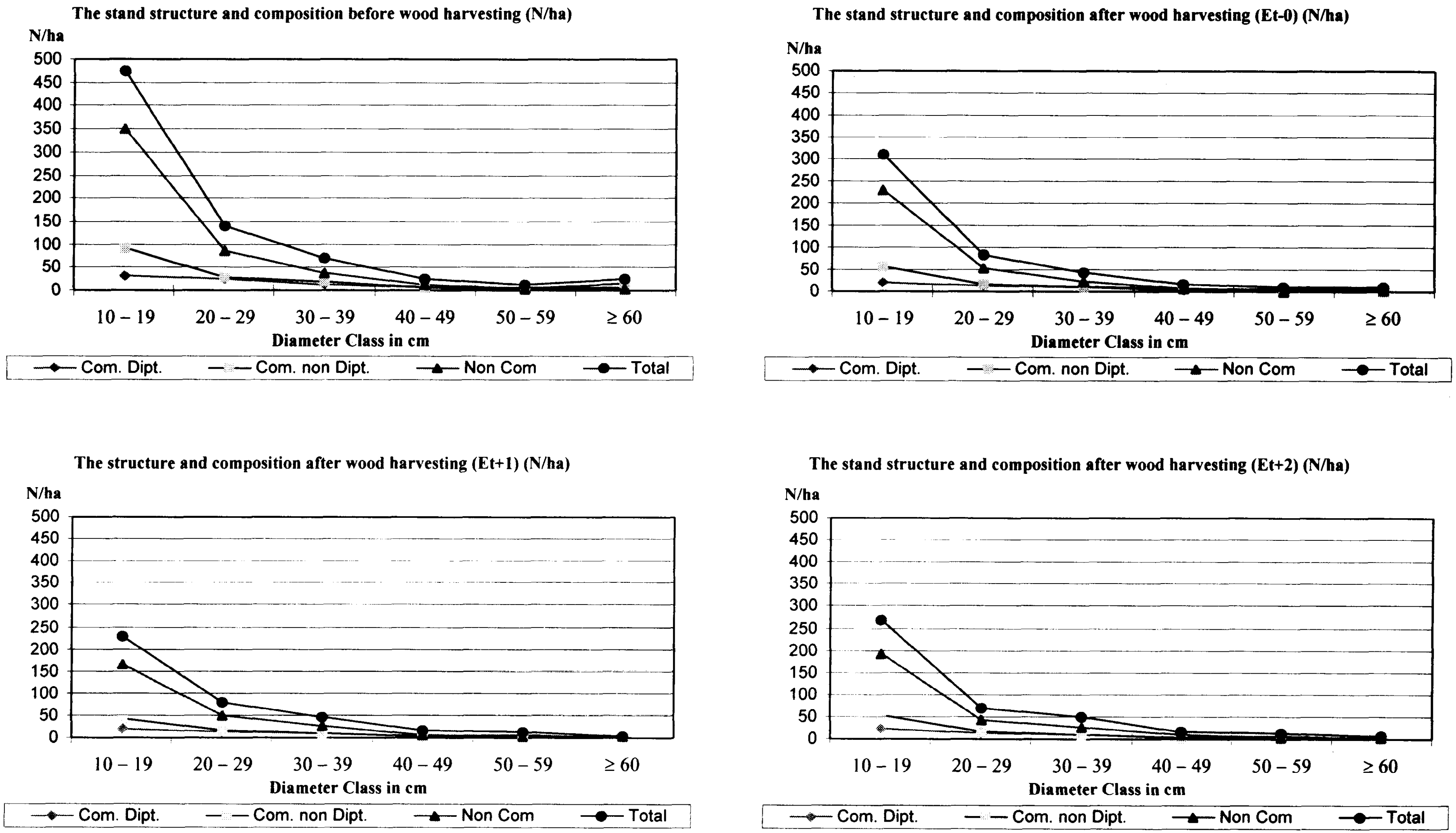
The stand structure and composition before wood harvesting (N/ha)

The stand structure and composition after wood harvesting (Et-0) (N/ha)

The stand structure and composition after wood harvesting (Et+1) (N/ha)

The stand structure and composition after wood harvesting (Et+2) (N/ha)

Figure 4. The dynamic changes of the stand structure and composition before and after wood harvesting in permanent plot II, in PT. Narkata Rimba.



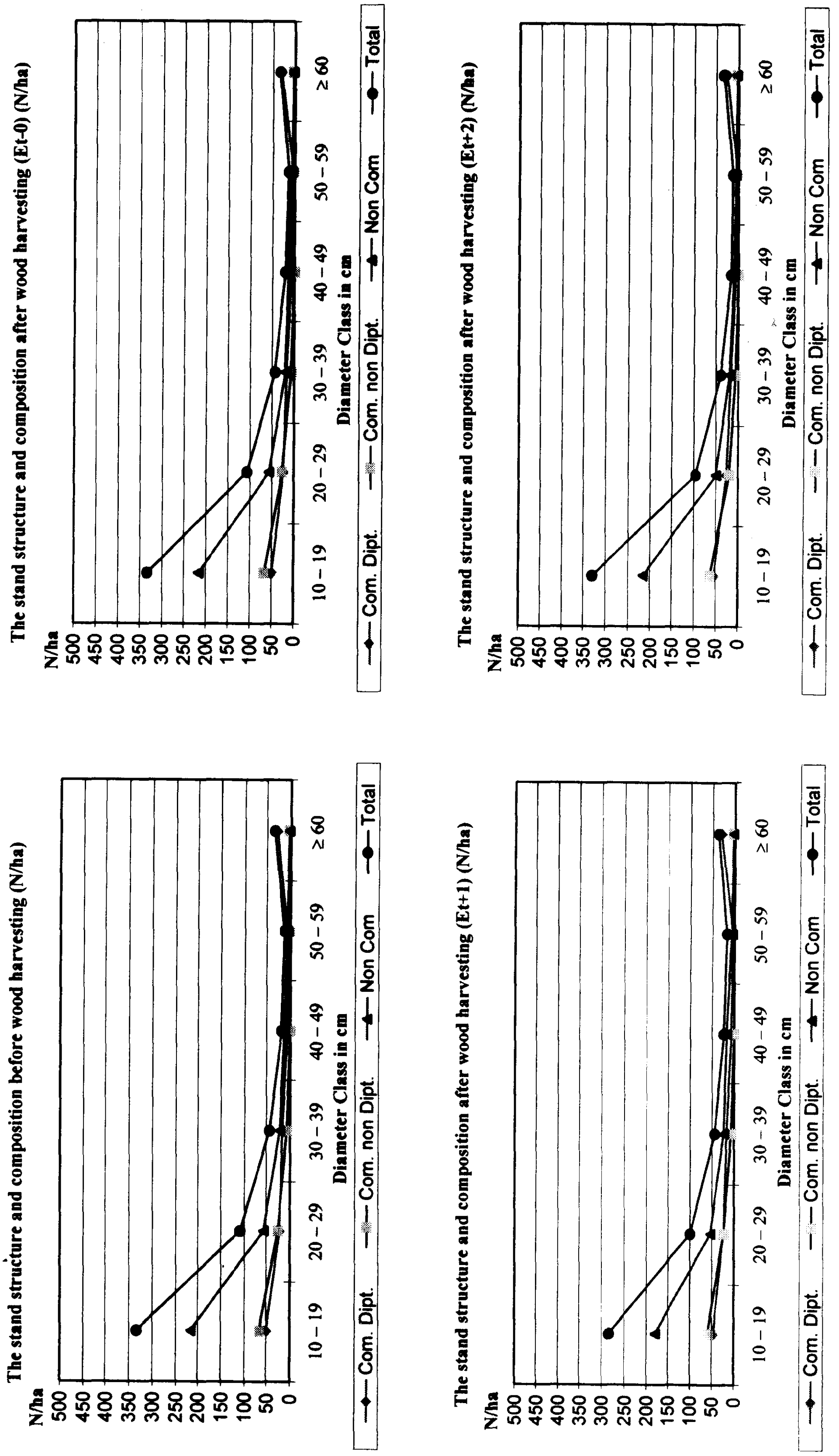
The stand structure and composition before wood harvesting (N/ha)

The stand structure and composition after wood harvesting (Et-0) (N/ha)

The structure and composition after wood harvesting (Et+1) (N/ha)

The stand structure and composition after wood harvesting (Et+2) (N/ha)

Figure 5. The dynamic changes of the stand structure and composition before and after wood harvesting in permanent plot III, in PT. Narkata Rimba.



The stand structure and composition before wood harvesting (N/ha)

The stand structure and composition after wood harvesting (Et-0) (N/ha)

The stand structure and composition after wood harvesting (Et+1) (N/ha)

The stand structure and composition after wood harvesting (Et+2) (N/ha)

Figure 6. The dynamic changes of the stand structure and composition before and after wood harvesting in permanent plot IV, in PT. Narkata Rimba.

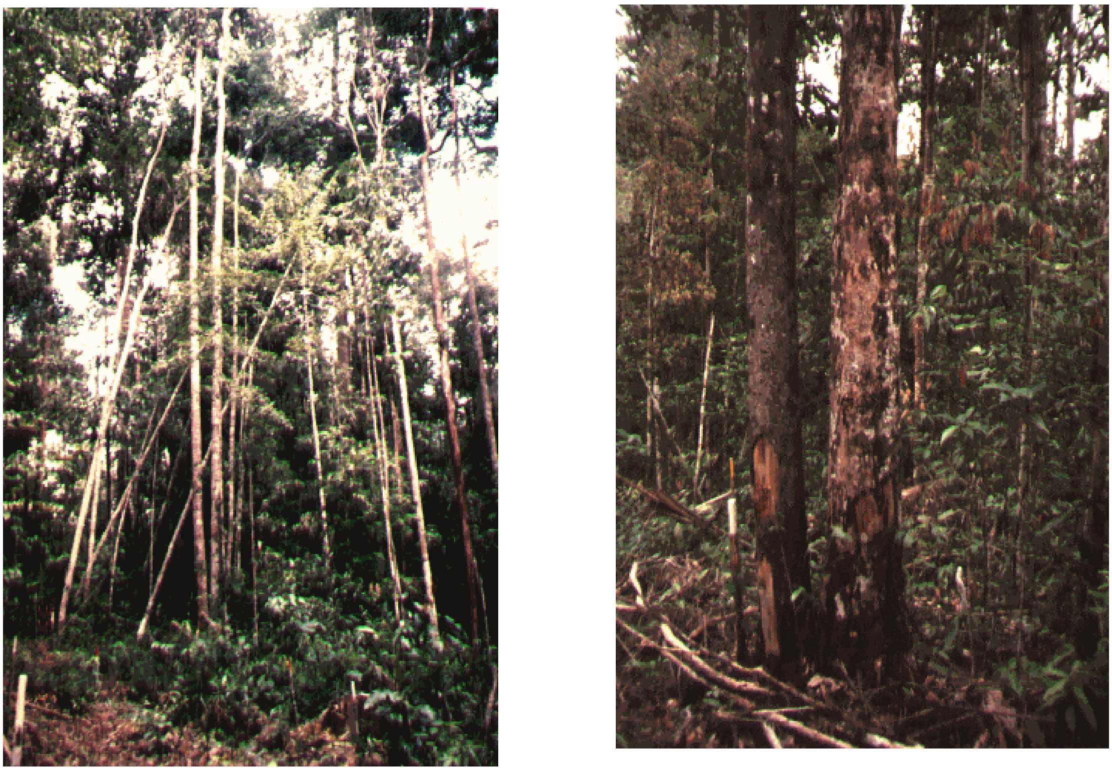
Figure 7. Fallen trees caused by felling.

Figure 8. Crown damage.

Figure 9. Broken stem.

Figure 10. Bark and stem injury.

Figures 11 and 12. Broken stem condition three years after wood harvesting.



Figures 13 and 14. Stand, bark and stem condition three years after wood harvesting.

Figure 15. Skidtrail condition one year after wood harvesting

Figure 16. Skidtrail condition three years after wood harvesting

The Accomplishments of Leizhou Forestry Bureau in Managing Tropical Forest

Shi Mingzhang

Abstract

Leizhou Forestry Bureau (LFB) is situated in Thundering Peninsula, west Guangdong Province, southern China. Historically the Peninsula suffered terribly from disasters of windstorms, sandstorms, droughts, barren lands and tidal waves. From the founding of the Bureau in 1954 through the year of 1977, the total area reforested by LFB was about 300 thousand hectares in the Peninsula. During this period the climate improved significantly: Yearly average precipitation increased by 454 mm and windstorms subsided.

The Bureau began improvement cuttings in 1963, then began clear cutting small areas in 1970. After 1986 the rotation age was decreased to 5-7 years instead of more than 20 years, and the main product was changed from mining timbers to chips for export. Assisting with many kinds of forest products and integrated processing, the Bureau became a multiple producing enterprise. Through the end of 1993 the total accumulated profit is equal to 42 times the total investment.

Key words: *Eucalyptus ;* man-made forest; short rotation; chips

Introduction

Leizhou Forestry Bureau’ is situated in Thundering Peninsula, in the southwestern part of Guangdong Province. The name of the peninsula is owed to the fact that the average yearly thundering days are over 196. The Bureau was founded in 1954 as the Forest Center of Eucalyptus, West Guangdong Province, and enlarged to a Bureau in 1963 with ten forest centers. LFB planted eucalypts and conifers all over the four counties and one municipality of the Peninsula, extending about 70 km east and west and 130 km north and south. The planted forests are connected to one another.

The geographical coordinates of the Peninsula are N20” 16’ to 21° 55’ and E 109” 39’ to 110” 36’. It faces Hainan Island across the Qiong Zhou Strait. Yearly average temperature is 23.5°C, rainfall 1855 mm, evaporation 1762.9 mm, days of precipitation 129, relative humidity 80.4%, amd the average annual number of typhoons above force 7 is 4-7. These data indicate a typical tropical monsoon climate.

Originally there grew flourishing tropical and subtropical forests all over the Peninsula. Due to slash and bum cultivation, high forests became shrubs, and shrubs turned to grass lands. Recently a great part of the grass lands degenerated into deserts and sand dunes. Consequently the Peninsula suffered disasters of windstorms, sandstorms, droughts, barren lands and tidal waves, and the peopie lived a miserable life. Since the Tang Dynasty, Five Dynasties, and Northern Song Dynasty (618-l 127) the Peninsula was treated as a penal colony for prisoners.

Since the founding of Leizhou Forestry Bureau things have changed radically: The climate was improved first, then considerable successes have been achieved in forest management. The result is an example worth examining.

1. Improving the Climate of Thundering Peninsula

Before the foundation of the People’s Republic of China, according to the incomplete meteorological records, 37 out of 38 years in the period of 191 l-1949, there were droughts of different degrees. More than one hundred thousand people died from famine and pestilence in the serious droughts of 1943 and 1946.

After Liberation, the Leizhou Forestry Bureau took vigorous action to plant both commercial forests and windbreak forests. In the meantime, the Bureau of Reclamation and Farming of West Guangdong Province, in addition to planting tropical crops such as rubber, sugar cane, sisal hemp, fruits, tea etc., also planted windbreaks vigorously. The farmers were brought along to plant windbreaks and fuelwood forests. By 1977, after more than twenty years, these plantings altogether totalled 300 thousand ha and brought the forest coverage of the Peninsula to 22.2% with substantial improvement of the local climate.

Rainfall Increase. Between 1913 and 1953 the yearly average rainfall of Suixi County was 1410 mm; in the first ten years (1955-1964), after reforestation the average increased 68.5 mm to 1469.5 mm. In another ten years (1965-1974) as the planted area increased again and the trees grew larger, the yearly average rainfall increased to 1855 mm, or 454 mm higher than in the period before reforestation. All the other counties on the Peninsula were alike.

Along with the increased rainfall, all other climatic factors such as temperature, humidity and evaporation, improved as well. The dry season became shorter, the rainy season came earlier etc. These results are good for agriculture and other plantings.

Reduce the Damage Caused by Windstorms. Beside the protection of rubber plantations and other tropical crops, agricultural farms near the sea shores also benefited from the windbreak forests. In Dongli Commune, surrounded by sandy sea shores on three sides, there circulated the saying before Liberation: “sand flies as mist and cloud in breeze, and overspreads the sky as strong wind blows; sand scalds feet in sunshine, and jumps high in the rain.” Sand dunes more than 10 km long moved inwards more than 250 m from the seashore, and forced two villages to move away. Sand covered 200 ha of farm and more than 4000 peasants fled from famine. After Liberation

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[1] The data in this paper have been abstracted from records of the Bureau or from Mujia (1977), Yuan Chaodieng (1992), and Li Shuming (1992).

the Commune planted more than 2200 ha of forests to fix the sand dunes. Within ten years through this reforestation the peasants seized back from the sea farm land more than 500 meters wide, enlarging the cultivated land by nearly 2000 ha. Output of crops increased 1.2 times.

Another example is Tangsai Production Brigade. In the year 1954 the area was hit by a force 11 typhoon with more than 70% of the houses in Tangsai being destroyed. A similar storm struck in 1972 but this time, because of the windbreak forests, only 4% of the houses were destroyed. This striking contrast made the masses see clearly the advantages of forests. Meanwhile, it was unavoidable that some peasants took possession of scattered national forests as their own. The local government, for the purpose of encouraging the peasants to plant and protect the forests, divided small, scattered and nearby national forests to collective ownership, and a little part to individual ownership. As for the Bureau, in the year 1962 they owned 112,933 ha of forests but after divesting some of these forests to local people, 50,860 ha remained in the Bureau's possession in 1982. Today the forests of the Bureau are joined together in a single block, convenient for intensive managing.

2. Achievements in Forest Management

In the forty years since its founding, the Leizhou Forestry Bureau, besides improving the climate of the Peninsula and the living condition of the peasants, has made considerable achievements in forest management.

Eucalyptus planting began in 1954. After the establishment of the Bureau in 1963, improving cuttings began. Self-sufficiency in funds began in 1966. At the beginning of the reforestation programme, all the funds were provided by the Government, including those for salaries, construction of buildings and roads, purchasing machinery, fuels and lubricants , collecting and purchasing seed, transportation and storage etc.

The Bureau began clearcutting small areas in 1970 with a yearly output of 70,000-90,000 m^3. By 1988 a total of 2277.2 thousand m^3 had been produced, including 558.2 thousand m^3 of commercial timber, 1194.2 thousand m^3 of small-diameter timber, and 542.8 thousand m^3 of fuelwood. Through 1993 the accumulated total income was 750 million Chinese Yuan, which was equal to 42 times the total national investment. The value of fixed assets was 24 million Chinese Yuan.

Since the founding of the Bureau, there were three important strategic revisions in management objectives.

The first time was at the beginning of reforestation when the objective was to make the Peninsula green by selecting drought-tolerant species suitable to tropical and subtropical regions. The species selected were mainly *Eucalyptus exserta* and *Eucalyptus citriodora.*

The second time was changing the objective to produce mine timber. This period lasted from 1963 to 1980. In this period, the main product was mine timber with a diameter at the small end less than 24 cm. Logs with larger diameters were used for purling and logs unsuitable for mine timbers were used to produce bobbins by lathing. Also a fibreboard mill was been built during this period in order to utilize chunks, branch twigs and crooked sticks. Meanwhile the level of mechanization of timber harvesting was increased and electrical chainsaws began to be used together with a portable generator. Even harvesting systems from Finland were tested. These included the feller-forwarder 882 KK, delimber-buncher 880S and loader-forwarder 928. But due to the difficulty of importing spare parts for repair, the result of testing was unhopeful and the original equipment was refitted for other uses.

The third change in management direction was to establish a capital-intensive, short-rotation system. The reasons which promote this change were as follows:

1. *The Eucalyptus* mine timbers could not compete with those of northern conifers, either in quality or price.
2. Even short and small logs as well as crooked sticks and slash could be used to produce chips, which could be sold at a higher price than mine timbers.
3. From the sixties to the seventies, experiments showed the result that the chips of *Eucalyptus* were good for making pulp and paper but the quality of the pulp decreases as log diameter increases. The most suitable age *f Eucalyptus exserta and Eucalyptus leizhou* No.1 are 5-7 years and for *Eucalyptus citriodora,* 7-10 years. *Eucalyptus leizhou* No.1 is a new species bred by the Bureau.

At present the distinguishing features of Bureau's forest management are as follows:

1. Follow a rotation of 5-7 years.
2. Select the best seeds and grow seedlings in containers as stock for tissue culture.
3. Weeding twice a year, for the first two years after planting.
4. Re-examine the plantations every two years. Eucalyptus grows quickly, with height growth up to 4-6 m and diameter up to 3-5 cm in three years. With increased management intensity the growth rates would be even higher.
5. After the initial generation is felled, the forest is permitted to regenerate by sprouting. This provides an increase in timber product of about 2% in the second generation as compared to regeneration by planting.
6. A mill producing 100 thousand tons o *Eucalyptus* chips annually has been built and a stable, long-term export contract obtained. The Bureau owns special chip-transport vehicles, a chip dock, and mechanized loading equipment.
7. For the sake of bringing the resource potential into full play, the Bureau has built a fibreboard plant with yearly capacity of 2,000 tons, a plant to manufacture 3,000 tons of boxes for fruit transport, and a fertiliser factory.

8. The forest area has been divided as follows. The topography of most forest farms of the Bureau are smooth and gentle, with average slopes about 5º. Subcompartments are divided into rectangles, each with an area of about 13 ha. The division lines around the subcompartments can be used as truck roads. Road density reaches about 20-25 m/ha. Labourer can go to work by biking. The Bureau owns graded roads with an average density of 3.15 m/ha and the total of both graded and ungraded roads has a density of 5.36 m/ha.

Leizhou Forestry Bureau has been built as a multiple-product enterprise, with the main produce of chips assisted by processing of many forest by-products.

3. The Effect of the Model of Leizhou Forestry Bureau

In the more than forty years since the founding of the Republic, most forestry bureaux of the country concentrated on felling with little attention to planting. As a result, regeneration has not kept pace with felling and many forestry bureaux find themselves in a difficult position of resource crisis. Moreover, the majority of the forestry bureaux depended only on income from timber sales, with little or no effort to promote sales of by-products. As a consequence many forestry bureaux have faced increasingly difficult economic situations. In contrast, due to its changes in management direction as mentioned above, the Leizhou Forestry Bureau has prospered during this period. For instance, a *Eucalyptu s* pulp and paper plant, producing 50 thousand tons a year, is being built.

This experience of Leizhou Forestry Bureau has radiated gradually to the surrounding districts. Six counties of west Guangdong Province have now formed a production and export network for *Eucalyptu s* chips. From 1988 to the end of 1991, the accumulated total exported was 470 thousand tons of oven-dry chips (about half from Leizhou Forestry Bureau). In the single year of 1991 the export of *Eucalyptu s* chips from Guangdong, Guangxi and Hainan was 335 thousand oven-dry tons valued at more thant 30,000 thousand U.S. dollars in foreign exchange. As for Leizhou Forestry Bureau only, up to the end of 1993, the total export of chips was 460 thousand oven-dry tons, valued at 45,800 thousand U.S. dollars in foreign exchange 2.

The strategy of Leizhou Forestry Bureau was to first make the environment green, bringing benefit to the inhabitants and solving the problem of living and working in peace and contentment. The next step was to fully utilise the main and by-products of the forest, making the country rich and the people prosperous. Future plans are to convert from chip export to production of paper in order to raise the economic benefit a step further and even more raise the cultural level of the people.

It may be that many districts of the world have similar environmental conditions as the initial conditions of Leizhou Forestry Bureau. If all those districts took the similar steps successfully, the development and environmental protection of the whole globe would be very much improved.

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[2] Forestry Paper of China, 1994-10-l 8 (In Chinese).

Damage Evaluation of the Remaining Standing Trees in a Timber Yarding Operation (Case Study)

José Ciro Hernández-Díaz and
Mariano Delgado-Pacheco

Summary

Equipment productivity and damage to residual trees were estimated at a timber yarding operation with *"motogrúa"* (yarder), as a reference to compare proposals intended to improve the yarding methods most commonly used in Mexico.

The performance of three *motogrúas* was evaluated with regard to yarding, yarding and loading, and just loading of sawlogs and electrical transmission line poles. The average size of the pieces was 0.778 m^3r (round timber) and mostly just one piece was yarded per turn, since only the mainline is pulled out to directly tie and yard the logs.

In this report reference is made to the analysis of damage to the residual trees caused by the yarding operation. Data were gathered at seven sites after the yarding operation had taken place, to observe the width, length and layout of the yarding roads, as well as the damage suffered by the residual trees standing inside those roads. The following results were found:

Given a cut volume of 65 m^3rwt/ha (whole tree), equivalent to 41 m^3r/ha, timber yarding with *motogru ’a* resulted in drastic damage to 1.845 m^3r/ha of residual commercial size trees, equivalent to 37% of the volume of this type that remained standing in the yarding roads.

Also, more than 68% of the non-commercial size trees (with less than 10 cm of normal diameter), standing inside the yarding roads suffered severe damage.

A recommendation is made to define and clear in advance the yarding roads to be used, not only making a more sound yarding operation, but also seeking to reduce the number of hang-ups and therefore the time and effort needed from the equipment and people. This would lead to improved efficiency and reduced production costs.

Key words: Damage evaluation, timber yarding, *motogrtia.*

1. Introduction

This report is an extract of the document entitled “Analysis of timber yarding with *motogrri a* at a forest firm (case study)” (Hernandez y Delgado 1995), which is being published in Spanish as a scientific paper of the *“Camp0 Experimental Valle de1 Guadiana (CEVAG) “,* at the *Centro de Investigaciones de la Region Norte Centro (CIRNOC)* of the *Instituto Nacional de Investigaciones Forestales Y Agropecuarias (INIFAP)* ,in Mexico.

For this study, besides INIFAP we had the cooperation of a forest harvesting firm named *“Forestal Lfder ”* and of Unit 8 for the Forest Conservation and Development (UCODEFO 8), “Regocijo”, Durango, Mexico.

The objective of this report is to share the results obtained in regard to the damage caused to the remaining standing trees, during the timber yarding operation with *motogrúa* , as a reference that shall lead to improved working methods.

2. Methodology

2.1. Characteristics of the area of study

The study was conducted in a place called “Sierra de1 Nayar”, located in the jurisdiction of the UCODEFO 8, in the state of Durango, Mexico (Table 1).

This area was characterized from the forest management study and the tree marking reports prepared by the UCODEFO, and from the production files of the studied firm. In the table, algebraic operations were made among some of the known variables, in order to obtain other valuable data suggested by the FAO (198 1).

At the studied area the silvicultural method used was the Mexican Method for Irregular Forests Management, which includes harvesting the oldest trees while leaving standing at least two-thirds of the stand for seed production and natural regeneration.

2.2. Timber yarding with *motogrtia*

For timber yarding, the studied firm uses mainly *motogrúa* (Figure 1). The crew on each *motogrúa* consists of one machine operator and two helpers who directly hook or tie the logs with the mainline.

2.3. Damage Evaluation to the Residual Trees

In order to determine the damage caused to the residual trees during the timber yarding operation, data were gathered at seven places where *motogrúas* had worked. The observation was done after timber yarding had been completed to the road, but before loading and hauling had taken place; therefore it was possible to evaluate the logs harvested at each place. The research methodology was as follows:

1) A traverse was made along each yarding road defined by the pass of the logs. The width of this road was measured each 10 m, as well as the total length and the average slope.

2) The remaining standing trees in the interior of the yarding road were classified in two categories: a)"commercial" trees (diameter above 10 cm) and, b) “non-commercial” trees (diameter below 10 cm).

Table 1. Characteristics of the study area. The study period was January-September 1990.

	Concept	Magnitude	Source[1]
a	Total timber volume existing per hectare	163.147 m^3 rwt/ha 113 adult trees	Forest management study a/d
b	Cutting intensity	40.0%	Forest management study
c	Marked volume	65.259 m^3 rwt/ha	a*b
d	Average volume per tree	1.440 m^3	Forest management study
e	Trees marked per hectare	45.3 trees/ha	c/d
f	Trees harvested for sawlogs poles	30.2 trees/ ha 15.1 trees /ha	Files of the firm
g	Product distribution	66% Logs and poles 12% Secondary prod. 22% Cellulosic and waste products	Forest management study
h	Estimated average volume per piece of sawlogs (primary) and tops (secondary)	0.778 m^3/piece 0.173 m^3/piece	d*g / (no. of pieces/tree)
i	Number of pieces per hectare	36 Sawlogs 15 Poles 45 Tops	Estimated based on the data shown above

[1] The letters indicating algebraic operations refer to the sections of this table.

Figure 1. Motogrúa used for timber yarding and loading.

3) The "commercial" trees were measured by diameter and height to determine volumes and were subdivided according to damage level as "sound" (not damaged), "with light damage" (doesn't affect the quality or the survival capacity of the tree), "with medium damage" (diminishes the quality of the timber, but not the survival capacity) and "with severe damage" (causes death to the tree). See Figure 2.

Figure 2. Commercial trees showing light damage (A) and drastic damage (B) due to the timber yarding operation.

4) The "non-commercial" trees were counted and classified as "damaged" or "non-damaged" trees. In the first group the observed damage was so severe that trees would not be expected to recuperate. The "non-damaged" trees suffered no damage, or the damage was so slight that they should recuperate and continue their normal development.

5) An estimate was made of the degree of damage caused to the residual trees at each yarding site, per cubic meter yarded from the stump to the road. Figure 3 shows an example of the analyzed yarding sites, with the main gathered data.

At each landing it was attempted to determine the volume of the logs; however, the irregular arrangement of the logs made it difficult and dangerous to take direct length and diameter data. Therefore, the logs were just counted and the predominant length was determined; on this basis the volume was estimated taking as a reference data of other logs with similar characteristics in the same area.

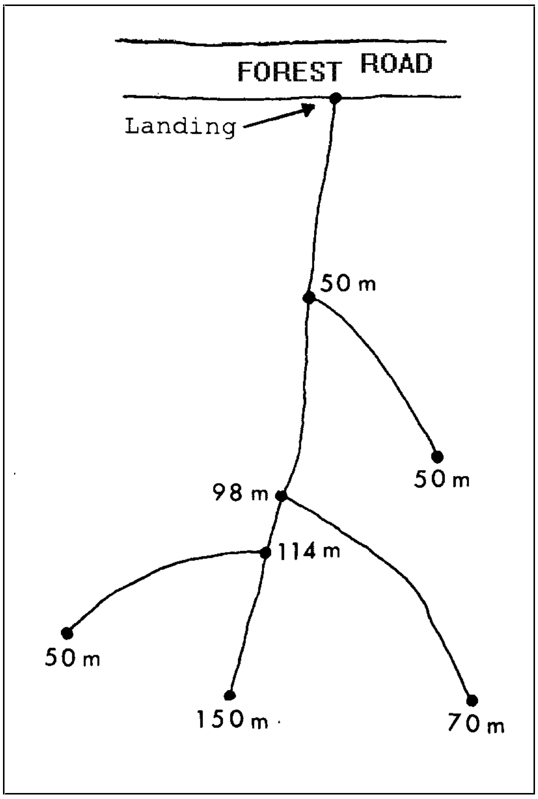
Yarding Site No. 5

Area (approximate): 0.82 ha
Slope: 58%
Yarded volume: 12.122 m^3r
Yarded logs: 16

Commercial volume with:
- Drastic damage: 0.497 m^3r
- Medium damage: 2.121 m^3r

Non-commercial trees inside the yarding roads:
- Damaged: 35
- Sound: 5

Figure 3. Example of one analyzed yarding site.



The intersections of the main and secondary yarding roads were determined, as well as the distance between consecutive roads. With these data it was possible to draw diagrams to estimate the area covered by each yarding site. The volume and number of sawlogs and transmission line poles harvested per hectare were also computed.

6) Statistical confidence intervals (Bhattacharyya and Johnson 1977) with a 95% of confidence were estimated for the main variables including the "damaged volume/m^3r harvested".

3. Results and Discussion

The minimum, maximum and average volume harvested in each analyzed yarding site are shown in Table 2. These field data complete and reinforce the data summarized in Table 1 of this report.

In accordance to the forest measurement study, a volume of 65.259 m^{3}rwt (cubic meters of round timber whole tree) were marked to be harvested in average per hectare (section "c" in Table 1), out of which a 66% are primary products (section "g" in Table 1). That 66% is equivalent to 43.071 m^{3}r/ha (cubic meters of logs per hectare), a figure similar to the 41.420 m^{3}r/ha estimated as the average log volume harvested per hectare in Table 2.

Table 2. Volume and number of logs harvested per hectare.

Site or log deck(No.)	Area /log deck (ha)	Volume /log deck (m^{3}r)	Pieces /log deck (No.)	Volume /ha (m^{3}r)	Pieces /ha (No.)
1	0.37	15.516	18	42.163	49
2	0.48	27.584	32	57.701	67
3	0.63	21.864	24	34.589	38
4	0.36	14.654	17	40.705	47
5	0.82	12.122	19	14.819	23
6	0.38	21.550	25	57.011	66
7	0.34	13.927	19	40.962	56
Maximum	0.82	27.584	32	57.701	67
Minimum	0.34	12.122	17	14.819	23
Average	0.46	18.174	22	41.420	49

Confidence Interval (95%)= Vol./site ± 4.789

Also, in Table 1 there is an estimation of 36 sawlogs and 15 poles per hectare, and in Table 2 an average of 49 pieces per hectare was obtained.

In order to analyze the damage caused to the remaining standing trees, data coming from direct field observation (Table 2), are preferable to data coming from files (Table 1). However, there is a great similarity between the two sets of data, suggesting the file data may be relied upon to analyze production and productivity variables.

3.1. Damage to the remaining commercial trees

The average volume harvested at the seven studied sites was 18.174 m^{3}r/site (Table 3), although there is a large variation among them. In the methodology it was described how some of the data of Table 3 were obtained. Another portion of the data in that table was derived from the Appendix Tables 1 to 7 in the original report (Hernández y Delgado 1995).

In Table 3 is shown the volume of standing commercial trees which suffered damage to varying degrees. On average, the equivalent to 4.5% of the harvested volume stays standing in the yarding roads, but with a level of damage so high that it would be preferable to mark it and to harvest it during the same cutting season; however, currently this is not done.

In this analysis. an average of 41.420 m^{3}r/ha were harvested, and it is estimated that about 1.864 m^{3}r/ha were drastically damaged due to timber harvesting with *motogrúa.*

Since a *motogrúa* can yard 238 m^{3}r per week, it is considered that it can drastically damage more than 10 m^{3}r of commercial trees per week, leading to an economic loss since those trees are not intended to be harvested during the same cutting cycle.

Taking into account also the medium-level damage, almost another 16 m^{3}r per week would be added to the economic loss, since there is a reduction of the quality of the wood to be obtained from those trees when eventually harvested.

In total, the timber volume with drastic and medium damage amounts to 11.2% and the timber volume with light or no damage is equivalent to 19%, with respect to the harvested volume.

Out of the commercial volume standing in the yarding roads, which represents 0.302 m^{3}r per cubic meter harvested, 37% suffers drastic or medium damage, causing a direct economic loss since it is not harvested, and besides that, also represents an ecological risk due to a larger danger of fires, plagues and diseases because it is dead or weakened material.

Table 3. Estimation of damage caused to commercial standing trees during the yarding of sawlogs and transmission line poles, in each analyzed site.

Site or log deck(No)	Volume harvested per site (m^{3}r)	Width of yarding road (m)	Sound (m^{3}r)	Volume by damage class		
				Light (m^{3}r)	Medium (m^{3}r)	Drastic (m^{3}r)
1	15.516	1.3	0.085	0.146	0.032	0.037
2	27.584	2.8	0.141	0.031	0.021	0.005
3	21.864	2.5	0.127	0.037	0.085	0.127
4	14.654	1.0	0.041	0.090	0.017	0.027
5	12.122	1.8	0.015	0.115	0.175	0.041
6	21.550	2.7	0.100	0.011	0.137	0.067
7	13.927	2.5	0.100	0.290	0.002	0.008
Maximum	27.584	2.8	0.141	0.290	0.175	0.127
Minimum	12.122	1.0	0.015	0.011	0.002	0.005
Average	18.174	2.1	0.087	0.103	0.067	0.045
Confidence interv. 95%	4.789	0.6	0.039	0.082	0.057	0.036

3.2. Damage to small trees

Table 4 shows the damage suffered by the small trees standing in the yarding roads. An average of 80.7% of trees with less than 10 cm of diameter to the breast height (d.b.h.) suffered severe damage.

Table 4. Estimation of the damage caused to small trees during the yarding of sawlogs and transmission line poles, in each analyzed site.

Site or log deck (No.)	Volume harvested per site (m^{3}r)	Width of yarding road(m)	Trees with less than 10 cm d.b.h.			
			Sound (No.)	Damaged (No)	Sound (%)	Damaged (%)
1	15.516	1.3	11	34	24.4	75.6
2	27.584	2.8	11	40	21.6	78.4
3	21.864	2.5	18	69	20.7	79.3
4	14.654	1.0	12	26	31.6	68.4
5	12.122	1.8	5	35	12.5	87.5
6	21.550	2.7	6	44	12.0	88.0
7	13.927	2.5	3	22	12.0	88.0
Maximum	27.584	2.8	18	69	31.6	88.0
Minimum	12.122	1.0	3	22	12.0	68.4
Average	18.174	2.1	9	39	19.3	80.7
Confidence interval(95%)	4.789	0.6	4.4	13.2	--	--

These small, still non-commercial size trees are difficult to evaluate in reference to the economic loss that they represent; however, such a loss is real since the forest will need a certain amount of time and other resources to replace those trees with others of similar dimensions. Besides that, these damaged trees also contribute to the ecological risk by increasing the danger of fires, plagues and diseases.

On the other hand, it is also certain that not all of the small trees currently existing in the forest would reach commercial size because of the natural mortality due to competition. This is another aspect to be considered when evaluating the real damage due to timber yarding.

From Table 4, dividing the average of the column "damaged trees" by the average of the column "volume harvested per site", it is noticeable that there was a damage of 2.14 small trees per cubic meter of harvested timber.

Observations relating to both commercial and non-commercial size trees show that the level of damage suffered by those trees during the yarding operation with *motogrúa,* and the width of the yarding road which is defined by the logs while being yarded, is directly proportional to the number and volume of the yarded logs. Those variables also depend on the number and the length of the yarding roads.

It is useful to note that when there are trees inside the yarding roads, the harvested logs suffer a larger number of hang-ups, which lead to greater human and equipment time and effort losses, diminishing the productivity and increasing the production costs.

It is advisable to determine the location of the yarding roads in advance (or at the same time as the marking operation for the trees to be harvested), in such a manner that the personnel of the forest technical direction review and mark to be felled all the trees inside the roads, regarding them as a part of the annual authorized volume, based on the corresponding forest management study.

4. Conclusions

1) Sawlog and transmission line pole yarding with *motogrúa,* is done by direct pulling, working with just one piece at a time.

2) Given a cutting volume of 65.259 m^{3}rwt/ha, equivalent to 41.420 m^{3}r in logs, 1.864 m^{3}r/ha of commercial logs are drastically damaged. If the 6.5% which suffers medium damage is included, the total damaged volume amounts to 4.556 m^{3}r/ha.

3) The total remaining commercial volume standing in the yarding roads is 0.302 m^{3}r per harvested cubic meter. Of this volume, 37% suffers medium or drastic damage. This represents economic losses and an increased risk of plagues and diseases.

4) At least 68.4% of the trees with less than 10 cm of diameter at breast height which were inside the yarding corridor suffered severe damage. It was estimated that 2.14 of those trees were damaged for each cubic meter of roundwood yarded.

5) It is essential to plan and clear the yarding roads in advance in order to ensure that fewer standing trees are severely damaged. Trees which are damaged should be harvested as soon as possible, and no later than during the next cutting cycle.

5. Literature Cited

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Impact of Selective Logging on Silvicultural Values in a Mixed Dipterocarp Forest in Sabah, Malaysia[1]

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Abstract

This study focuses on the response of the residual stand to pre-logging treatments and operational planning.

The main study is a comparative experiment with a randomised block design where the long term effects of four modes of selective harvesting are evaluated in permanent plots: unsupervised logging; unsupervised logging with pre-felling climber cutting, directional felling and pre-marked skid trails; directional felling and pre-marked skid trails with pre-felling climber cutting; and no logging (control). The study comprises 20 treatment plots of 5.76 ha each, i.e. four replicates per treatment. Square net plots of 1 ha inside the plots were enumerated before logging. Climber cutting, where allotted, was carried out one year ahead of logging. Logging has been done at full intensity on all plots, except control. The entire commercial and accessible volume was logged.

An additional experiment concerning felling only in which the effects of pre-felling climber cutting and directional felling were investigated has also been conducted; damage levels, gaps created, accuracy in directional felling as well as effects of climber cutting were investigated. A single tree plot design has been employed. No permanent plots are included. The study comprises 88 trees surrounded by a sampled local stand of 140 X 140 m.

The felling experiment was conducted in a forest holding a stem density ranging from 3 1 O-440 trees/ha above 10 cm dbh. Diameter distribution followed a negative exponential curve. Stem density was significantly higher on medium slopes (16-30”). Dipterocarps accounted for 27% of the total number of trees, and for 57% of the basal area. There were lo-20 trees bigger than 60 cm diameter at dbh, minimum felling diameter in Sabah. Dispersal of dipterocarps bigger than 10 cm dbh was significantly aggregated, but approached random as dbh increased. There was an average of 192 climbers ha-’ bigger than 2 cm dbh. Dead trees accounted for 3% of the total stocking.

A felling instructor was employed to perform directional felling. Selection of felling direction was governed primarily by retention of potential crop trees and risk of log breakage. The average range of possible felling directions was found to be 185”. Of the trees felled 39% fell within 5” of the desired lay, 24% within 6-l0o, 15% within 11 -20°, and 22% fell beyond 21’. Climber cutting showed no effect on felling accuracy. When the feller was forced to attempt at putting the tree close to the limit of his estimated range accuracy was lessened. Felling big trees in very steep slopes also adversely affected accuracy.

Key words: Tropical rain forests, selective harvesting, directional felling, climber cutting

Location and Agencies Involved

A research cooperation designed to investigate the possibilities to improve selective logging is underway in mixed dipterocarp forest within the Sabah Foundation Concession Area in northern Borneo.

The study is established in very close cooperation with the staff of RBJ in Gunung Rara Forest Reserve, in Sabah Malaysia. Agencies involved are Rakyat Berjaya Sdn. Bhd. (RBJ) of Sabah, the company responsible for managing the Sabah Foundation Concession Area, and the Department of Silviculture, Swedish University of Agricultural Sciences (SUAS). The study is financed mainly by the Swedish Board for Research Cooperation with Developing Countries (SAREC).

Basic Ideas behind the Study

The forest management system currently used in Sabah is selective with a diameter limit of 60 cm dbh. In general the extraction rates are high with rates exceeding 100 m^3 per ha being rather common. Some 20% of the concession has been set aside as forest reserves and fruit trees, and rare trees are left untreated according to agreements with the Forest Department of Sabah. Protected zones along rivers and streams are established. Felling with chainsaws and yarding by bulldozers is the dominant technology.

To use a diameter limit stated by the forest department as the only selection tool is for a silviculturist a rather crude method and there seems to be a large potential for a further development of the whole forest management system. Today the market can accept smaller trees and the tallest trees are frequently attacked by rot and hollow. Tall trees create big gaps and destroy more potential crop trees than intermediate sized trees. Big trees are often good seedtrees. A more sophisticated selection system will be designed and tested inside the frame of this project.

No silvicultural efforts to improve the status of the forest have any chance to be successful if the logging system is undeveloped. Consequently, the first step in this project was to try to improve the logging system.

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[1] This paper is a compilation of the first three papers concerning results from two experiments established in primary tropical hill rain forests in Sabah, Malaysia:
- A comparative experimental study of selective logging in primary tropical rain forest in Sabah, Malaysia.
- Structure and composition of primary hill mixed dipterocarp forest in Sabah, Malaysia and their implications for silviculture.
- Accuracy of directional felling and influence of climber cutting in primary mixed dipterocarp forests in Sabah, Malaysia.

The approach of the first studies was to try to develop a system that substantially reduces logging damage while allowing logging at normal intensities and the use of the 60 cm and above rule. Furthermore the system must be readily described and easily taught to the ranger and all levels of staff. Finally, it must not require maps not already available, and it must not be associated with unacceptable costs.

The forest type is a primary mixed hill dipterocarp forest. The plot topography ranged from very steep to mildly undulating with altitudes ranging from 320 to 680 m a.s.1. The soil types are mainly Orthic Acrisols. During the study the weather conditions were harsh, with daily heavy rains but unpredictable periods without rain, 14 days or more were not uncommon.

Three Components in Logging Systems Design Were Set in Focus

Skid Trail Alignment

The strategy of skid trail alignment in this project was to minimize damage and facilitate skidding. To allow harvesting at normal intensity while keeping skid trail coverage low, skid trails were aligned as parallel to one another as nature allowed, following natural borders e.g. streams, ravines, ridges and forest reserves. Sharp curves were also avoided. Skid trails were aligned at a distance of about 60 m from one another, starting 30 m from a natural border. Where streams had to be crossed, culverts consisting of hollow logs were installed. To make directional felling easier, skid trails were opened up before felling commenced. To help protect “potential crop trees”, those along the skid trails were painted with an orange band.

Directional Felling

Felling should be viewed as the first step in wood transportation. In this study trees were felled towards skid trails, even at the expense of “potential crop trees.” Where possible under this constraint, care was taken to avoid damaging “next crop trees.” An angle of about 45 degrees between felled trees and skid trails was strived for, except for trees close to trails. Tree crowns were directed to fall into skid trails to minimize gap creation. For trees that could not be felled towards skid trails, we opted for the direction that caused least problems when winching the log to the tractor.

Felling debris on skid trails e.g. long branches and pushed over trunks, the source of much logging damage, were cut into pieces before being pushed aside by the tractor. To avoid damage to the forest adjacent to skid trails, logs to be extracted were not allowed to accumulate on skid trails. This restriction had no implications on efficiency, as fellers simply moved somewhere else to fell.

If damage is to be avoided while efficiency is maintained, it is very important that logging is carried out as a teamwork. Frequent communication between fellers, tractor operators and hookmen was found very useful in avoiding and solving logistical problems.

Climber Cutting

There are reasons to believe that pre-felling climber cutting could further lessen the impact of harvesting (Fox 1968, Appanah and Putz 1983, and Putz, Lee and Goh 1984). In Fox (1968) promising results are achieved. But, as admitted by the author, due to variations in topography, stand density and extraction levels, it is not possible to state that the effects observed were due to climber cutting. In Appanah and Putz (1983) felling damage with and without pre-felling climber cutting was examined tree by tree, 25 trees per treatment. Based on statistically significant results, it is concluded that felling damage may be halved by pre-felling climber cutting. In Liew (1973) spot treatment is advocated to reduce costs.

Structure and Composition of the Forest

In both experiments described below data were collected to get preliminary information about the structure and species composition of the Sabah hill forests.

Evidence available on hill forests indicate that stand characteristics are irregular (Burgess 1970, Tang 1974, and Lee 1982a). Lee’s (1982a) review of silvicultural conditions in hill forests stresses lack of seedlings in virgin stands, slow growing and shade demanding regeneration, heavy seedling mortality in connection to harvesting, and irregular stocking of commercial trees. Burgess (1970) classifies hill forests into well stocked seraya ridge forests, less well stocked mid-slope forests, poorly stocked valley bottoms and lower slopes (called non-commercial forests), and precipitous forests (steeper than 45”).

The effect of slope on seedling abundance is investigated in Burgess (1975). Abundance declines with slope steepness, but is deemed serious only on slopes steeper than 50”. Seedlings were further found to be strongly aggregated. A fact attributed to the non-random distribution of seed bearers, limited seed supply, and the fact that simultaneous gregarious flowering is rare in hill forests. Investigations of spatial distribution of trees in Sarawak indicate that they too are aggregated (reviews by Whitmore 1984 and Bruenig 1991).

Design of the Experiments Established

Experiment 1

In Experiment 1 the effect of pre-felling climber cutting and directional felling were investigated separately. This proved necessary to distinguish the impact of felling from that of yarding. The experiment comprises 88 commercially sized trees at a minimum spacing of 140 m. The local stand (140 X 140 m) surrounding half of the trees was subjected to climber cutting one year ahead of felling. Directional felling was carried out by an experienced Swedish feller on half of the trees and the other halves were felled by local fellers. In both groups half of the tree plots were treated with climber cutting. On all plots the stand structure was studied on four circular plots randomly distributed inside a radius of 50 m from the selected tree. All trees above 60 cm were registered inside a radius of 40 m.

Sampling Procedure

A baseline parallel to the main direction of a logging road was established. The baseline was subjectively aligned to enable inclusion of as many sampling points as possible.

Perpendicular to the baseline, 16 parallel transects at a spacing of 160 m were made through the study area. For every transect, the first loggable tree, i.e. an apparently healthy tree of commercial species bigger than 60 cm diameter at breast height (dbh) (minimum felling diameter in Sabah), encountered 70 m from the baseline was selected as a centrepoint for sampling. Centre points were allowed to be at a maximum right angular distance of 15 m from the transect. After the first sampling point along a transect, consecutive centre points were at a minimum spacing of 140 m.

Around every centre point, all trees with a dbh of at least 60 cm were recorded, positioned and described within a circle 40 m in radius (see Figure 1).

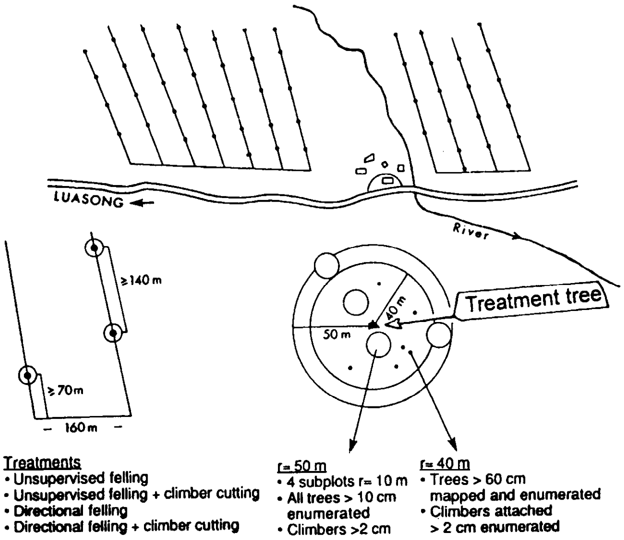

Figure 1. Principal design of Experiment 1.

Half of the trees selected in Experiment 1 were felled by an experienced Swedish feller. On this material a special study "Accuracy of directional felling" was made. Hypotheses tested in this were:

1. Directional felling is enhanced by pre-felling climber cutting.
2. A skilled feller is able to place the tree within 10° from an intended lay.
3. The possible felling range is influenced by the tree lean.
4. Leaning trees have to be felled with their lean.
5. Accuracy is influenced by tree size and slope.

Registered data collected before and after felling are presented in Figure 2

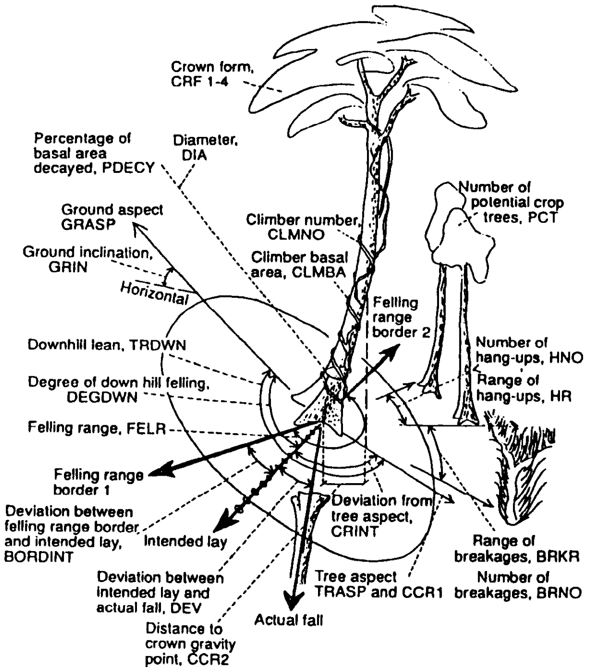

Figure 2. Variables derived from field measurements. Arrows indicate aspects measured with the compass. The ravine indicate a possible breakage zone. Potential crop trees could also cause hang-ups.

Experiment 2

The main question addressed for this experiment is "Can the residual stand left after selective logging be relied upon to form an acceptable crop within a reasonable timespan, and to what extent will the residual stand be improved through pre-felling climber cutting, directional felling and pre-alignment of skid trails?" To answer this question credibly, data from a number of re-enumerations is going to be required. The immediate question that can be answered, however, is to what extent logging damage can be reduced and structure improved through controlling the harvesting process.

This, mainly a growth and yield study, is a randomised block experiment in which the long term effects of the following four modes of selective logging are evaluated in permanent plots:
- local logging practices
- local logging with pre-felling climber cutting
- directional felling and pre-marked skid trails
- directional felling and pre-marked skid trails with pre-felling climber cutting
- no logging (control).

The study comprises 20 treatment plots of 5.76 ha each, i.e. four replicates per treatment. Net plots of 1 ha inside the plots were enumerated before logging. In the enumeration all trees bigger than 10 cm dbh were described and mapped. Saplings and seedlings were sampled in circular sub-plots inside the net plots. Climber cutting, which was assigned as one of treatment, was carried out one year ahead of logging. A randomised block design has been used with average slope as the sole criterion for block creation (see Figure 3).

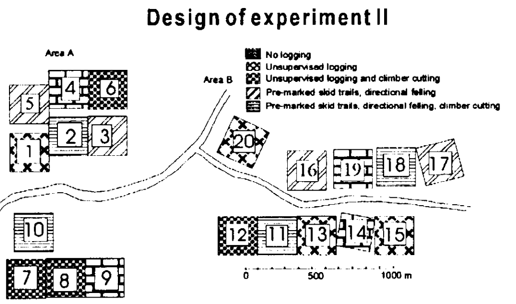

Figure 3. Principle design of Experiment 2.

Plot establishment, including climber cutting, was completed in June 1992. Harvesting commenced in June 1993 and was completed in August 1993. The first post-harvesting enumeration was completed in February 1994. The plots will be re-enumerated at least five times at two year intervals.

Results

Preliminary Results from Experiment 1

Structure and composition of the forest

Diameter distribution

Diameter distribution followed a negative exponential distribution for dipterocarps as well as non-dipterocarps (Figure 4).

Stocking was highest on medium slopes and lowest on steep slopes. There was a significant difference ($P<0.05$) in number of trees between medium and steep slopes and in basal area between mild and medium slope ($P<0.\ 05$).

Non-dipterocarps were consistently more frequent on medium slopes, whereas dipterocarps appeared to be equally distributed on mild and medium slopes.

There were just over a hundred dipterocarps ha^{-1} above 10 cm dbh, and almost 300 non-dipterocarps. The total basal area was 28.3 m^2 ha^{-1}, of which dipterocarps accounted for about 16 $m^2 ha^{-1}$ (57%).

Dead trees

Dead trees accounted for 3% of the total number of trees. Dipterocarps as well as non-dipterocarps accumulated in percentage over diameter, more pronounced for non-dipterocarps. Frequency of dead for both commercial groups increased exponentially over diameter, but with different exponents.

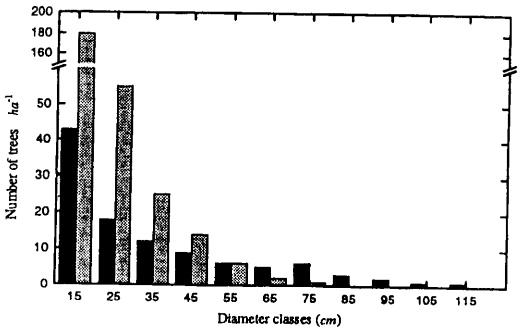

Figure 4. Diameter distribution of trees by commercial groups, in 10 cm dbh classes (class middle given). Dark columns denote dipterocarps and grey columns non-dipterocarps.

Climbers

There were almost 200 climbers ha^{-1}, with diameter ranging from 2 cm to 32 cm dbh. Climber abundance was similar on mild and medium slopes but lower on steep slopes. The differences were not significantly different, though ($P > 0.05$).

Accuracy of Directional Felling

Accuracy of directional felling was high as 39% of the trees fell within 5° from intended lay, 24% within 5°-10°, 15% fell within 11°-20° and 22% fell outside 10° (Figure 2).

The average felling range was 185°, and for leaning trees ($>2^{\circ}$) it was about the same (171°, $n=9$). A multiple regression revealed a significant relationship between felling range and climber basal area, number of buttresses and the appearance of potential crop trees.

Among the 41 trees, 11 were leaning more than 1°. None of these was felled against its lean ($\pm 90^{\circ}$). In a regression analysis no tendency to downhill lean in steep slopes was found.

Accuracy of Directional Felling after Climber Cutting

Within the 18 pairs of this treatment the deviation from intended lay among climber cut trees was unexpectedly higher, 19°, than among the untreated trees, 9°. The difference was non-significant. After removal of four trees that fell very far from intended lay, some with rot, 15 blocks remained. In this truncated material the deviation among climber cut trees was the same as among those not climber cut, 9° and 9° respectively.

Preliminary Results from Experiment 2

The analyses of field data are not completed, but some preliminary comments on the logging system adopted can already be made.

From an environmental and safety standpoint skidding uphill is preferable to downhill. Streams rarely have to be crossed. Skid trails are also more readily aligned when skidding uphill.

There are methods for skid trail alignment that would further reduce logging damage, e.g. restricting them to ridge tops. Such restrictions, however, would not allow logging at full intensity, the constraint of this experiment (see Figure 5). Another obvious restriction would be to require soil drying before skidding after rain. This was not done for reasons of comparability of treatments.

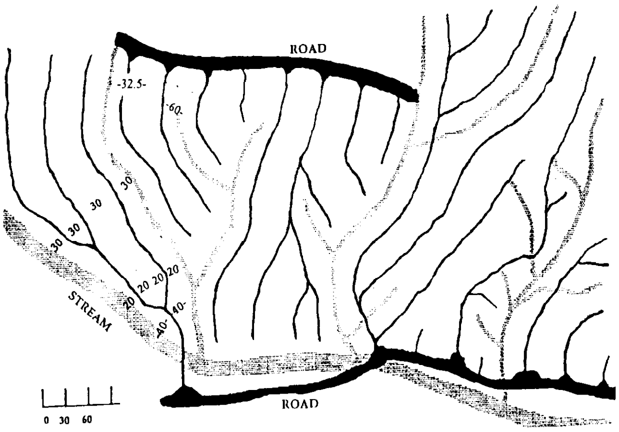

Figure 5. Design of skid trail alignment used in Experiment 2.

Alignment of skid trails according to the method outlined was found to be very straightforward and easily understood by field staff. Painting "next crop trees" may not have saved all of those painted, but is useful in restricting the tractor operator to demarcated trails. There is no reason to believe that skidding would be less efficient on pre-aligned trails, rather the contrary. Keeping tractors on skid trails was thus not a problem. Shorter logs would reduce damage along skid trails, as would winching over greater distances. The thick winchrope currently used is probably needed, given the size of logs extracted. A device to help pulling the winchrope is desirable. Equipment for this is available. There is thus great scope to further improve tractor logging.

Directional felling is a key issue. If unsuccessful, felling damage will be unacceptably high and skidding will be time consuming and cause additional damage. Not only felling skills are required. Quite often, the best felling direction is not immediately obvious, and many trees cannot be felled in the optimal direction. A problem solving approach is needed. An organized training programme where great attention is paid to logging damage should be implemented, perhaps using a team of mobile instructors. Highly skilled instructors from Nordfor Training and Consulting, a Swedish consulting company, performed the directional felling in this experiment and gave training to local fellers.

Discussion

Differences in stocking between slope classes are hardly surprising as topography has been found important for composition, growth and distribution of tropical forest (see review by Richards 1952 and Basnet 1992). It therefore seems reasonable to classify Sabah hill forests into forest types similar to those defined in Burgess (1970), and let these forest types form the basis for silvicultural prescriptions, i.e. adapt silviculture to local stand conditions. As knowledge of Sabah hill forests increases, factors other than slope may be included in a forest type classification.

A study of a lowland forest in Peninsular Malaysia, referred to in Whitmore (1984), has arrived at a mean annual mortality rate of 1.7%, roughly evenly distributed over diameter. Data collected over 12 years from a hill forest in Sabah indicated a mean annual mortality rate of 1.4%, with a great annual variation (Udarbe unpubl.). Dead trees accounted for 3% of the trees in this study, and could accordingly be assumed to represent about two years' mortality, indicating a fairly quick decomposition of dead stems. The increasing proportion of dead trees observed for larger diameters can most likely be attributed to the fact that they remain standing longer than smaller trees.

The distribution of dead dipterocarps over diameter suggests a low annual mortality rate, with relative mortality increasing with diameter. The same seems to hold true for non-dipterocarps, although their mortality seems higher. If a constant growth and degradation rate is assumed, the higher mortality rate could explain why the number of non-dipterocarps diminishes so sharply with diameter. Should mortality be higher for bigger trees than for small and degradation rate the same, that would suggest that increment declines with diameter.

Climber abundance was lower than that found by Appanah and Putz (1983). This does not warrant a recommendation against climber cutting, but its effect on felling damage would most likely be more modest. The aggregated dispersal pattern of climbers supports Liew's (1973) and Chai's (1991) advocacy of spot treatment.

Pre-felling climber cutting did not improve the accuracy in directional felling. The first hypothesis of this study, that directional felling is enhanced by pre-felling climber cutting, had to be rejected.

The second hypothesis, that a skilled feller is able to place the tree within 10° from an intended lay, could not be rejected as 63% of the trees were placed within this range. In reality a deviation of 10° means that the top is felled 9 m from intended lay if the tree is 50 m high. The precision obtained is in agreement with Hendrison (1990) who found that 80% of the trees fell in the desired direction.

The feller mostly considered it possible to direct the tree within a wide range (185°) and this was not decreased when trees were leaning. The third hypothesis was thus rejected.

It was noticed that some trees felled in this experiment were big and badly decayed at the same time. In a normal harvesting operation such trees probably would have been left standing because they had a low commercial value and were risky to fell. In this study some of these trees fell far away from the intended lay, thus causing a lower mean accuracy than during a normal harvest.

No tree was felled against its lean and that is why the fourth hypothesis, leaning trees have to be felled with their lean, cannot be rejected. Hendrison's (1990) finding, that trees could be felled against their lean, cannot be supported by this study, neither rejected. The reason is that our feller never chose to try.

The analyses of factors reducing the felling accuracy in this study showed that placing a tree close to the felling range border reduced the accuracy. Big trees were felled less accurately, especially when they were growing on steep slopes. Decay also seemed to reduce the accuracy. In cases when the tree was standing upright and considered possible to fell within a big felling range, the accuracy tended to decrease. Leaning trees were placed more accurately than the rest, which is contradicting to what Hendrison (1990) found in Surinam. The fifth hypothesis, that accuracy is strongly influenced by tree size and slope, could not be rejected. However, avoidance of hang-ups, breakage and potential crop trees sometimes forced the feller to make an attempt to place the tree close to the felling range border and this consequently reduced the accuracy.

In a recent interview with the feller he considered the results of this study being in accordance with his impressions. However, in addition he had found that accuracy was low in cases when the crown of the tree could not be seen. He also had the opinion that buttresses help control directional felling.

In Experiment 2 pre-felling climber cutting, in addition to reducing felling damage, has been found useful when opening skid trails with tractors. Fewer trees are torn down by tractors where climber cutting has been carried out. Climber cutting is ecologically questionable, climbers and fruits on climbers being an important source of food for the fauna. Data on the usefulness of pre-felling climber cutting will be available through this study. More user friendly and efficient tools for climber cutting are however needed; promising equipment is already available on the market.

When using this logging system it is important that operatipns are well supervised. If they are not, a situation where only easily available trees are extracted could arise. In this experiment one forest labourer followed the skidder daily, making sure that all logs were skidded, and that no unnecessary destruction of the residual stand took place.

Conclusion

The results of this study do not motivate a pre-felling climber cutting. However, there might be other reasons to carry out this treatment, for example, if damages to the residual stand can be reduced. Safety for the feller is another reason for an introduction of climber cutting if it reduces the risks.

The ability of a skilled feller to direct trees, demonstrated in this study, could be utilized by forest managers to increase the value of the residual stand by salvation of next crop trees and to lessen the destruction of log by breakage. If skid trails are aligned before the felling, an important transport of timber towards the trails can be carried out by directional felling. The safety of a feller is probably enhanced by his ability to avoid hang-ups. Hence, it seems worthwhile to educate the fellers, to organize a teamwork between fellers and crawler operators, and to mark the skid trails before felling.

Directing the tractor to operate on skid trails will increase the area of untouched terrain and thus favour the flora and fauna in the tropical rain forest.

What Next

Sound logging practice is a prerequisite for sustainable forestry. The development of logging practices will continue in this study but the focus will mainly be on silvicultural refinement of logging. A critical issue is adapting logging intensity to local stand conditions. More flexible diameter regulations is an obvious step in this work. What will be strived for is a residual stand where trees in all diameter classes are present, i.e. better preservation of structure. Species composition will be in focus as well as preservation of flora and fauna.

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The Economic Planning Unit (EPU), Prime Minister's Office, Kuala Lumpur has granted research permits for the non-Malaysians involved. Experimental sites and excellent logistical support have been provided by Rakyat Berjaya Sdn. Bhd., the company responsible for managing the Sabah Foundation Forest concession. The study has been financed by the Swedish Authority for Research Co-operation with Developing Countries (SAREC). Additional funding has been provided by Swedish International Development Authority (SIDA).

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Problems and Chances for Forest Operations in Amazon Basin

Jorge Roberto Malinovski

1. Introduction

The Amazon basin covers 6.4 million square kilometers. In the next 20 years Latin America will likely become a major supplier to the world market of tropical wood, and will need to improve sustainable forest management as an important criterion for this development. In Latin America, Brazil is one of the most important suppliers because it includes 65% of the Amazon territory, of which 90% is still virgin. In this area the precipitation occurs more intensively during normally a five or six months rainy season. Such precipitation brings annual floods which define the so-called "varzea " (flood plains).

The varzea forests extend along the banks of the rivers which form the Amazon Basin. Highlands or "Terra Firme " forests are found on the lands above the flood levels, and are characterized by dense vegetation with trees up to 40 m in height. Highlands represent about 89% of the Amazon region.

Amongst the challenges facing the forestry sector of the Amazon, special attention must be given to studies related to the rationalization of forest exploitation activities. The establishment of sustainable forest production systems can offer opportunities for national and international forest companies to guarantee a continuous supply of raw material.

Approximately 400 tree species have potential markets in the Brazilian Amazon, but many of them are not used because of undesirable characteristics such as high density or low durability, or because of a lack of knowledge on the technological properties. At present about 40 species have local market acceptance and only a fraction of that total reaches the international market.

The main questions with respect to rational use of wood resources in the Amazon Basin are:

- Is it feasible to manage tropical forests for self-sustained production of wood without causing irreversible damage to the environment?
- Is it feasible to use native species for enrichment planting?
- How is it possible to reduce the logging residues that remain in the forest after logging?
- Are technological characteristics of new or potential species known in order to make commercialization feasible?

2. The problems in the region

The Brazilian Amazon, comprising approximately 3.3 million km2 of terra-firme (highland) forest and 55 thousand km^2 varzea (periodically flooded lowland) forest, has great problems of road infrastructure. Since road density is fairly low, transportation is made mainly through the rivers of the region by using floats and rafts. Only a few wood companies are able to transport logs to their yards entirely along roads.

In addition to the low road density, the occurrence of abundant precipitation makes the transportation in the region extremely difficult. During the rainy season the rainfall may reach 1.600 mm. Hence, the poor quality of the roads makes them impassable between December and May.

Another noticeable problem in the region relates to soil types. In the Amazon about 92% of soils are dystrophic whereas only 8% are eutrophic. This implies that most soils are of low fertility, susceptible to erosion, and therefore probably will not be able to maintain their potential productivity if degraded. Thus, it can be said that a major part of the Brazilian Amazon Region is more suitable for activities related to forestry, which uses the soil less intensively, than for activities associated with traditional agriculture and cattle ranching.

As important as the aspects above is the intensive logging of only a few species which are considered valuable for commercial purposes. The intensive exploitation of such species has led to reduction of their regeneration capacity in the residual forest after harvesting, leading to potentially serious consequences for future harvesting. One of the main causes of this is the poor knowledge of the physical and mechanical wood properties of many species occurring in the Amazon. Actually, only the market dictates what species should be logged and processed by both domestic and international industries. The reduction in the number of mother trees by excessive logging of selected species will certainly reduce seed production and will also affect the germplasm stock of the most valuable species.

Besides the above-mentioned facts there is also a lack of clear understanding of which silvicultural system would be adequate for every species. It is essential to clarify the species requirements for planting in pure stands or for enrichment planting inside the forest. For this purpose, it is important to know the habitat and life history of the species to be exploited.

Biological cycles are not well understood for a great number of species in the Amazon, since there are not enough studies on the growth pattern climax and senility of them. Presently, management rules are based only on the minimum diameter of the trees to be logged. However, these rules may have little sense since there are species which may reach over 2.5 m DBH while others rarely reach 50 cm DBH. The consequence of such a rough criterion is that for some species trees extremely old trees are cut, while for other species the young trees which have not yet reached their maximum potential volume are felled.

The exploitation systems utilized in the Amazon region are very simple and conventional. In the varzea areas the trees to be logged which are located below flood level are marked and cut during the dry season. The logs are kept until the rainy season, when the logs are allowed to rise on the flood. They are then collected into rafts called "jangadas" and transported to factories situated sometimes over 1.000 km from the logging area.

Exploitation in terra firme areas is done using chainsaws, after which the logs are moved to floats, rafts or trucks by using skidders or bulldozers, and then transported to the factory.

In both cases, in varzea or terra firme, only the very best logs are considered, which means that potentially useful wood is left in the forest. Roughly speaking, we can say that generally 30% of the potentially commercial wood volume remains in the forest as waste. This waste usually deteriorates very rapidly die to the high humidity inside the forest.

The traditional systems of exploitation consider only the standing wood volume, not taking into account the potential growth in the future. It is common practice to take into account for harvesting only a percentage in relation to the volume to be logged without distinguishing commercial and non-commercial species. The result of this is that the forest may eventually recover its total volume but will never recover its original species composition and structure. The forest is thus permanently impoverished as a result of being harvested.

The following data summarize typical conditions of exploitation in the Amazon forest:

clay soils, topography with slopes ranging from 0% to 25%;

- first cut of the native forest;

use of commercial wood for sawmill, veneer and plywood industries.

A forest inventory of an area of 9.5 ha, in which all trees over 50 cm DBH were measured showed that:

- 54.94% of the volume was of species useable for veneers, or 12.5 m^3/ha;
- 22.69% of the volume was of species useable for high-quality veneers, or 0,99 m^3/ha.
- 18.05% of the volume was of currently non-commercial species, or 4,12 m^3/ha.

The inventory also showed that the forest is not homogeneous in terms of spatial localization of the trees. Normally the more commercially valuable trees are concentrated on flat areas (highland plateau and lowland plain); few valuable trees are typically found on hillsides.

Another sampling inventory in the area, carried out for trees IO-50 cm DBH, revealed that:

- 43.77% of the total volume was of non-commercial species;
- 23.48 of the total volume was of species useable as sawntimber;
- 18.5% of the total volume was of species useable for veneers;
- 13.89% of the total volume was of palms;
- 0.36% of the total volume was of high-quality veneer species;

In terms of number of stems the results were as follows:

sawnwood	84 stems/ha on average
plywood	66 stems/ha on average
veneer wood	1 stem/ha on average

In addition, the forest showed 51 stems/ha of commercial species on average and 207 stems/ha of species which are non-commercial at present. This corroborates the need to carry out the logging and extraction operations with care, avoiding damage to the advance growth which represent trees that should be felled in the second cut.

From the results of these inventories it is possible to say that there is a relatively low stock of advance growth and medium-sized trees of the valuable species beneath the forest canopy, which indicates the necessity to use silvicultural techniques, e.g., enrichment planting, to improve the economic potential of the forest in the future.

3. Chances of the forest operations in the region

To assure sustainable forestry in the Amazon over the long-term it will be necessary to change the mentality and the manner of the technicians and industrial businessmen acting there. Today they are only concerned with the direct (economic) value provided by the forest; *i.e.,* short-term financial benefits. Hence, they cut and extract trees without taking into account the principle of sustainability in forest management. This must change, or at least the risk to the environment should be assessed.

Forest management should be conducted on a sustainable basis, considering the species of the forest altogether and not only those which are most valuable at the time of harvesting. Appropriate percentages of all species should be removed, ringbarked or poisoned in order to give favorable conditions to all species, especially those most valuable ones.

In order to avoid cutting trees which are either too young or too old, the single criterion of DBH of all species put together should be replaced by a system of information including tree dimensions by species and also the soil type of the extraction place.

In relation to volume no more than 35-40% should be removed to reduce great impacts on the residual trees, which not rarely have their crowns, branches and roots damaged when nearby trees are felled. Maintenance of mother trees is another necessary practice if seed production of desirable species is to be guaranteed.

The silvicultural behavior of naturally regenerated individuals must be investigated so that requirements for successful enrichment planting may be defined.

In the case of the varzea forest, natural regeneration of valuable species is rarely observed in the field. This is due to the four-month flood season which makes the establishment and growth of seedlings difficult. In such areas it may be necessary to plant large saplings (1-3 m height) in order to ensure regeneration success.

Forest operations should be planned and executed over longer periods than is common at present. The tree marking and liana cutting area operations should be implemented at least 2 years before felling to give time for the lianas to decay (which helps reduce damage to residual trees). Tree marking, ringbarking and poisoning of undesirable large trees must be done around 1 year before felling. Killing undesirable species avoids abundant seed production and eventual domination by these species. Extraction must be planned for the most suitable part of the year and must also take into account the forest type. In terra firme, wood extraction must be preceded by a pre-harvesting forest inventory to determine the wood volume which may be harvested, its quality, and also the spatial position of the trees to be felled. In this context, the cost/benefit ratio of opening-up skidtrails must always be carefully analyzed, once the establishment of road network determines the type of machine to utilize and the associated environmental risks.

Besides the correct specification of equipment to be used in extraction operations (to avoid impact on residual trees), it is necessary to reduce wood waste. This means that a greater percentage of each felled tree should be utilized, an objective which can be achieved by reducing the diameter and length of logs which can be used in the factory. The use of more advanced processing technology will also allow utilization of branch wood.

Finally, it is of great importance to process the raw material as near as possible to the source, *i.e.*, the Amazon region, because this can be effective in augmenting the aggregated value of the timber products. Doing so will also permit conversion of part of the profits of the timber business as a means to finance projects on sustainable forest management.

4. Conclusions

The utilization of forest resources in Amazon as well as the related extraction operations should be carried out taking into account at least the following:

- Avoid disturbing the ecological balance in the forest by harvesting with minimum impact;
- Omprove and rehabilitate the potential productivity of the forest;
- Obtain positive financial results without degrading the environment and without impoverishing the residual vegetation within the forest;
- Utilize integrated technologies for sustainable forest management and implement forest operations (felling, extraction and transportation) in ways that are compatible with the rational use of the resources.

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Table 1. Number of trees and percentages from 25 plots for all trees 10 ≤ DBH < 50 cm.

Type of wood product	Number of trees/ha			%
	Minimum	Maximum	Average	
Plywood	31.8	159.2	66.2	18.50
Veneer wood	—	31.8	1.3	0.36
Sawnwood	31.8	222.8	84.0	23.48
Non-commercial wood	—	350.1	156.6	43.77
Palm Trees	—	159.2	49.7	13.89
			Total %	100.00

Table 2. Average wood volume for all trees with DBH > 50 cm (100% forest inventory for 9.5 ha). An average of 8.50 commercial trees per hectare were found on the plot.

Plywood m^3/ha (%)	Veneer wood m^3/ha (%)	Sawnwood m^3/ha (%)	Non-commercial wood m^3/ha (%)
12.5393	0.987	5.1789	4.1207
(54.94)	(4.32)	(22.69)	(18.05)

Applying Skylines to Partial-Cuts in the Tropics

D. Ed Aulerich

Abstract

This paper explains the approach used by Forest Engineering Inc. to apply skyline systems for partial-cut harvesting of tropical forests. Skyline systems were installed in plantations for thinning and in old-growth natural forests for selective-logging. The steps taken in the planning, training, equipment selection, and application to ensure success, both environmentally and economically, are presented.

Key words: Planning, cable, partial-cuts, tropics

Introduction

It is not enough to have a policy that promotes sustainable forestry. There has to be the desire (Tiki 1992) and ability to implement a plan that will ensure a sustainable forest, as well as a sustainable forest industry (Aulerich 1994).

With any harvesting operation, the success of failure will depend upon the planning, technique, and equipment needed to do the job. The key is to know what is needed, develop what is lacking, and then proceed in an organized fashion to accomplish the task.

As in all projects, Forest Engineering Inc. (FEI) first evaluates the situation from the standpoint of terrain, timber type and size, present methods being utilized (Derus 1994), personnel knowledge, and information availability. it is important to have a very good idea of what needs to be done, if anything, to improve the present situation. Once this information is obtained, a plan of strategy can be developed that may range from some minor adjustments in technique or equipment to a fully designed program of training, equipment selection, and application.

Although this paper briefly describes FEI's program presently underway for PT. Sumalindo Lestari Jaya (SW), Indonesia, the approach is consistent with FEI's implementation of harvest projects throughout the world.

Conditions

The first prerequisite is an evaluation of each situation. This means we must become familiar with the conditions encountered in the project.

In the SW project, two very different conditions faced FE1 engineers-terrain and timber type.

Terrain and Timber Conditions

Plantation

The initial project area is a plantation located in the flat, sometimes swampy, coastal plain of East Kalimantan, Indonesia. Access is by river or by road from Samarinda, although in the initial stages the road was not a dependable mode of transportation during wet weather.

The forest consists of numerous species, including *Acacia mangium*, *Eucalyptus* spp., *Gmelina arborea*, *Paraserianthes falcataria*, and many others. The estimated rotation age is somewhere between 6 and 10 years. This means that the tree at harvest will have a diameter of approximately 15 to 20 cm and contain 0.1 to 0.2 m^3.

Most of the terrain is relatively flat with slopes up to 40%; however, about one-third of the area is applicable to cable harvesting methods with slopes in excess of 40%.

Natural Forest

The natural forest area is quite different in timber and terrain. First of all there is no access to the area except by river boat or helicopter. The area is nearly 500 km from a major town up the Mahakam River. Once leaving the river, the only method of travel is a logging road going into the interior another 100 km to a series of camps. Some of the grades on the road are in excess of 30% adverse.

The timber in this area is mixed. The main timber type being logged is Meranti *(Shorea* spp.). Although the terrain was completely forested, the commercial species available is less than 100 m^3/ha, or approximately 6 trees per hectare. The average log size is approximately 7 m^3.

The terrain is mountainous and broken, with slopes exceeding 100% in many places. Some peaks exceeded 1000 m in height. Numerous rivers dissect the area.

Past and Present Harvest Techniques

Most of the gentle land presently in plantations was harvested with crawler tractors during the last several decades. Much of the steeper terrain in the natural forests is also being harvested with tractors. This requires many skid roads with the resulting mass soil movement. Most of the time that a skid tractor is working, it is building skid roads to reach the logs. Ibbotson estimates that at least 70% of an operating day is spent doing this activity with these types of operations (Ibbotson 1991).

Tractor logging on steep slopes is dangerous, expensive, and environmentally less acceptable than other systems. However, it is a system that is widely used. part of the reason for its use is a misunderstanding or lack of knowledge about other alternative techniques (Jonsson and Lindgren 1990) that has led to poor forest policy, such as the banning of cable system use in the Indonesian natural forests until changed in 1992.

Personnel Evaluation

A most important ingredient to make the project a success was that management had to be totally behind the effort. SLJ management recognized the need for the steps that had to be taken to implement the project and was willing to assign the people and the resources to the task.

Another vital resource was the young group of dynamic engineers and foresters who were interested in the project and who devoted a great deal of effort to make it work. many of the foresters and engineers had academic degrees in the sciences, but few had any practical field experience in harvesting operations. They were familiar with the latest computer models and GIS techniques but had little recognition of the field conditions that would influence the operations.

Re-Introduction of Cable Systems

Cable systems, primarily highlead, had been used in Indonesia for many years until a government restriction in the late 1980s. Paper Industries Corporation of the Philippines (PICOP) did extensive cable logging on the Kayan River area in the 1970s.

In 1992, SLJ and FEI started the program that would re-introduce cable systems into the natural forest. the primary goals were to reduce the amount of soil movement and to reduce harvesting costs on the steep slopes. Cable logging was also considered an alternative harvest method for the wetter sites in the plantations.

The program consisted of three major steps. The first was to start a program of planning the areas, since the success of cable operations depends heavily on the planning effort.

A second major step was to develop an efficient cable logging work force. The basic cable techniques of rigging, moving, and yarding with the tower and lines was (and still is) a major training task.

Other disciplines associated with the operation also needed training in technique. This included the planners and cutters. This meant that a program of developing a cutting crew that could cut (directional felling) for the tower was vital. Felling is extremely important when cutting for cable operations, especially in partial-cuts.

The third major effort was to obtain the equipment that would be needed to do the planning (maps, computers), the operating (yarders, carriages), and the support facilities that would be necessary to implement the cable system in the forest.

Planning

Since the knowledge level of cable systems was limited, the first effort was to develop a basic understanding of the requirements for cable systems. Initially a series of workshops were held in-house to present the different cable systems and what conditions and facilities are necessary to make them effective.

Accurate topographic maps are a requirement for efficient cable planning. A program of developing adequate maps was instigated and is an ongoing effort at the present time.

Training of planners is also another major undertaking. A policy was established to require all planners to spend some time (minimum of two months) in actual cable logging operations. This meant for many that they would be working on a small training yarder. This effort is paying off at the present time as some of the planners, who had initially trained on a small tower, have now worked several months on a larger tower with the regular rigging crew. Activities required of the planners include pre-layout, rigging, and actual yarding operations.

Along with the training effort on cable harvesting, a road engineering training and designing program was started. The purpose was to correctly locate roads and to reduce the roading requirements, thus reducing the amount of material that needed to be moved to build the road network that adequately serviced the cable operations. Harvest planning and roading must be done together to assure cost and environmentally effective operations that are physically possible to implement (Figure 1).

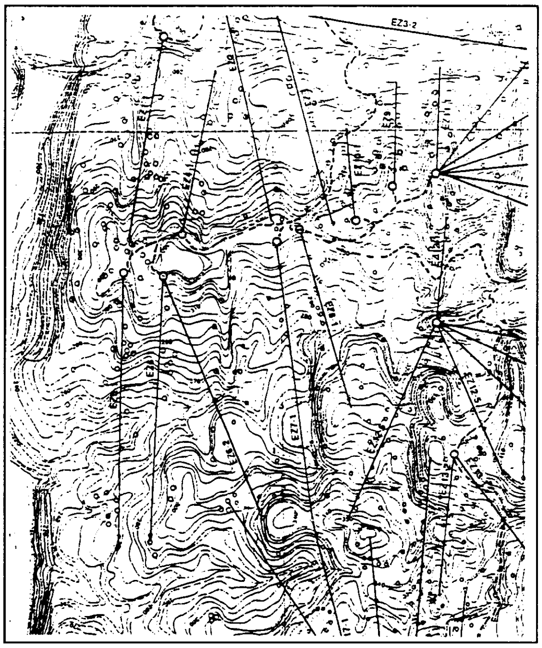


Figure 1. Logging plan showing proposed roads, landings, and skyline corridors (commercial trees indicated by open circles).

Technique

Since there was limited exposure to cable systems by any of the work force, a program to develop techniques was started. Initially this consisted of in-house workshops held in the classroom but was shortly expanded to include actual field operations. A Koller K-300 three-drum yarder equipped with a multispan carriage was purchased to be used as a training machine (Figure 2). Rigging of the tower, tailtrees, and intermediate supports was coupled with measuring the profile and calculating payload possibilities. Both partial-cuts and clear-cut harvest techniques were applied.

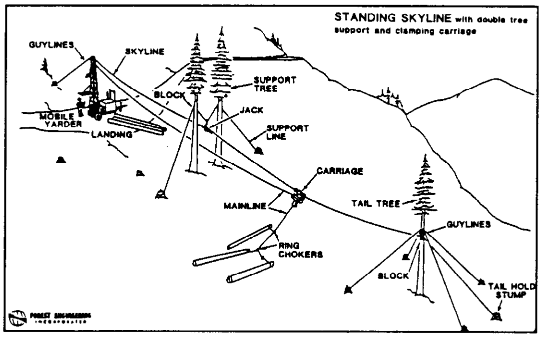


Figure 2. Koller K-300 rigged as a multispan system.

This program is a never-ending exercise that continues to train both rigging personnel and planners. Cutting for this machine, which requires directional falling, is also part of the training program.

Although the K-300 is presently being used as a training and research yarder, it will be used as a final harvest machine in the plantation. At present it is being used as a land-clearing and research unit.

Equipment

Several different types of equipment have been evaluated and acquired to make the cable program a success. Also, several computer applications have been written to complement the total effort.

After a year of crew training on the Koller K-300 and the development of a planning map and harvest plan, a larger medium-sized yarder was acquired and moved into the natural forest. This machine was a Thunderbird TTY-70 slackline yarder with a drum-lock, slack-pulling carriage (Figure 3). The carriage was also equipped to allow for multispan yarding. This operation is presently active in a training mode that will continue for the next several months.

At the same time, a small yarder application is being conducted in the plantation using a continuous line capstan system (Figure 4). Several monocable winches, manufactured by Miller Timber Services (Aulerich, Hardwick, and Miller 1993), are being tested in thinning *Acacia mangium* and *Gmelina arborea* stands. This operation serves as a training ground for crews, while at the same time providing material for a medium density fiberboard plant.

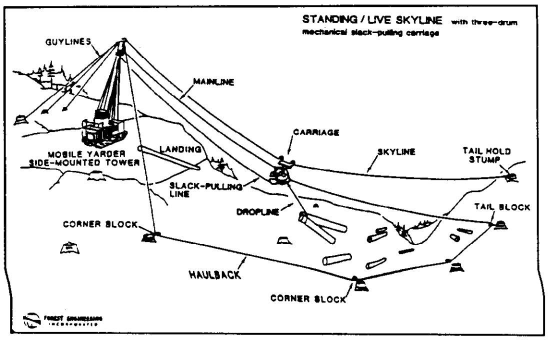


Figure 3. Standing skyline system with a drum-lock, slack-pulling, drop-line carriage.

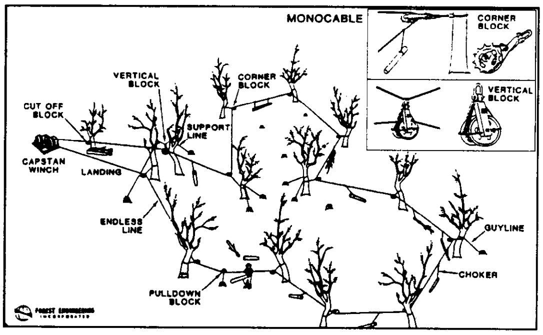


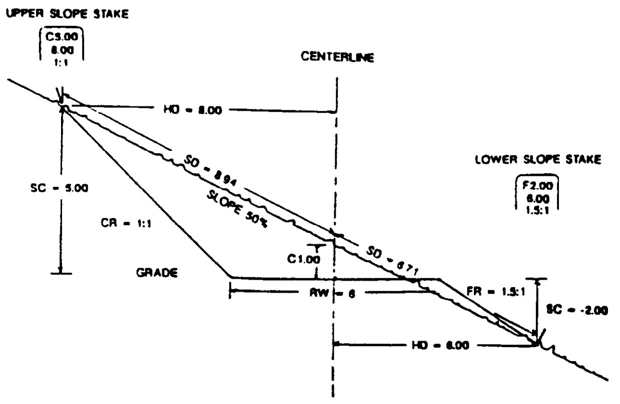
Figure 4. Monocable-capstan system used to yard small material.

Roading Efforts

Since road planning and construction is such a major part of any cable logging operation, especially in the mountains, a great deal of effort is being made to locate the roads that will service the harvesting operations. The major planning effort is to first locate where the landings are to be placed and then to locate the road system itself.

One of the primary goals of the skyline project was to reduce the amount of costly roads as well as the amount of earthwork needed in order to build an acceptable road. Since no field book was available for field design of the roads, one was developed by FEI and tested on SLJ operations (Aulerich and Shen 1994) This is illustrated in Figure 5.

By totally designing and staking all major roads and spur roads, the amount of earthwork required was reduced considerably with a large reduction in cost. The roads could also be located so that they would provide the best possible landing sites for the tower.



UPHILL						50	DOWNHILL					
CR 0.75 : 1			CR 1.0 : 1			CENTER LINE	CR 1.0 : 1			CR 0.75 : 1		
SD	SC	HD	SD	SC	HD		SD	SC	HD	SD	SC	HD
6.71	4.00	6.00	8.94	5.00	8.00	1.00	6.71	-2.00	6.00	6.71	-2.00	6.00
6.98	4.32	6.24	9.38	5.40	8.40	1.20	5.37	-1.20	4.80	5.37	-1.20	4.80
7.24	4.64	6.48	9.84	5.80	8.80	1.40	4.02	-0.40	3.60	4.02	-0.40	3.60
7.51	4.96	6.72	10.29	6.20	9.20	1.60	3.43	0.07	3.07	3.45	0.08	3.08
7.78	5.28	6.96	10.73	6.60	9.60	1.80	3.58	0.20	3.20	3.64	0.17	3.26
8.05	5.60	7.20	11.18	7.00	10.00	2.00	3.73	0.33	3.33	3.83	0.29	3.43
8.32	5.92	7.44	11.63	7.40	10.40	2.20	3.88	0.47	3.47	4.02	0.40	3.60
8.58	6.24	7.68	12.07	7.80	10.80	2.40	4.02	0.60	3.60	4.22	0.51	3.77
8.85	6.56	7.92	12.52	8.20	11.20	2.60	4.17	0.73	3.73	4.41	0.63	3.94
9.12	6.88	8.16	12.97	8.60	11.60	2.80	4.32	0.87	3.87	4.60	0.74	4.11
9.38	7.20	8.40	13.42	9.00	12.00	3.00	4.47	1.00	4.00	4.79	0.86	4.28
9.66	7.52	8.64	13.86	9.40	12.40	3.20	4.62	1.13	4.13	4.98	0.97	4.46
9.93	7.84	8.88	14.31	9.80	12.80	3.40	4.77	1.27	4.27	5.17	1.09	4.63
10.20	8.16	9.12	14.76	10.20	13.20	3.60	4.92	1.40	4.40	5.37	1.20	4.80
10.46	8.48	9.36	15.21	10.60	13.60	3.80	5.07	1.53	4.53	5.56	1.31	4.97
10.73	8.80	9.60	15.65	11.00	14.00	4.00	5.22	1.67	4.67	5.75	1.43	5.14
11.00	9.12	9.84	16.10	11.40	14.40	4.20	5.37	1.80	4.80	5.94	1.54	5.31
11.27	9.44	10.08	16.55	11.80	14.80	4.40	5.52	1.93	4.93	6.13	1.66	5.49
11.54	9.76	10.32	16.99	12.20	15.20	4.60	5.66	2.07	5.07	6.32	1.77	5.66
11.81	10.08	10.56	17.44	12.60	15.60	4.80	5.81	2.20	5.20	6.52	1.89	5.83
12.07	10.40	10.80	17.89	13.00	16.00	5.00	5.96	2.33	5.33	6.71	2.00	6.00
12.34	10.72	11.04	18.34	13.40	16.40	5.20	6.11	2.47	5.47	6.90	2.11	6.17
12.61	11.04	11.28	18.78	13.80	16.80	5.40	6.26	2.60	5.60	7.09	2.23	6.34
12.88	11.36	11.52	19.23	14.20	17.20	5.60	6.41	2.73	5.73	7.28	2.34	6.51
13.15	11.68	11.76	19.68	14.60	17.60	5.80	6.56	2.87	5.87	7.47	2.46	6.69
13.42	12.00	12.00	20.12	15.00	18.00	6.00	6.71	3.00	6.00	7.67	2.57	6.86
13.68	12.32	12.24	20.57	15.40	18.40	6.20	6.86	3.13	6.13	7.86	2.69	7.03
13.95	12.64	12.48	21.02	15.80	18.80	6.40	7.01	3.27	6.27	8.05	2.80	7.20
14.22	12.96	12.72	21.47	16.20	19.20	6.60	7.16	3.40	6.40	8.24	2.91	7.37
14.49	13.28	12.96	21.91	16.60	19.60	6.80	7.30	3.53	6.53	8.43	3.03	7.54
14.76	13.60	13.20	22.36	17.00	20.00	7.00	7.45	3.67	6.67	8.62	3.14	7.71
15.03	13.92	13.44	22.81	17.40	20.40	7.20	7.60	3.80	6.80	8.82	3.26	7.89
15.29	14.24	13.68	23.26	17.80	20.80	7.40	7.75	3.93	6.93	9.01	3.37	8.06
15.56	14.56	13.92	23.70	18.20	21.20	7.60	7.90	4.07	7.07	9.20	3.49	8.23
15.83	14.88	14.16	24.15	18.60	21.60	7.80	8.05	4.20	7.20	9.39	3.60	8.40
16.10	15.20	14.40	24.60	19.00	22.00	8.00	8.20	4.33	7.33	9.58	3.71	8.57
16.37	15.52	14.64	25.04	19.40	22.40	8.20	8.35	4.47	7.47	9.77	3.83	8.74
16.64	15.84	14.88	25.49	19.80	22.80	8.40	8.50	4.60	7.60	9.97	3.94	8.91
16.90	16.16	15.12	25.94	20.20	23.20	8.60	8.65	4.73	7.73	10.16	4.06	9.09
17.17	16.48	15.36	26.39	20.60	23.60	8.80	8.80	4.87	7.87	10.35	4.17	9.26
17.44	16.80	15.60	26.83	21.00	24.00	9.00	8.94	5.00	8.00	10.54	4.29	9.43
17.71	17.12	15.84	27.28	21.40	24.40	9.20	9.09	5.13	8.13	10.73	4.40	9.60
17.98	17.44	16.08	27.73	21.80	24.80	9.40	9.24	5.27	8.27	10.92	4.51	9.77
18.25	17.76	16.32	28.17	22.20	25.20	9.60	9.39	5.40	8.40	11.12	4.63	9.94
18.51	18.08	16.56	28.62	22.60	25.60	9.80	9.54	5.53	8.53	11.31	4.74	10.11
18.78	18.40	16.80	29.07	23.00	26.00	10.00	9.69	5.67	8.67	11.50	4.86	10.29
19.05	18.72	17.04	29.52	23.40	26.40	10.20	9.84	5.80	8.80	11.69	4.97	10.46
19.32	19.04	17.28	29.96	23.80	26.80	10.40	9.99	5.93	8.93	11.88	5.09	10.63
19.59	19.36	17.52	30.41	24.20	27.20	10.60	10.14	6.07	9.07	12.07	5.20	10.80
19.86	19.68	17.76	30.86	24.60	27.60	10.80	10.29	6.20	9.20	12.27	5.31	10.97
20.12	20.00	18.00	31.30	25.00	28.00	11.00	10.43	6.33	9.33	12.46	5.43	11.14

WHEN CUT AT UPPER STAKE						ROAD WIDTH	WHEN FILL AT LOWER STAKE					
3.58	1.60	3.20	4.47	2.00	4.00	10M-0M	8.94	-4.00	8.00	8.94	-4.00	8.00
2.68	1.20	2.40	3.35	1.50	3.00	9M-1M	6.71	-3.00	6.00	6.71	-3.00	6.00
1.79	0.80	1.60	2.24	1.00	2.00	8M-2M	4.47	-2.00	4.00	4.47	-2.00	4.00
0.89	0.40	0.80	1.12	0.50	1.00	7M-3M	2.24	-1.00	2.00	2.24	-1.00	2.00

Figure 5. Slope stake tables (lower portion of figure) and location of slope stakes on a typical road cross-section (upper portion).

Conclusions

Policy should not be legislated without a thorough understanding of the requirements of implementation. This understanding of implementation requirements is acquired through comprehensive planning, evaluation, and experience.

Careful planning and using the right techniques and equipment are necessary to make cable harvesting operations in tropical forests a success economically and environmentally.

Although this project is still in its early stages of implementation and evaluation, the findings look very favorable. There has been a major reduction in the roads required, and an acceptable level of production is indicated.

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Management of Ecosystems in Indonesia

Rubini Atmawidjaja

Introduction

Natural ecosystems are communities whose elements are closely linked and interrelated. The tropical rainforest ecosystems consists of various layers of vegetation from lower plants to seedlings, saplings, poles and trees. Other living organisms can also be found in the forest, such as micro-organisms, larger wild animals, pests, saprophytes, epiphytes, and parasites.

The formation of the tropical rainforests has been caused by an evolutionary process; in a natural succession the environment, and its influencing factors, such as climate and habitats, went through a cycle of adaptations. The tropical forests is also able to rehabilitate itself: toppled old trees are converted to soil by micro-organisms and the space is filled by seedlings so that rejuvenation processes occur naturally. The same also happens to the other ecosystems, such as mangrove forests, bamboo forests, sago and nipa palm forests, etc.

Human influences such as the utilization of the natural ecosystems through logging, harvesting of other crops, hunting or trapping, and the like, could change the natural ecosystem to such a degree that it might not recover to its original condition.

Management of the forests by scientific and technological methods could pave the way to reap benefits from the natural ecosystems and avoiding destruction, even though changes in the natural ecosystems will still take place.

This paper attempts to present a compromise between human needs and destruction of the natural ecosystems—in particular tropical rainforest—in order to mitigate world-wide environmental degradation, such as global warming, pollution and decreasing biodiversity, through sustainable forest management.

Management of Man-Made Forest

This system of forest management was invented by a German and introduced to Indonesia through a Dutch forester in the 17th century. It was applied to teak forests which had grown as natural forests since the time of Syailendra, the Hindu era in Java.

This type of forest management divides the area according to the planting year of the teak. Stands of teak are therefore formed by age-classes from I to XII. Age-class 'I' consists of trees of 1 to 10 years of age, age-class 'II', from 10 to 20 years of age, and age-class 'XII' of trees from 111 to 120 years of age.

Depending on the policy of cuttings, a rotation or cutting scheme can be established at the age-class IV or VIII or others, which means a stand of teak of 40 years and over or 80 years and over will be clear-felled, and the cleared terrain re-planted.

Because of this policy of clear-felling followed by re-planting, the teak forests are up to the present still productive. Because of the law of supply and demand, which often overcomes considerations of sustainability, there have, however, been some deviations from the established patterns.

At present, the loggers operating in the teak forest have decreased their cutting cycle from 80 to 40 years solely based on economic considerations. However, the sustainable yield concept is still maintained, i.e. every year there are 40 year old trees to be cut.

This forest management system is generally only applicable to forests planted with one species only, such as teak, mahogany, pines, albizzia, anthocephalus, eucalyptus, agathis, and puspa. The cutting cycle depends on the growth rate (buxon volume) of the respective species; for mahogany this cycle can be 40 years, for pines 25 years, for eucalyptus and albizzia 7-8 years, and 30 years for agathis. The cutting cycle also depends on the end use, or the timber products planned to be produced. The growth of teak is illustrated in Figure 1.

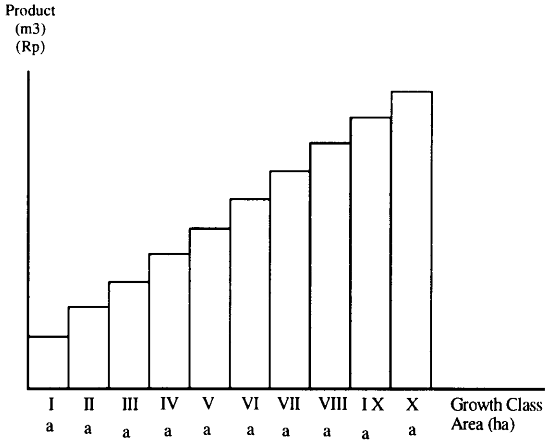

Figure 1. Growth diagram for teak.

The theoretical figure can be represented as an inverse S curve, see Figure 2. During the early years the growth rate is very low, at a later stage the rate increases dramatically only to drop again after a certain number of years and ultimately to halt completely.

The policy of cutting is based on determining the (R) when the growth is optimum (Opt). This is based on the consideration that it is not economical to incur expenditures till maximum growth has been reached, while the biggest market demand is for the timber quality of age class R.

Animals found in these plantation forests, such as tigers, deer, and birds are protected, except for wild boar. Cutting is not carried out in areas with steep gradients and areas prone to landslides. Should felling be necessary, it will be done selectively, not on the basis of clear-felling. Springs, lakes and rivers found in the forests are protected by maintaining the vegetation around them.

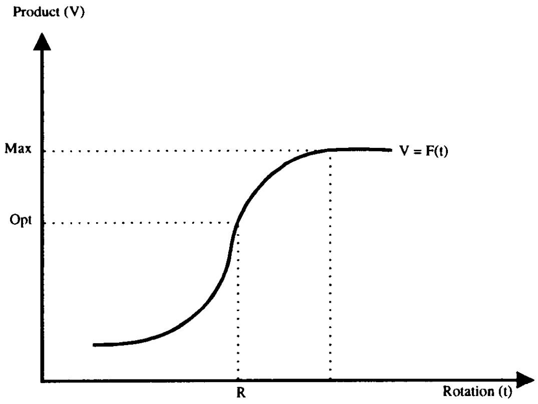

Figure 2. Growth curve.

Management of Natural Forests

In the 1960s the forestry policy was shifted to the utilization of forest outside Java in order to earn foreign exchange for the national development efforts. This began in East Kalimantan, and finally spread to Irian Jaya. Foreign investors from Singapore, Malaysia, the Philippines, Japan, the United States, France, and Korea, invested heavily in order to export logs to their respective countries.

Mechanical logging was picked up by Indonesia from those investors. No word of criticism on the management of rainforests was ever heard at that time. Forest concessions were given for 20 year periods in the form of logging rights (Hak Penguasahaan Hutan, HPH), and the concession holders carried out logging according to market considerations, although the Government of Indonesia (Ministry of Forestry) had already produced logging instructions based on the principle of sustainable production.

Only in the 1980s did Indonesia tighten the existing regulations by imposing several kinds of sanctions to the transgressors in the form of fines and cancellation of the logging rights.

The following legislation was issued before HPH licenses came into being:

a) Selective cutting for trees of 60 cm diameter or over;
b) Mother trees should be maintained on each hectare;
c) Re-planting should be carried out;
d) Annual cutting quotas were to be determined by the Ministry of Forestry;
e) Annual cutting block would be 1/35 part of the forest concession area;
f) Duration of HPH is 20 years;
g) Certain animals and plants were to be protected;
h) Springs had to be maintained and no logging was allowed around the springs.

Damages brought about the HPH holders are caused by lack of control of the forestry authorities and due to the human nature of most HPH holders. As a matter of fact, the 35 years cutting cycle on which the annual cutting block of 1/35 part of the concession area is based, together with a concession period of 20 years, assures sustained forestry production, because at the end of the concession period approximately half of the concession area, or 15/35 part, is still untouched (See Figure 3).

By following the "Forestry Agreement" at the time the forestry concession holders receive the right to the production forest, and exercising control over the annual cutting quota, the deviations can be controlled. The HPH management system takes into account that the forests also serves as a habitat of great biodiversity, sources of springs, prevention of floods and landslides, formation of micro-climates, space for the local communities to harvest forest products, sites for recreation and for research activities.

Now, at the start of the second 25-year development plan, with all critics and boycott threats, Indonesia and her timber industry still have to rely on the resources of the tropical rainforest until time that the industrial plantation forests will come into production, i.e. in approximately 25 years time.

There are around 500 processing companies which use timber as a raw material, located throughout Indonesia. The processing units do not only derive their raw material from the vicinity, but also from other islands. Similarly, the output is not only destined to fulfill domestic needs, but is also exported to earn foreign exchange.

The efficiency of timber utilization, starting from cutting to processing, is still very low; the amount of waste is approximately 65-70%. Appropriate science and technology should be applied on a wider basis, in order to increase incomes, quality and added values, and create new employment opportunities.

In order to enhance sustainable development, the HPH holders should stick to the agreements stated in the Forestry Agreement. Orientations toward economic interest only, should be re-assessed by paying attention to the environment and biodiversity, so that every HPH holders shall put aside a portion of the forest ecosystems to be used as an indicator for evaluating the cleared forest, and simultaneously maintaining the specific ecosystems of Indonesia's tropical rainforest.

Management of Conservation Forests

Wallace classified the biodiversity, fauna and flora into the Indo-Asian, the Indo-Australian and the Wallace zones. The Indo-Asian zone (Sumatra, Kalimantan, Java) is dominated by big mammals, such as elephants, rhinoceros, the wild ox of Java, orang utans, and tigers; the Wallace Zone (Sulawesi, Nusatenggara, Maluku) by endemic animals, such as babi rusa, anoa, komodo, deer, snakes, crocodiles, and psitidae; and the Indo-Australian Zone (Irian Jaya) by marsupials, crocodiles, and various bird varieties.

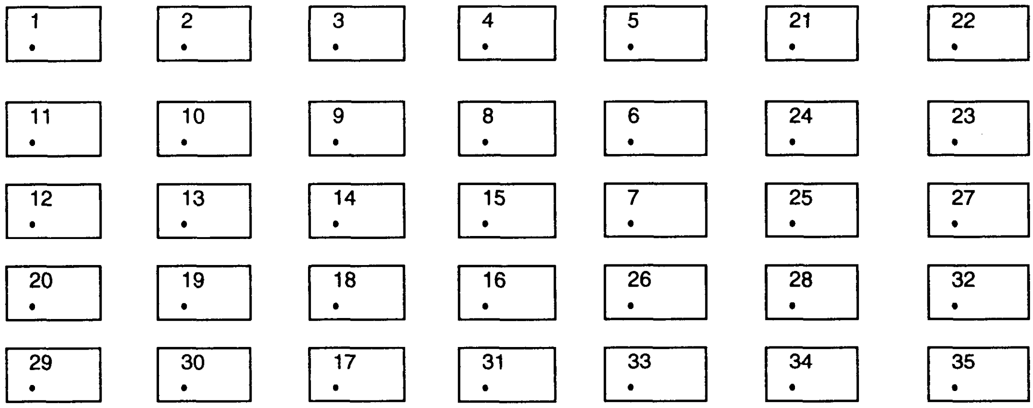

Figure 3. Cutting Blocks of a HPH.

Wallace did not group the trees according to the three zones of fauna habitats. However, the uniqueness of dominating trees can be observed through their distribution over Kalimantan: Dipterocarpaceae species; Sumatra: Agathis, Pines; Java: Teak, *Altingia excelsa,* Pines; Sulawesi: Diospyros, Eucalyptus; Maluku: Pericopsis; Nusatenggara: *Santalum album;* Irian Jaya: Araucaria, Pometia.

The concept of forest conservation areas is conducted through the establishment of national parks; the maintenance of natural reserves and grand forest gardens; the formation of forested city parks; and the maintenance of natural caves. This management system is aimed at sustaining the biodiversity and habitats and is commonly called *in situ conservation.* The domesticating or culture system of biodiversity, known as *ex situ conservation,* which provides supplement to natural conservation, is intended to educate the society in the cultivation of wildlife, especially of those regarded rare. The international market demand for rare animals is very high and offers good prices , which encourages the communities around the forests to catch and collect these varieties of flora and fauna, without paying attention to the prevailing national as well as international regulations.

The national park system divides the conservation areas into several zones, the most important ones are core zones, protection zones, intensive use zones, and buffer zones. The core zones are not allowed to be touched by humans, except for special officials, and flora and fauna are left to breed naturally and to adapt to their environment. The core zones surrounded by protected zones, a place or space for wildlife to move around and expand in order that specific ecosystems are always maintained. The intensive use zones are designated for research activities, conservation Education and recreational purposes .Physical facilities, such as clinics, lodging, restaurants, rooms for seminars and reading, small museums and other facilities needed, are provided for the convenience of visitors. Skilled guides, security and health officers are available 24 hours per day, and communication equipment enables centralized monitoring of happenings within the national parks. Transport vehicles, required for daily as well as for emergency purposes will also be made available.

Mangrove forest ecosystems in the coastal areas which have been declared as part of the national parks are individually managed and have zonations covering core zones, protected zones, intensive use zones, and buffer zones.

Conversion of mangrove forests to other purposes, such as brackish water ponds for shrimp farming, area for industry and reclamation, is only possible if these are not included in national parks and protected areas, but environmental impact analysis procedures have to be followed.

Policy on the use of national parks by the local indigenous communities who have lived in the parks for generations is executed to fulfill their needs for forest products, however, without causing or worsening negative impacts on the wild living resources within the national parks. On the other hand, the local communities are requested to participate actively in sustaining the environment of the national parks.

Not less than 125 governmental decrees support and govern the Management of Conservation Areas, including Law No. 5, 1967 on Basic Rules for Forestry; Law No. 4, 1982 on Basic Rules for the Management of Living Environment; Law No. 5, 1990 on the Conservation of Living Resources and Ecosystems, and Presidential Decree No. 43, 1978 on the Convention on International Trade in Endangered Species (CITES).

Management of Protection Forests

In principle all natural forests possess multiple functions, i.e. production, conservation, protection, and recreation. To manage the forests according to their main functions, the Ministry of Forestry groups the forest according to the Agreed Use of Forests (Tata Guna Hutan Kesepakatan, TGHK).

The criteria used to determine protection forests are slopes, soil type, and rainfall. Based on these criteria, human activities in the protected forests are not allowed to disturb the hydro-orological stability, by causing floods, erosion and landslides. It is obvious that clear felling in the protection forest areas will disturb its control functions, consequently, rain water which should have been held by the crowns, the plants underneath and the offal will be exerting kinetic energy which will loosen soil granules, to be swept away by run-off on the surface. The muddy water flowing on steep slopes will sweep away objects like stones and trees.

On the open terrain along steep slopes, reforestation is needed to control the floods. The management of protection forests in the semi-arid or dry regions is meant to collect the water during the rainy season and to use it during the dry season, while in the high rainfall regions like in the tropical rainforest, to control floods and erosion.

The management of protection forests in Indonesia has been prioritized to 39 river basin areas which are already in serious or critical conditions, through the concept of saving forests, land, and water. At present, protected forests of good condition comprise only 22% of the 30 million ha of protection forests agreed to under TGHK.

The legal base for protection forest management is formed by:

- Presidential Decree No. 32, 1990 on the Management of Protected Forests
- Governmental Regulation No. 28, 1986 of Forest Protection
- Governmental Regulation No. 29, 1985 on Environmental Impact Analysis
- Governmental Regulation No. 35, 1991 on River Basin.

In order to increase the efficiency of the management of protection forests it has been proposed to establish an implementation unit called Protection Forest Management Unit.

Naturally, the protection forests possess vegetation composition as trees, cover plants, offal, and a thick layer of humus. The critical areas of protection forests are protected through reforestation and terracing.

Conclusions

The national ecosystems in Indonesia cover tropical rainforests, monsoon forests, edaphic forests and semi-arid forests.

According to the Agreed Use of Forests, the national forest areas have production, protection, and conservation functions.

It is possible to convert the production forests to other (non-forest) utilization such as settlement, estate crops, industry, mining and fish farming.

The management of the forest ecosystems according to their functions, is based on the principle of sustained use. The production forests should produce timber; protection forests should assist in the control of floods, erosion, the protection of water sources; and finally conservation forests should support the protection of biodiversity and habitats.

International collaboration should result in optimizing the functional use of forests.

The active participation of the local communities is required in the sustainable utilization of forest resources.

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About this volume. This publication is a collection of papers which were presented at a symposium organised as part of the XX World Congress of IUFRO, the International Union of Forestry Research Organisations, in Tampere, Finland, 6-12 August 1995. The symposium was convened by IUFRO Subject Group S3.05-00 "Forest Operations in the Tropics" (now re-designated as Research Group 3.05.00 in the revised IUFRO structure). In view of the theme of the XX World Congress, "Caring for the Forest: Research in a Changing World,"the organisers of the symposium requested participants to focus on the topic"Forest Operations for Sustainable Forestry in the Tropics. "Altogether 12 presentations were given, nine of which are reproduced in these Proceedings The authors of the remaining three presentations decided not to prepare formal manuscripts for this publication because of prior arrangements to publish their papers elsewhere. The papers in these Proceedings summarise results from research dealing both with environmental and social impacts of forest operations and also with efforts to develop promising new technologies for planning, implementing, and controlling forest operations so that such impacts are significantly reduced. Although this small set of papers can provide only a very limited introduction to this important subject, the volume is offered as a contribution to the dissemination of research on sustainable forestry practices.

About IUFRO. The International Union of Forestry Organisations is one of the oldest international non-governmental organisations in existence. Established in August 1892, its membership now comprises 715 forestry research institutions which represent more than 15,000 scientists in 115 countries. IUFRO is not itself a research organisation but rather an association of research organisations. Its principal function is to provide opportunities for scientists from the member organisations to learn from each other, either at meetings or through publications such as this volume. This is done largely through eight Divisions, each of which is subdivided into Research Groups such as 3.05.00, "Forest Operations in the Tropics," which produced this volume. IUFRO provides an extensive electronic networking capability through its World Wide Web site at http://iufro.boku.ac.at/, where more information about the Divisions, the Research Groups, and their activities can be obtained.