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RECOMMENDATIONS FOR CONTROLLED TIMBER HARVESTING IN THE SBK FOREST CONCESSIONS

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ACRONYMS

AAC	Annual Allowable Cut
AKG	Alas Kusuma Group
ARD	Associates in Rural Development
BAPPENAS	Badan Perencanaan Pembangunan National (National Development Planning Board)
dbh	Diameter breast height
FAO	Food and Agricultural Organization
HPH	Hak Pengusahaan Hutan (TPTI Forest Concessionaires)
HPT	Hutan Produksi Terbatas (Limited Production Forest)
ITTO	International Tropical Timber Organization
KANWIL	Kantor Wilayah (Regional Office)
MOFr	Ministry of Forestry
NRMP	Natural Resources Management Project
RKL	Rencana Kerja Lima (Five Years Work Plan)
RKT	Rencana Kerja Tahan (Annual Work Plan)
SBK	Sari Bumi Kusuma (Company)
TPn	Tempat Penumpangan
TPTI	Tebang Pilih Tanam Indonesia (Indonesian Selective Cutting and Planting System)
USAID	U.S. Agency for International Development

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PREFACE

This consultancy on improving timber harvesting techniques in the tropical rain forest of West Kalimantan was undertaken in the framework of the USAID-supported Natural Resources Management Project (NRMP), from July 2 to August 6, 1992. A three-weeks field trip was made to the Nanga Nuak forest concession of the PT Sari Bumi Kusuma (PT SBK) as part of the programme that had to be carried out in close collaboration with staff of this wood processing company (Appendix 1).

In spite of the relatively short time to execute the programme, the three-weeks fieldwork could be carried out in full, except that training was restricted to a two-days demonstration of felling and skidding techniques. The main constraints appeared to be delays from heavy rain and lack of accommodation close to the research site. The limited participation from SBK and the complete absence of counterparts from the Ministry of Forestry were practical restrictions to realize a comprehensive training course. Nevertheless, the programme could proceed satisfactorily thanks to the assistance of NRMP and SBK staff.

I wish to thank Mr. M. Elmo Drilling, the NRMP natural forest management advisor, and Mr. Izefri, the NRMP field assistant, for their invaluable assistance and enthusiastic participation in the field surveys. The SBK staff at Nanga Nuak was very helpful with information and logistic support, for which I would like to thank the camp manager Mr. Adlin and the inventory supervisor Mr. Yudi. I have also appreciated the interest for this consultancy from the SBK managing director, Ir. Mamat Mullyana. Much support was given by NRMP staff, in particular by the party leader Dr. Colin MacAndrews.

EXECUTIVE SUMMARY

The PT Sari Bumi Kusuma has the responsibility of managing a forest concession of approximately 270,000 ha along the border of West and Central Kalimantan. The company is considered as one of the best of Indonesia in following the TPTI rules with regard to timber harvesting and regeneration practices. The company is also actively involved in the NRMP which aims at developing a sustainable forest management system for the Dipterocarp hill forests of Kalimantan.

During a three-weeks field survey in the concession area, the harvesting system of SBK was observed and appraised on efficiency and environmental impacts. Most attention was given to logging operations and their impact on the forest ecosystem, but the focus was also on the road and transportation system. The findings of the survey indicate that SBK has got already a solid basis for implementation of sound forest management, but that a gradual change of the present harvesting system is required to achieve the final goal of forest conservation and sustained timber yield.

Harvesting operations are fairly efficient considering the tough terrain and climatic conditions. The company is able to organize a regular supply of raw material (logs) to the processing plants in Pontianak, in spite of the long distance of more than 140 km of (forest) road and approximately 450 km of river transport. Especially road transport is well organized and guaranteed by an armada of 25 truck-trailer combinations. Forest roads are also well designed, constructed and maintained. Felling and skidding production are encouraged by incentives. Tractor and power saw operators are skilful and able to meet the production targets.

Although efficient in many respects, the SBK logging system is sill conventional and unavoidably attended by substantial forest damage and harmful environmental effects. The areas visited by the consultant showed clear examples of felling and skidding damage and of deforestation caused by road construction. There were logging compartments with a total affected area exceeding 40% of the forest under harvesting. The main damage inducing factor is the construction of forest roads which may lead to erosion, and consequently to siltation of rivers, massive loss of forest vegetation and compaction of the forest soil. Next destructive is skidding, with similar effects as road construction, followed by felling with vegetation damage only. A large portion of the damage done by skidding, is caused by intensive manoeuvring of the tractor in the stump area, an operation that can be carried out with less soil damage if the crew is trained for controlled skidding. The incentive system, aims at stimulating production, appeared to induce damage, especially in felling operations where directional felling is considered as a loss of time. As a rule, logs are felled down hill instead of towards the slope, which increases the risk of excessive damage to residual trees.

Planning of harvesting operations and modification of the present logging system may reduce forest damage with 30 %, or even with 50%. This was demonstrated by a small experiment of direction felling and controlled skidding. The direct result was a reduction of the length of skid trails and of tractor movement in the stump area, and consequently, a reduction of the disturbed and compacted forest floor. In another trial, the felling and skidding crew had to cooperate to determine the right lay of a tree to be felled, so that damage to residual trees could be restricted.

The survey made clear that harvesting impacts in the SBK concession could be restricted by modification of the present system. Little physical investments are needed to achieve this aim, while forest staff should be instructed and trained for the new system. Most important is to stimulate an awareness for damage control and sustained timber production. Workers are able to understand what that means and are capable to adapt rapidly to a new system. A strategy has been detailed for three levels of damage control including the consequences for efficiency and costs of operations.

SBK has got already an excellent basis for planning, damage control and sustained management; that is the cruising or 100% preharvesting inventory. Cruising maps were used to select a site for training and research. A training in controlled and organized logging is envisaged and a number of experiment are planned to demonstrate how damage restriction can be obtained, while maintaining or improving logging efficiency. The programme needs to be prepared for a start in the dry season of 1993. One professional felling instructor should be contracted for a period of three weeks. One felling, one crawler tractor and one wheeled skidder crew have to be assigned to the logging area for a period of one year. A number of permanent sampling plots (PSP's) have to be located in the experimental area for long-term observations, for instance, to monitor the recovery of the forest soil and vegetation from logging impacts.

1. INTRODUCTION

1.1 Objectives of the NRM Project

The Natural Resources Management Project (NRMP) is a cooperative research and policy programme with the National Planning Board (BAPPENAS) and Ministry of Forestry (MoFr) of Indonesia, and two private companies, the PT. Sari Bumi Kusuma (PT. SBK) of the Alas Kusuma Group, and the PT. Kurnia Kapuas Plywood (PT. KKP) of the Bumi Raya Utuma. The programme is assisted by the United States Agency for International Development (USAID) and the International Tropical Timber Organization (ITTO), and implemented by Associates in Rural Development (ARD) from Burlington, US. The major objective of this programme is to assist the Government of Indonesia in the development and implementation of sustainable resource management and policies to ensure long-term economic development in the nation. In conjunction with the research and development activities, the NRMP seeks to strengthen the institutional capacity of the various agencies and the private sector by providing training and educational opportunities both within Indonesia and abroad (Curran and Kusneti, 1992).

Forestry is of great economic significance for Indonesia. In the NRMP, much attention is given to the management and conservation of this natural resource.

1.2 Aim of the present study

There is a world-wide concern about the future of tropical rain forests (TRF). The area of TRF is decreasing in an alarming rate or is degrading rapidly as a result of intensive exploitation or conversion to other forms of land use. One way to maintain TRF's as a source of timber and other products and services, is to use them wisely on a sustainable basis. This means that timber production should be organized to avoid overexploitation and to reduce the environmental impacts.

The factors behind the process of deforestation and forest degrading are up to a certain extend the same for many tropical countries, although population pressure is often a dominant factor. Following the timber harvesting practices of the past decades, it becomes clear that this form of forest use might have strong impacts on the quality of the remaining stand, and consequently also on the adjacent environment (BIOTROP, 1978). In this respect, harvesting intensity and terrain topography are decisive factors determining the rate of forest and environmental degradation.

The aim of the present study is to assess logging impacts and to find means for improved and damage-restricting harvesting. According to The Terms of Reference (Appendix 2) and project documents (NRMP, 1992) the following activities have to be performed:

- To design a forest harvesting system as a component of a sustainable forest management system, which has to be develop during the course of the NRM Project.

- To design a training programme for counterpart and company staff in damage-restricting harvesting techniques, including directional felling and organized skidding.

- To design a research programme to study the long-term effects of conventional and controlled timber harvesting.

2. METHODOLOGY

2.1 Fieldwork

After a short period of orientation at the office in Jakarta and two meetings with SBK management and forestry officials (Kanwil) in Pontianak, the fieldwork in the SBK forest area was carried out in four successive steps:

- The current harvesting practices were observed with emphasis on cruising, felling and skidding, but also including road construction and timber transportation.
- Harvesting damage was assessed in a compartment with ongoing forest operations.
- Preparations were made for the layout of a compartment where training and research could be conducted in the near future.
- A number of trees were harvested to demonstrate directional felling and controlled skidding.

2.2 Measurements and data collection

Simple tools and methods were used to measure and to calculate forest damage. Felling and skidding gaps and skid trails were measured with the aid of a tape, a compass and a slope meter (see "Manual for Research and Training"). The affected area was calculated in m^2 and expressed as a percentage of the harvested area. The felling gaps and skid trail system were mapped to identify the shape of the gap and the pattern of terrain transport. A full description of the measuring methods is given in the "Manual".

Harvesting operations were observed to study the existing felling and skidding techniques and to assess the length of a work cycle. A stopwatch, a diameter tape and a photo camera were used to make the records.

A section of a harvesting compartment was cruised to measure and to map the area occupied by main and branch roads. This exercise was undertaken to assess the efficiency and quality of roads and their impact on the forest environment.

Inventory (cruising) data were studied to select a suitable site for training and research and to design a programme for this purpose.

Administrative and recording procedures were examined in order to appraise the overall efficiency of forest operations and long-distance transport of timber.

2.3 Data processing and mapping

The recorded felling gaps were mapped and the gap areas were calculated. A section of the skid trail system was mapped and the affected area calculated. The same was done with regard to secondary (branch) forest roads. These parameters were used to assess forest vegetation and soil damage.

Daily records and data from annual reports were analyzed to obtain an impression of operational efficiency. Interviews with the local management provided more insight in the harvesting strategy and the SBK perception on sustainable forest management.

3. TIMBER HARVESTING IN THE SBK FOREST CONCESSION AREA

3.1 Forest concession area

The forest concession of SBK, located in Central Kalimantan along the border with West Kalimantan, is 270,000 ha in area (Fig 1). The concession area is divided into two parts, the catchment area of River Seruyan Hulu (Kalbar), and that of the River Jelai-Delang (Kalteg). Around 250,000 ha is allocated as Limited Production Forest (HPT) while the remaining area is non-forest land. According to the TPTI selection felling system, a felling cycle of 35 years has to be used to achieve sustained yield and to determine the annual allowable cut (AAC), which is in this case the equivalent of an annual coupe of approximately 5,300 ha.

The concession has been granted for a period of 20 years. Planning of timber harvesting operations is based on a Five-Years Work Plan (RKL) and an Annual Work Plan (RKT). According to this plans, the AAC has been assessed to range from 140,000 m^3 (from the first year) to 230,000 m^3 (after the third year) with a maximum of 370,000 m^3. However, annual production is still below 200,000 m^3 since the start of harvesting operations in 1980, as is demonstrated by the figures in Table 1.

Table 1: Planning and realization of timber production in m^3 per species from April 1991 until January 1992 (10 months)

Species	Planning	Production
1. Meranti	136,700	113,443.54
2. Keruing	6,500	5,719.65
3. Kapur	9,700	7,882.42
4. Bangkirai	16,000	13,432.89
5. Jelutung	5,000	345.15
6. Mersawa	2,900	2,411.92
7. Melapi	16,100	13,992.79
8. Others	26,600	22,136.54
Total	215,000	179,315.90

3.2 The harvesting system

The harvesting system can be classified as a long-wood logging system (FAO, 1977). It includes all timber harvesting operations and long-distance transport methods which are common in tropical rain forest countries, from road construction, felling with chain saws, skidding with crawler tractors, piling with wheeled and crawler loaders, truck transport to river terminals and final transport with rafts and barges.

Cable yarding systems and wheeled skidders are not used. Operations are properly planned and are based on a 100 % pre-

harvesting inventory (cruising). A decisive factor in harvesting planning is the weather. In the rainy season timber transport is hampered by reduced trafficability of roads and skid trails due to steep terrain and heavy soils, and in the dry season river transport is largely prohibitive due to shallowness of the River Melawi.

Timber harvesting is an ongoing process throughout the year. It consists of a set of suboperations which can be considered to be executed in a logical sequence, starting with road building and ending with river transport, but which in reality are all executed at the same time. The suboperations are discussed in the following text in the sequence of execution.

3.3 Road construction

The road system, currently consisting of more than 150 km of main roads, is well designed and constructed, giving good access to logging compartments. The main roads are of the "all-weather" type, well drained and stabilized with gravel taken from the numerous rivers and tributaries, which intersect the entire forest. Branch roads are connecting the main road with the felling compartments; they are not gravelled and their use is limited by weather conditions. During rainy days transport is temporally hampered or delayed. Given the steepness of the terrain and conditions of the dominant clay soils, the road system is of a remarkable high quality, although not free from erosion hazards and problems caused by disturbed hydrology (see section 4.1). The roads are intensively maintained throughout the year. There are two D8K-Caterpillar tractors, four D7G-Caterpillar tractors, 14 dump trucks and one motor grader available for road construction.

3.4 Cruising

The cruising is a 100% enumeration of harvestable commercial trees and of nucleus trees. The minimum dbh for cutting is 60 cm for Dipterocarp trees and 50 cm dbh for other commercial species. Nucleus trees are spotted from 20 cm dbh and up. The survey is performed by a nine-men crew composed of three topographers, five tree spotters and one foreman, who leads the crew and records locations, dimensions and species of identified trees. The tree spotters are spaced 20 m from each other and are cruising the forest simultaneously. The topographers measure distances, slopes and other terrain characteristics such as creeks, gulleys and rock formations. One topographer is responsible for the recording of these data.

Forest and topographic data are processed and laid out in a map of scale 1:1000, which is a powerful tool for the planning of

access roads and harvesting operations. The maps are completely designed at the camp office and are available one year before the start of felling.

There are seven (nine-men) cruising teams employed throughout the year.

3.5 Felling operations

Felling is carried out by a two-men crew, consisting of a chainsaw operator and an assistant who helps to locate selected trees from the cruising records. The assistant cleans the underbrush and cuts lianas from the tree to be felled. A Stihl 070 chainsaw with a 80 cm long bar is used for actual felling, topping of the crown and crosscutting of the usable bole into one or two logs. The bud end of a tree is often cut off when flutes or defected parts occur. Crosscutting is only done to facilitate skidding when a log is too heavy or too long for extraction. Generally, long-wood skidding is attempted. The assistant may help with topping and crosscutting.

Trees selected for felling, are not directed, but are felled according to their lean because the chainsaw operator aims at cutting as quick and as safe as possible. The crew is rewarded with an incentive for the number of trees felled. The crew is skilful and able to cut 15 to 25 trees a day. No attempts are made to prevent damage to nucleus trees. Most trees are felled down hill (from the slope) and not towards the slope as is required to reduce forest and wood damage.

Felling is performed by 15 (two-men) crews throughout the year.

3.6 Skidding operations

The type of terrain transport is ground skidding with the aid of D7-Caterpillar crawler tractors, equipped with dozer blade and cable winch. The extraction of logs from the stump area starts shortly after felling. The tractor is operated by one driver who is assisted by a hookerman. Both travel together on the crawler to the forest to search and to collect the felled timber. Logs are directly connected by the hookerman to the winch line without the aid of chokers (cables with two bud ends, termed as "nibbons", and a sliding lock, termed as "bell"). Logs are skidded from the stump area to a forest landing or TPn (Tempat Penumpangan) where they are unhooked and arranged for measuring and crosscutting to transport lengths (10-12 m). The maximum skidding distance is 1 km.

Not less than 21 D7-tractors are required for skidding, for yarding (and piling) and to help with branch road construction.

3.7 Yard operations

The forest landing or TPn is the place where extracted timber is numbered, debarked, measured, crosscut to transport lengths, piled, and loaded on trucks. Debarking is done manually; it is a prevention treatment against insects attack. Log handling, piling and loading is done with two crawler loaders and three wheeled loaders.

The TPn's are the first link in the stock keeping chain, which is of great significance to guarantee the log flow from stump area to processing plants in Pontianak. In addition to the numerous TPn's, most of them located at branch roads, there are two large log yards located along the main road, one at km 80 and one at km 54, with a capacity of 10,000 m^3 and 3000 m^3 respectively. The last yard is the river terminal at Nanga Popai. Temporary stocks of timber at the log yards and terminal is a must to overcome the transport delays, and to raft as much as possible in the rainy season.

3.8 Road transport

On the TPn's, logs are piled on trucks with crawler loaders and on the gravelled yards with wheeled loaders. The transport fleet consists of 27 vehicles, among which five new Renault truck-trailer combinations (CBH 350). The smaller types of trucks (Renault CBH 280 and Berliet CBH 280) are able to carry maximum loads of 20 to 30 tons depending on the steepness of the terrain. These units are used to carry the logs from the TPn's to the log yards for storing and for reloading to the more powerful Renault trucks with capacities of 35 tons (fixed trailer) and 45 tons (flexible tandem axle semi-trailer). At the river terminal, logs are dumped for storage and final transport to Pontianak.

The management of SBK pays much attention to truck transport to overcome the seasonal bottle necks in the transport chain. The transport fleet is kept in good condition by the well equipped work shops at km 35 and km 54. Timber stocks on the yards and the river terminal (called "log pond") have to be sufficient to transport as much logs as possible through the River Melawi during the rainy season. Because of this consideration, truck roads are intensively maintained to reduce transport delays.

3.9 River transport

At the log yard at the River Melawi, a tributary of the River Kapuas, floating logs are combined to rafts and pulled with small tugboats until the processing plants in Pontianak. Rafting in the shallow river gives a lot of problems and is often not possible in the dry season. Heavy logs (sinkers) are transported on barges with a loading capacity of 1500 m^3. Transport to Pontianak may take 10 days or even two weeks.

4. ASSESSMENT OF TIMBER HARVESTING IMPACTS

4.1 Logging damage

Even when timber harvesting is carried out in an orderly way, some environmental impacts are unavoidable. The intensity of these impacts is not only determined by the harvesting system, but also by terrain topography, soil conditions and forests structure. Large trees with extended crowns for instance tend to make larger felling gaps in the forest canopy than smaller ones. The steeper the terrain, the higher the risk of soil erosion. Soils with a high content of silt or clay are more susceptible to disturbance and compaction than sandy soils.

The harvesting impacts to be considered in this report are damage caused to the residual forest by felling and skidding operations and by road construction. This includes soil damage such as erosion, compaction and disturbance of soil structure, and damage to the forest hydrology.

Damage to the forest vegetation includes not only trees, but also damage to saplings, seedlings, plants and other plant components. A tree may be uprooted, broken or split, the crown partly destroyed, or the trunk debarked.

Felling impacts may result in felling gaps and in damage to residual trees. This is referred to as felling damage. Damage to the organs or elements of a tree is called crown, bark or root damage.

Skidding impacts may result in vegetation and soil damage. The effects are visible as skid trails and skidding gaps and the compaction and disturbance of the soil can be measured. This kind of damage is called skidding damage.

A more detailed description of logging impacts and damage characteristics is given in Appendix 3 and Hendrison (1990).

4.2 Impact of forest road construction

On basis of the survey of the road system and the mapping of branch roads in a felling compartment, the following comments can be made.

In terms of cost control and efficiency, the SBK forest road system can be regarded as well designed and well constructed. Much efforts are made to keep the roads in a in a good condition. Nevertheless, road building is on a large scale accompanied by considerable soil erosion, which finally results in siltation of rivers, and disturbance of the forest hydrology.

Levelling and stabilization of slopes are often insufficient as can be observed from the numerous erosion hazards along the

truck roads. Crossings of roads and rivers or gulleys are often provisionally bridged by piling logs in the stream and covering them with earth and gravel. This construction gives insufficient passage to water flow and often leads to stagnating water that might inundate hundreds of hectares of forest land. Many of such artificial swamps can be seen along main and branch roads. Some times, hollow trees are used as culverts but even then the flow rate is not sufficient to drain the adjacent area. The problems of siltation of rivers in the area, including the River Melawi (Fig 1), are well known and are a combined effect of road construction, gold mining and agriculture. The SBK operations are also contributing to this siltation.

Branch roads are of the same standard as main roads, except that they are not gravelled. The compaction in branch roads is considerable, while soil disturbance is severe and erosion hazards abundant. Significant damage is done to the vegetation and soil. The hydrology pattern is disturbed because of blocked water courses, improper drainage and insufficient bridging. Eroded sections where observed along cleared slopes including parts of the road body. Water courses were frequently polluted with sediments and silt, and stagnating water was frequently found along the roads.

The standard width for main roads is 12 m and for branch roads 8 m, but the clearance on each side of the road may increase the total deforested area up to 50 m or even more. The cleared sections, were all trees are felled or dozered by tractors, are needed to allow sunlight to quickly dry up the road body after rain.

Main roads are occupying approximately 5 % of the area which they give access to. In addition, branch roads are absorbing another 10 - 15% of the forest area which means that road construction alone might deforest up to 20% of the concession area. This assessment was made on basis of measurements carried out in the compartment which is presently harvested. A more intensive survey may give a lower percentage of forest clearing, but is expected to be still unacceptably high.

Slopes gradients are often exceeding the maximums specified for efficient and environmental sound road construction (see Table 2 and FAO. 1977). Even on main roads, slopes are often too steep (above 10°) to allow a maximum load on the transport vehicles. In addition, such slopes are causing erosion and, consequently, deterioration of the road body.

Table 2 Slope length and slope gradient of a branch road in a logging compartment (Petak 979)

Slope section	Slope length (m)	Slope gradient (°)	Slope orientation (N°)
1	100	9	290
2	100	14	305
3	83	13	331
4	100	8	340
5	89	8	333
6	95	16	300
7	74	11	289
8	86	14	330
9	100	8	320
10	100	13	350
11	37	7	310
12	100	11	260
13	100	10	293
14	45	8	290

4.2 Impact of skidding operations

A limited part of the skid trail system was measured and mapped. The recorded data of one trail section are listed in Table 3 to give an impression of the slope class and orientation. The projection of the trail pattern is presented in Fig 2. The following discussion is based on these observations.

Skid trails are connecting the stump area with the branch roads. There is no clear distinction between main and branch trails. Skid trails are constructed after felling by the tractor operator, assisted by the hookerman travelling with him on the skidder. This method is extremely damaging because of the manoeuvring of the tractor, which is accompanied by much deforestation, earth movement and finally soil compaction. The skidding direction is changed frequently on the way to the stump area. The operator often tries to make short cuts by travelling across the contour lines while levelling the slope with the dozer blade, thus inducing unnecessary soil disturbance.

The overview from the tractor operator's cabin to the stump area is not sufficient to find a log easily. When a log is found, it is directly connected to the winch line or is sometimes winched from the stump to the trail over a distance often not exceeding 10 m. Travelling, stopping, positioning of the log, and intermittent winching from a more stable position are common practices, which constitute an extension of skidding gaps and trail area.

Table 3 Slope length and slope gradient of a skid trail in a logging compartment

Trail section (no)	Slope length (m)	Slope gradient (°)	Slope direction (N°)
S1	23.6	15.0 (-)	17
	29.3	10.0 (-)	19
	15.8	8.0	19
	37.4	23.0	38
	12.0	12.2	46
	25.0	5.5	30
	26.2	6.6	16
S2	31.3	1.0	68
	13.2	9.5	69
	20.3	20.7	69
S3	25.2	20.0 (-)	291
	20.0	12.3 (-)	354
	29.0	9.0 (-)	17
S4	31.2	6.5	322
	17.5	12.5	323
	17.5	16.5	325
	19.3	15.0	57
	47.5	17.0	292

There are relatively few primary trails in a logging compartment. Crawlers are used to skid the logs directly to the branch road. In fact the branch road system is extended as close as possible to the stump area, so that fewer skid trails are required for extraction when compared with a system which uses wheeled skidders for log extraction. Compared with trails, branch roads are at least five times wider.

The use of wheeled skidders should be considered to reduce the length of truck roads. The terrain conditions allows wheeled skidding, if the trails are constructed along hill ridges or parallel to the contour lines. Branch roads are sometimes to steep for the loaded trucks, which then have to be pushed by the crawler tractors over a distance of a few hundred meters and, occasionally, more than one km.

4.3 Impact of felling operations

Every felled tree will cause some damage to surrounding vegetation while falling towards the forest floor. The area affected by a felled tree is called a felling gap. Within the gap, trees and poles, saplings and seedling might be damaged or might have survived the felling impact. Assessment of felling

damage refers both to the size of the felling gap and the number of damaged residual trees within the gap.

A number of observations were made in a compartment under harvesting. Felling gaps were measured and mapped and damaged trees within the gap were enumerated. The gap areas are listed in Table 4 and an example of a gap pattern is projected in Fig. 3.

Table 4 Area of felling gaps

Gap no	Gap area (m^2)	Slope gradient (°)
1	728	30
2	664	29
3	410	18
4	398	18
5	940	23

The limited number of observations does not allow statistically reliable conclusions on the median and distribution of gap areas, but the survey indicated that a substantial portion of damage could be avoided by some kind of controlled felling.

Trees are commonly felled in down hill direction instead of towards the slope. Especially in steep terrain, felling from the slope will increase the kinetic energy of a falling tree and consequently its potential to damage other trees. Moreover, a tree felled down hill may slide and may extend the gap area. These are probably some of the main causes of excessive damage that was observed in most of the felling gaps. Large openings in the forest, sometimes exceeding one ha, were found where clusters of trees had been felled and skidded away. These combined felling-skidding "gaps" were frequently observed during the surveys.

In addition to damage of residual trees, logs are also often damaged (split or cracked) as a result of improper felling. There is also usable wood left in stumps and in upper parts of topped trees. (A top section, straight and free of branches, of approximately 4.5 m length and 70 cm diameter, was found in a felling gap no 1). Sometime trees are damaged when they hit a stump or other laying tree.

The driving force behind the uncontrolled felling is the incentive system to reward production. In this respect, incentives have a damage inducing effect, because a felling crew will care only about the number of trees felled and not about damage prevention. Any obstacle that may reduce production is avoided and therefore directional felling is not applied in the current logging system. In order to perform a quick felling, trees are often cut with improper and unsafe techniques, for instance by making the felling cut to deep or by sawing an oblique back cut.

5. TRAINING AND RESEARCH

5.1 Damage-controlled timber harvesting

Timber harvesting in tropical rain forest has the simple aim of supplying raw material to the wood processing industry, which is often located in the coastal area along navigable rivers. The management of a concession is largely subjected to the needs of saw and plywood mills. Its main task is to maintain a regular flow of logs from forest to mill. There is a constant pressure on the management to achieve this goal.

Current harvesting practices are not compatible with sustainable forest management, because insufficient provisions are made to conserve the forest in such away that future harvests, or at least a second cut within the envisaged period of 35 years, are possible with little or few investments. If the present harvesting method of SBK, which is fairly into accordance with the TPTI, is maintained, the aims of sustained timber production, forest conservation and environmental protection will never be achieved. The first measures that should be taken, is the restriction of impacts resulting from road construction, and from felling and skidding. A kind of damage-controlled timber harvesting should be developed to realize sustainable forest management.

The basic idea of damage-controlled logging is to limit damage to the remaining trees and forest soil by a cautious planning and performance of harvesting operations. The remaining forest should have sufficient young trees, saplings and seedlings of valuable timber species to allow a rapid regrowth towards another harvest within 35 years. Limited human interference to stimulate the annual increment of nucleus trees is permitted, but intensive replanting with seedlings should be avoided, giving the costs and moderate success of these treatments. The ideal situation is that logged-over forest should be able to recover naturally through regeneration, and not by reparation. Therefore, damage control is the cheapest way to conserve the forest and is essentially a silvicultural tool of forest management.

Damage-controlled logging is based on planning and organization of all forest operations, and on a number of advanced harvesting techniques (see Conway, 1982; Hamilton, 1988; Hendrison, 1990). Data for planning can be obtained from the cruising or 100% inventory of harvestable and nucleus trees. That means that SBK can easily start with this harvesting system because they have a long experience with preharvesting inventories. The major condition for a change from a conventional to a sustainable system is a commitment for damage restriction to the residual forest. Forest roads and skid trails should be designed in such a

way that forest clearing is limited and the risk for erosion strongly reduced. Actual harvesting should made use of advanced methods, such as directional felling and organized skidding, in order to reduce the impact on vegetation and soil. The combination of improved planning and advanced techniques may lead to a strong reduction of the affected forest area.

Damaged-controlled logging is well compatible with operational efficiency. The costs of damaged restriction are paid off by increased efficiency of especially transport and skidding operations. The use of directional felling is essential, not only from a viewpoint of damage restriction, but also to realize efficient skidding. A possible increase of felling costs is thus largely compensated by a decrease of skidding costs.

The costs consequences and environmental benefits of damage controlled timber harvesting have been detailed for three schemes.

- Scheme A. Damage reduction by improved planning and organization. The present system of main and branch truck roads is maintained, but directional felling and controlled skidding are introduced.
- **Scheme** B. Damage reduction by improved planning and organization, directional felling and by using wheeled skidders. The branch roads are partly replaced by trails for wheeled skidders. Scheme A is extended with wheeled skidding.
- Scheme C. Damage reduction by improved planning and organization, directional felling, wheeled skidder use and log extraction by winching. Scheme B: is extended with winch extraction.

Table 4 Logging impacts and costs effects of conversion from conventional to damage - controlled timber harvesting.

Scheme A: improved planning and organization

Logging impact	Portion of affected forest area (%)		Costs effects (%) on transport skidding and felling	
	conventional	controlled	increase	decrease
main roads	5 - 8	5 - 8	-	-
branch roads	10 - 15	8 - 13	-	8
skid trails	10 - 12	7 - 10	-	5
skidding gaps	5	3	-	2
forest landing	2	1	-	-
felling gaps	15	10	10	-

Result: a reduction of the affected forest area from 47% (57%) to 34% (42%); increase of felling costs (10%); decrease of transport (8%) and skidding (7%) costs.

Scheme B: A + introduction of wheeled skidders

Logging impact	Portion of affected forest area (%)		Costs effects (%) on transport skidding and felling	
	conventional	controlled	increase	decrease
main roads	5 - 8	5 - 8	-	-
branch roads	10 - 15	4 - 6	-	15
skid trails	10 - 12	6 - 8	10	2
skidding gaps	5	3	-	2
forest landing	2	1	-	-
felling gaps	15	10	10	-

Result: a reduction of the affected forest area from 47% (57%) to 29% (36%); increase of felling costs (10%); decrease of transport (15%) and skidding (4%) costs.

Scheme C: B + winch extraction

Logging impact	Portion of affected forest area (%)		Costs effects (%) on transport skidding and felling	
	conventional	controlled	increase	decrease
main roads	5 - 8	5 - 8	-	-
branch roads	10 - 15	4 - 6	-	15
skid trails	10 - 12	6 - 8	10	-
skidding gaps	5	1	-	5
forest landing	2	1	-	-
felling gaps	15	10	10	-

Result: a reduction of the affected forest area from 47% (57%) to 27% (34%); increase of felling costs (10%); decrease of transport (15%) and skidding (5%) costs.

5.2 The research and training area

In close consultation with the management of the SBK concession, an area of 600 ha (six units of 100 ha) was selected as a site for research and training (see Fig. 4). The choice was based on the following considerations.

- The area has already been cruised and mapped. The maps of scale 1 : 1000, are giving terrain characteristics and locations of harvestable and nucleus trees.

- The area has to be harvested in 1993-1994, which gives sufficient time to make the necessary preparations for training and research.

- The six experimental units differ from each other in topography and forest composition, which gives an opportunity to compare logging impacts in different forest and terrain classes.

- The area is easily accessible from the main road for training and demonstration purposes.

A more detailed survey is required to determine weather the selected side is also suitable for long-term research of logging impacts. This research should be based on a number of permanent sampling plots (PSP's) to study long-term effects of logging impacts (see "Manual Research and Training").

5.3 Permanent Sampling Plots

For the convenience of data recording an inventory unit of 100 ha (petak) has been taken as an experimental unit. From each petak a map is available with topographic and forest data. The preharvesting inventory provides an excellent data base for research. A postharvesting inventory is needed to study the effects of timber harvesting.

In addition to the observations of the direct impact of logging, it is also necessary to study the long-term effects, such as the recovery of damaged trees and regeneration and chances in forest dynamics and soil quality. The long-term effects can best be studied in permanent sampling plots (PSP's) that occupies less than 1% of the harvested area.

There are different methods to establish PSP's (see Synnot, 1979; Jonkers, 1987). The method to be used, is based on a systematic sampling of the research area with square plots of one hectare. A detailed description of the method is given in the "Manual".

It is recommended to establish three plots of 1 ha in each petak of 100 ha. The location of the plots should be determined

into accordance with forest and terrain characteristics. For instance, plots should not be located on site where limited harvesting is expected because of adverse terrain conditions.

For more detailed observations a plot can be permanently divided into 25 subplots of 0.04 ha (20 x 20 m). During each assessment, each subplot is divided into quadrats of 10 x 10 m which are the basic areas for field records (recording units). The 100 quadrats are numbered from 00 to 99 from the plot coordinates (Synnot, 1979).

5.4 Logging experiments

There is a need for short-term research that should give immediate information on damage-restricting features of improved harvesting techniques, and on long-term research to study recovery processes of the forest after timber harvesting. The short-term research forms an integrated part of the logging experiments to be conducted in the selected site, while the long-term research forms an activity on its own that should start before the experiments, but that can be continued for several years. The experimental units are thus designed for both training and research.

The following strategies and methods should be studied in the logging experiments for the development of a damage-controlled timber harvesting system.

- **Directional felling.** Directional felling, or at least a kind of controlled felling, can contribute both to restriction of felling damage and improvement of skidding efficiency. The aim of this experiment is to examine the possibilities of introducing directional felling in SBK operations. A method will be developed to change the present felling technique so that trees can be felled into a direction in accordance with the skid trail system in order to facilitate collection of logs in the stump area.

- **Controlled skidding.** A detailed experiment of how to collect and transport logs from stump area to landing (TPn). The major aim is damage restriction which can be attained by proper planning of the skid trail system and by a more attentive method in the collection of logs. The same equipment as in conventional logging is used, but the skidding crew is expected to have an active role in damage restriction.

- **Controlled winching.** The possibilities will be investigated of winching logs from the stump area to the skid trail in order to restrict tractor movement in the stump area, and hence to minimize compaction. This experiment

would be difficult from a technical point of view given the size and weight of harvested logs.

- **Wheeled-skidder operations.** A very important experiment to replace part of the transportation of logs through branch roads, by ground skidding with wheeled tractors. This might give a substantial reduction of branch roads and, consequently, of cleared forest.

- **Log recording.** Testing a recording system for management control. The recording system envisaged, will attend all experiments to collect data both for costs and managerial control. In this way the efficiency and costs of the new or modified methods can easily be assessed and compared with the conventional method.

All experiments will have a training component. Chainsaw and tractor crews have to be trained to understand and to use the new methods. Most important is the development of a workers awareness for damage-control timber harvesting.

5.4.1 Directional Felling

Timber harvesting starts with tree felling (see FAO, 1980). This interference largely determines the conditions for sound and efficient logging. Considerable damage can be done to the forest vegetation by improper felling and, in addition, uncontrolled felling will hamper subsequent skidding. The importance of organised felling as a tool of efficient logging, is insufficiently appreciated in tropical forestry.

The basis of organized felling is directional felling. Directional felling has the aim to restrict damage to residual trees and to predetermine the lay of the felled tree on the ground in a direction convenient for skidding. The felling direction should be at an angle of 30° to 60° to the adjacent trail. This form of controlled felling serves both the objectives of efficiency and damage-control.

Operators need to be trained to carry out directional felling properly. A tree-weeks training is required to learn the basic techniques of how to determine the lay of a tree, how to make the right felling cut and back cut, how to handle trees with buttresses, and how to fell trees against their lean. After the basic training by a professional instructor, the experiment will proceed during actual harvesting so that other operators can be trained and the effects of directional felling demonstrated.

To assess the reduction in felling damage, the units which are harvested with directional felling should be compared with

units where conventional logging was carried out. For this purpose a postharvesting survey is needed of the area of felling gaps and the number of damaged trees.

More specifically, the following observations and measurements should be done in the logging experiments:

- The selected trees, which are already measured and recorded in tree location maps, should be described which regard to their felling characteristics (crown shape, lean, buttresses, occurrence of lianas, interaction with other trees,impeding underbrush, site slope).
- The felling of a number of trees should be closely observed to measure the time elements of a felling cycle (tree spotting, felling preparations, actual felling, bucking, work delays).
- After, felling the lay of the tree and the felling gap should be measured and possible wood damage assessed
- In the PSP's, the damaged trees above 20 cm dbh are counted and classified.
- In a number of subplots damage to seedlings and saplings is assessed.

5.5 Controlled skidding

Like directional felling, controlled skidding aims at increasing operational efficiency while reducing skidding damage (Froehlich et al., 1978). The starting point is again a detailed operational planning on basis of cruising data. The same procedure as in the felling experiment can be followed with regard to pre- and postharvesting observations. In addition, the following steps have to be taken to conduct skidding experiments:

- The skid trail system should be designed on basis of cruising data. Terrain conditions like slope class, hydrology, soil quality and rock formations are of importance for the location of main trail. Branch trails are connecting the main trails with the stump area in the shortest possible way.
- The main trails are opened prior to felling, in accordance with the map design.
- A number of skidding operations are closely observed by measuring and recording the time elements of a work cycle or roundtrip time (return-, collecting-, hooking, - travelling and unhooking time).
- After skidding, the actual skid trail pattern is compared with the design, in order to assess efficiency and skidding damage.
- Soil samples can be taken in the PSP's to study the long-term effects of soil disturbance and compaction.

The training component aims at teaching organized skidding to the tractor operators, for instance how to avoid extra damage during trail opening and skidding operations, how to search logs and how to extract them efficiently to the main trail.

Special attention should be paid to the introduction of wheeled skidder operations, because these machines can probably be operated effectively on distances of 2 - 4 km, on smaller trails than the branch roads for logging trucks. At least one wheeled skidder should be tested on its ability to extract logs economically. If wheeled skidders can be used in the SBK forest, this might comprise a substantial reduction of forest damage (see Table 5).

5.4.3 Controlled winching

This experiment is an extension of the experiment on controlled skidding. The possibilities will be investigated to use the winch systems of wheeled skidders and crawler tractors to extract logs from the stump area to the trails. Winching can reduce damage in the stump area, because the manoeuvring of the tractor is reduced and in principle restricted to the skid trails. This technique should be carefully examined in relation to the prevailing terrain and forest conditions, which might impede efficient winching. Other factors of importance for this technique, such as the length of timber and dimensions of the winch line, should be taken into account. The outcome of this experiment might be a limited use of the winch system for logs of average dimensions.

6 RECOMMENDATIONS

The timber harvesting operations in the SBK forest concession area at Nanga Nuak are well organized in terms of transportation efficiency. The company is able to maintain a regular log supply to its wood processing plants in Pontianak.

Operational efficiency however, doesn't automatically leads to sustainable forest management. The present logging practices are far from sound with regard to forest conservation and protection of the environment, and form a serious limitation for sustainable forest management. The residual forest is heavily affected and not able to recover sufficiently for a next timber harvest within 35 years. In this respect, the findings of this consultancy are into accordance with those of Curran's investigation on the implementation and sustainability of the TPTI (Curran and Kusneti, 1992).

Measures should be taken to change the logging system. The following recommendations are made for the NRMP to help SBK on the way to wise forest management.

A training programme in conjunction with experimental timber harvesting should start in 1993 to test improved logging methods and to develop a damage-controlled harvesting system. The logging compartments, selected for this purpose, should be laid out with a skid trail system and observation plots, before the start of the experiments.

Felling, skidding and road building regulations should be elaborated with regard to damage prevention and operational efficiency to complete the relevant stipulations in the TPTI.

The introduction of wheeled skidders should be considered to partly replace the truck transport on branch roads. The use of this machine can be tested in the logging experiments.

Immediate measures should be taken to avoid the adverse effects of road construction, such as stagnating water, pollution of water courses, erosion and excessive earth movement and disturbance.

Some postharvesting measures should be taken to eliminate or reduce the negative effects of road construction. Blocked water courses along branch roads and skid trails can be opened by removing the obstructing logs from the creeks. Potential fire hazards, formed by piled logging debris and rejected logs on landings (TPn's), should be cleared, for instance by controlled burning.

Cruising data should be used for a detailed planning of felling and skidding operations, in order to reduce forest damage and to increase logging efficiency.

A manual should be composed with detailed instructions, training and research schemes, layouts of the experimental site, and descriptions of the logging experiments, in order to support the implementation of the proposed measures.

7 FIGURES

Fig. 1 Location of the SBK forest concession in Central Kalimantan

Fig. 2 Projection of a skid trail pattern in a logging compartment

Fig. 3 Example of a felling gap pattern

Fig. 4 Map of the experimental and research site

Fig. 1 Location of the SBK forest concession in Central Kalimantan

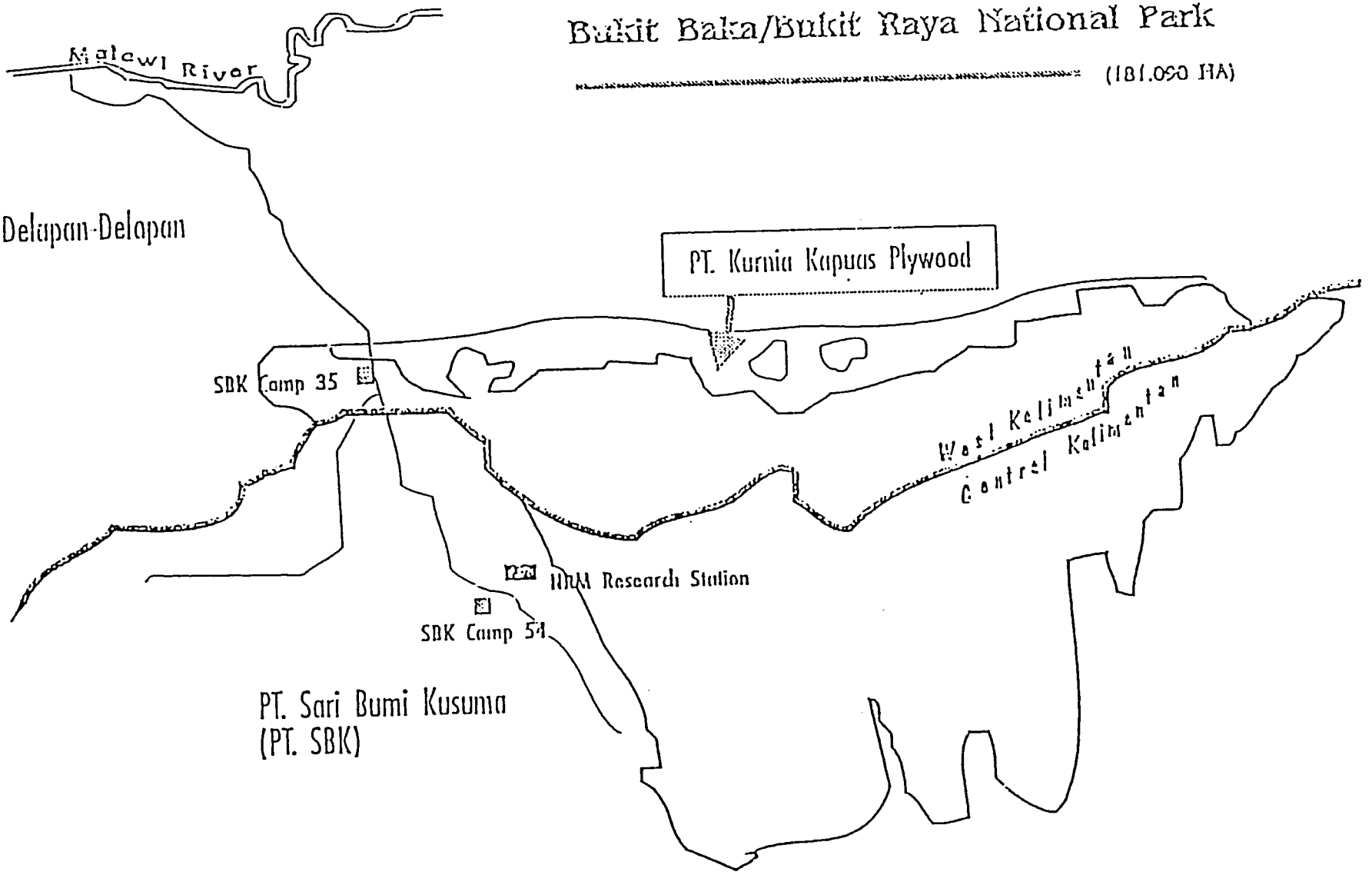


Figure 6: Station Location

Fig. 2 Projection of a skid trail pattern in a logging compartment

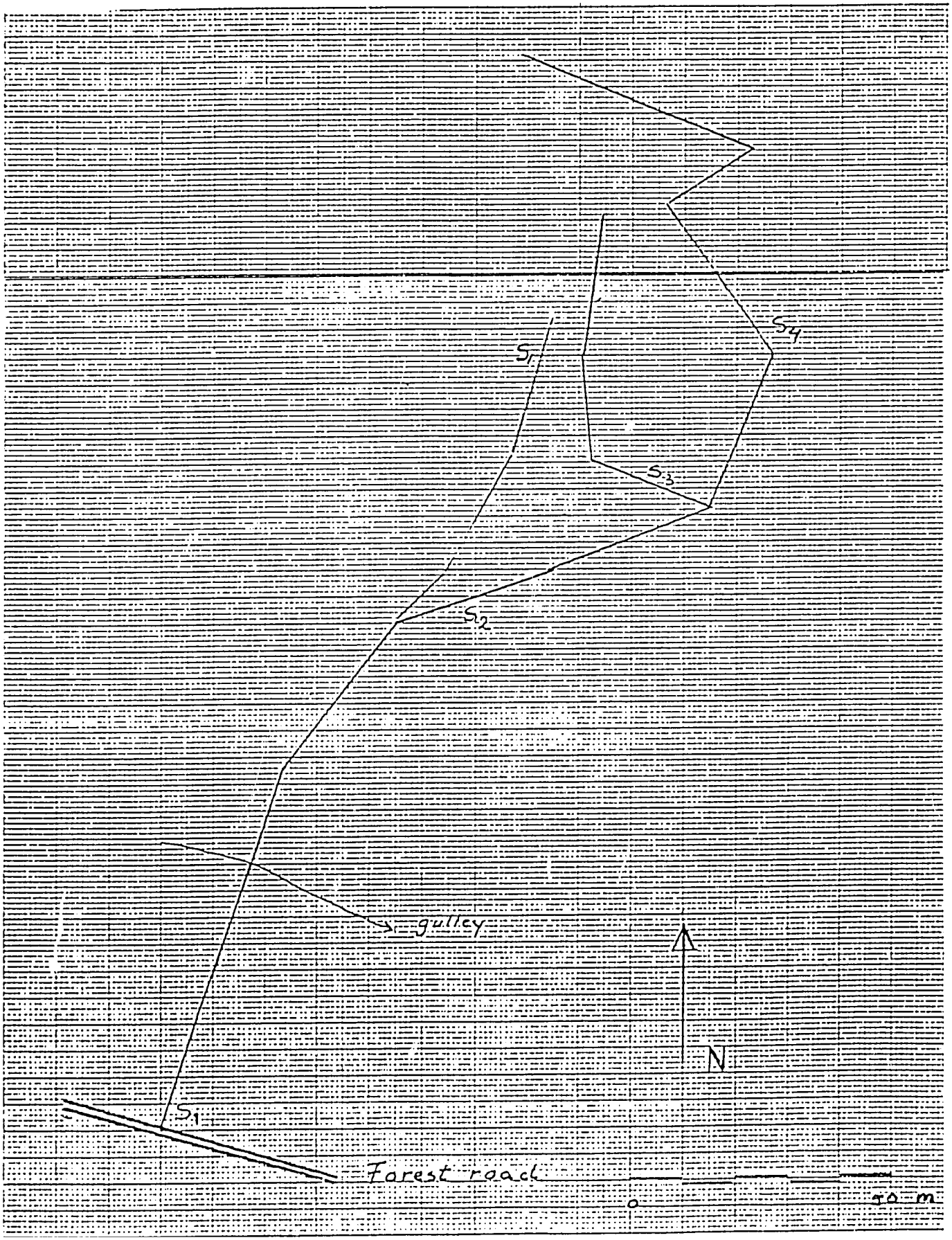


Fig. 3 Example of a felling gap pattern

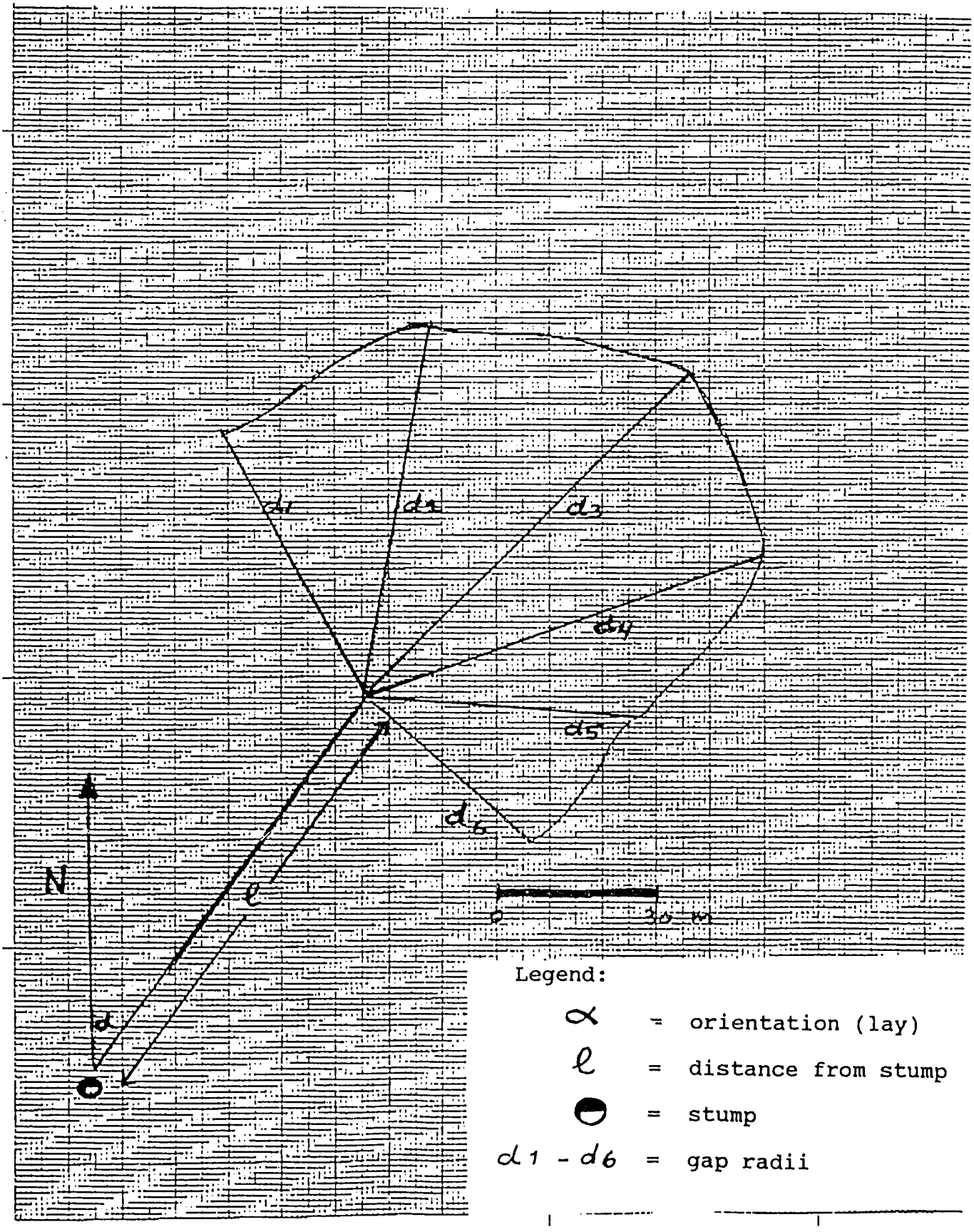
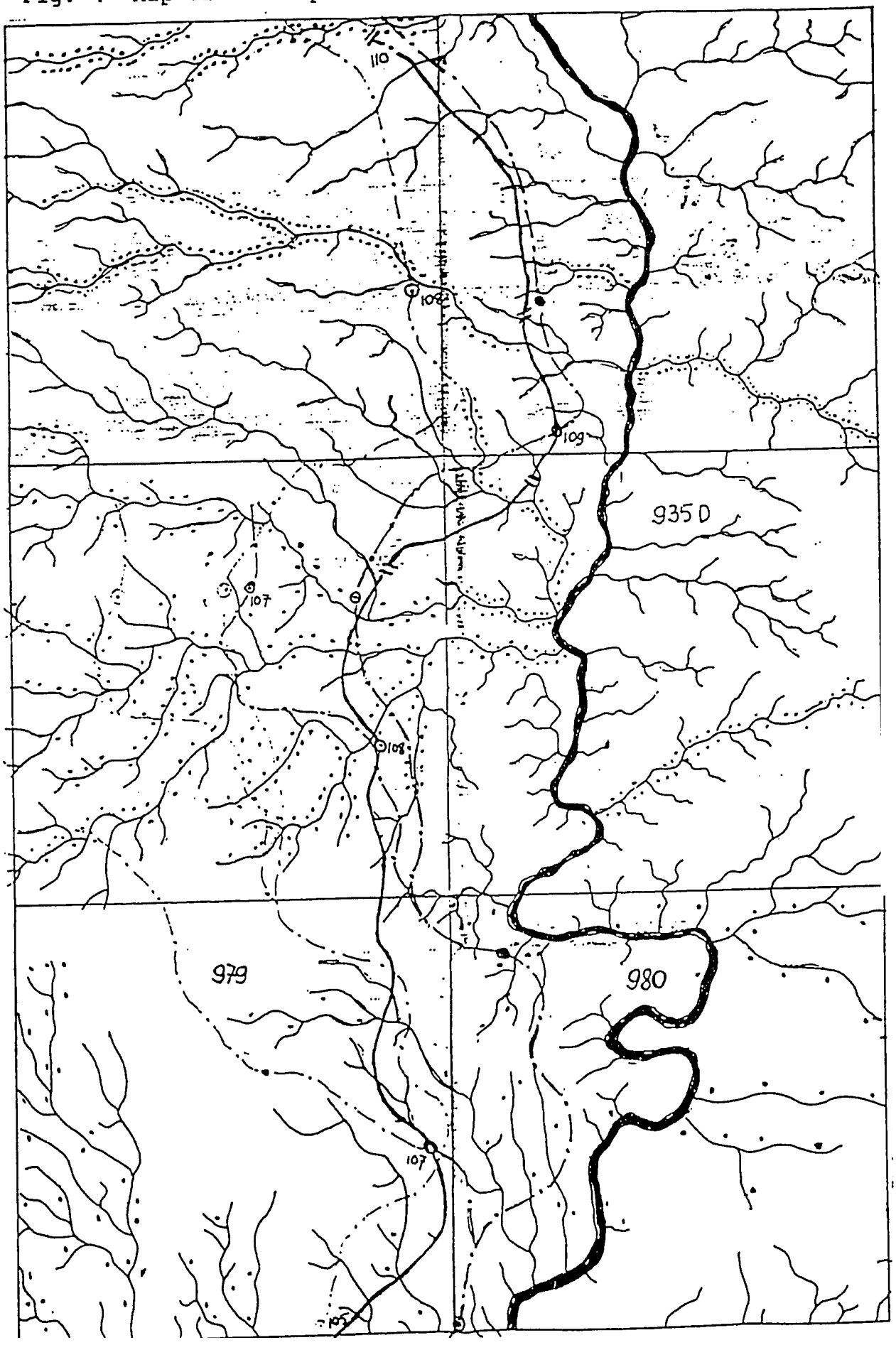


Fig. 4 Map of the experimental and research site



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9 APPENDIXES

9.1 ITINERARY

July 1 (Wednesday).

Departure from Amsterdam.

July 2 (Thursday).
- Arrival in Jakarta City

July 3 (Friday).
- Meeting at NRMP office with Dr. Colin McAndrews and other NRM staff.
- Discussing work to be done.
- Reading project documents.

July 4 (Saturday).
- Reading project documents.

July 5 (Sunday).
- Departure to Pontianak.

July 6 (Monday).
- Making arrangements for Travel Permit (Surat Jalan).
- Meeting with Ir. Mamat Mullyana and other SBK staff.
- Preparations for fieldwork.

July 7 (Tuesday).
- Meeting Mr. Izefri. to discuss field work.
- Meeting at Kantor Wilayah (KANWIL) with Ir. Suhender, Dr Colin MacAndrews and participating staff.

July 8 (Wednesday).
- Departure to Nanga Pinoh with small aircraft (9.30 h).
- Arrival at Nanga Pinoh (11.00 h).
- Leaving with the speedboat to Nanga Popai (13.00 h).
- Arrival Nanga Popai (16.00 h), meeting Mr. Elmo Drilling.
- Leaving by car to camp km 54.
- Arrival at Camp 54 (19.00 h).
- Meeting Mr. Fernando Pottes, Mrs. Nancy and Mr.Elmo Drilling

July 9 (Thursday).
- Moving to Camp 35 (8.00).
- Meeting with SBK management: Mr. Yudih (cruising) and Mr.Asbani (administration).

- Meeting with Mr. Bachtiar, director research and development.

July 10 (Friday).
- Field trip to logging area to observe logging and transport operations.

July 11 (Saturday).
- Field trip to logging area to continue observations.

July 12 (Sunday).
- Discussions with SBK management to explain planned fieldwork.

July 13 (Monday).
- Moving to Camp 35 (because of heavy rain a planned field trip to the cruising area had to be postponed).
- Visiting Bina Dessa nursery and demplot.

July 14 (Tuesday).
- Visit to the cruising area.
- Meeting the cruising team.

July 15 (Wednesday).
- Studying cruising data.
- Designing a map of the proposed experimental logging compartment.

July 16 (Thursday).
- Visit to the logging area.
- Mapping skid trails and skidding gaps.
- Studying the truck road pattern and transportation system.

July 17 (Friday).
- Visit to the logging area.
- Mapping a number of single felling gaps.
- Mapping of a large combined felling gap

July 18 (Saturday).
- Studying data of the selected experimental site.
- Designing a programme for training and demonstration.

July 19 (Sunday)
- Processing of measurements and collected data.

July 20 (Monday)
- Visit to the experimental site.
- Selecting an experimental unit for demonstration.

July 21 (Tuesday)
- Observations in the in the experimental site.
- Mapping the branch road system in an experimental unit.

July 22 (Wednesday)
- Making preparations to demonstrate logging techniques.

July 23 (Thursday)
- Instructing and discussing directional felling with the field supervisor and felling crew at the experimental site.

July 24 (Friday)
- Visit to the experimental site to demonstrate controlled skidding and winching.

July 25 (Saturday)
- Short presentation on damage-controlled logging.

July 27 (Monday)
- Departure to Pontianak

July 28 (Tuesday)
- Meeting with SBK staff in Pontianak.
- Processing logging data provided by SBK Pontianak.

July 29 (Wednesday)
- Data processing
- Discussing TPTI issues with Mrs. Lisa Curran

July 30 (Thursday)
- Presentation of report at KANWIL.
- Meeting with Dr. Thomas McKenzie and Mr. Clive Hamilton.

July 31 (Friday)
- Departure to Jakarta.
- Report writing

August 1 (Saturday)
- Discussions with Dr. Eric Scarsborough and Dr. Colin MacAndrews.
- Preparing paper for presentation.

August 3 - 5 (Monday-Wednesday)
- Data processing.
- Writing and discussing draft report.

August 6 (Thursday)
- Final Presentation.

August 13 (Thursday)
- Departure to The Netherlands.

9.2 TERMS OF REFERENCE

Terms of Reference
Forest Harvesting Specialist

1. Background

Under the USAID-supported Natural Resources Management (NRM) the project has a team of advisors assigned to work in Bukit Baka carrying out activities under the NRMP Implementation Plan. This includes a Forestry Management Advisor, a Conservation Advisor and a Social Forestry Advisor. As the project moves forward with the implementation of field activities there is an urgent need for field assistance in the area of Forest Harvesting that will include the design and carrying out of training for improving techniques of managing natural production forest.

2. Tasks

a. Design and conduct training with and for the staff of private forest concession holders in and around the Bukit Baka/Bukit Raya National Park and Ministry of Forestry Staff on the design and implementation of improved techniques of managing natural production forest (primarily Dipterocarp species) including: directional felling, environmentally sound skidding road and trail design, road construction methods, and winch skidding and timber stand improvement (TSI) techniques.

b. Identify concession land where training will take place and identify areas where a series of research sites will be located.

c. In conjunction with the staff of private forest concession holder in and around Bukit Baka/Bukit Raya National Park, Ministry of Forestry Staff and Bukit Baka Station Staff establish research sites based on outputs of demonstration areas to study the long term effects of: directional felling, environmentally sound skiing, winch skidding, road construction, and timber stand improvements (TSI) on (Dipterocarp) natural production forest as well as the implementation of the Indonesian selective cutting and planting (TPTI) system.

3. Outputs

a. Training courses designed and conducted (see 2A).

b. Report prepared on the development of improved techniques for minimizing damage to residual production forest stands (primarily Dipterocarp species) based on the use of directional felling, improved skidding road and trail design, winch skidding, road construction, and timber stand improvements (TSI).

Qualifications

The Forest Harvesting specialist must have a Master Degree in Forest Management with at least four years professional experience working or teaching forest management. Must have a demonstrated expertise in developing improved management techniques for natural forest (containing Dipterocarpaceae species). Specialist must have a strong social analysis expertise and interpersonal skills as well as the ability to work well with senior official (Government and private sector) and colleagues. Bahasa Indonesian is desirable. Advisor must be able to live and work in a remote area.

Duration: 5 weeks

Reporting

The consultant will report to the Chief of Party liaising with the NRM/ARD Forestry Management Advisor and with the Government of Indonesia counterparts in Jakarta, Pontianak and Bukit Baka as well as with PT Sari Bumi Kusuma and PT Kurnia Kapuas Plywood.

9 .3 Classification of logging impacts

The reversible and virtually irreversible impacts of timber harvesting on a forest ecosystem can be presented in an analytic model (see Table 1.1), which is based on the stress-strain concept used by Ulrich (1983) to explain effects of acid deposition on forest ecosystem stability. Stress on a system results in strain within the system. This strain may be elastic (reversible) or plastic (long lasting). Plastic strain implies that some properties of the system have changed durably, either invisibly (latent) or visibly. Visible plastic strain is usually called injury (Ulrich, 1983; also see Levitt, 1980). In this study this model is used as a reference for the terminology related to logging damage.

Timber harvesting is a collective term for the set of operations commencing by opening up the forest and ending with transporting logs from landings. Each operation may affect several components of the forest ecosystem vegetation, fauna, soil, water and air. Consequently, the type of damage is described as vegetation damage, soil erosion, soil compaction, or water pollution. A component consists of a number of subsystems, each being subjected to stress or destruction. For instance, vegetation damage includes not only trees but also damage to saplings, seedlings, palms and other plant components; the larger the plant, the more visible the damage pattern. A large tree may be uprooted, broken or split, the crown partly destroyed, or the trunk debarked. Damage refering to the organs or elements of a tree is called crown, bark or root damage.

A damaged tree crown may regain its original assimilation capacity, and is, therefore, an example of elastic strain. Small cambium wounds on the stem may recover within a few months. The slow recovery process of compacted soils can be accelerated by the activity of fauna and microorganisms. This type of strain can be considered as plastic. The following examples are also classified as plastic strain. The forest ecosystem as a whole may degrade towards a new equilibrium on a lower level, resulting in a less luxurious forest, fewer timber species and decreased nutrient stock. Uprooted trees or trees with destroyed crowns are not "reparable". Even if they survive, the same ecological function is never regained. Heavily eroded soils on hill slopes should be considered as site loss.

Not all possible stress-strain interactions are classified as plastic strain in Table 1.1. For instance, the impact of road construction on subsystems (trees and soil) has not been detailed. This is a one-off operation and the loss of a relatively small proportion of forest area is accepted as the price for opening up the forest.

The present study concentrates on soil and stand damage caused by felling and skidding operations. Effects, such as loss of nutrients and plant species, are covered in other studies (see Section 1.4).

1.3.1 Stand damage

Felling intensity. The visible damage done to the surrounding vegetation by felling even of a single tree is obvious. A large emergent tree may form a felling gap of a few hundred square metres in which small trees and numerous saplings and seedlings are destroyed. While damage in the immediate vicinity of a felled tree is

TABLE 1.1. Impacts of logging operations

Logging operations	Stress factors	(Sub)system affected	Elastic strain	Plastic strain
Felling	falling tree, lianas	forest ecosystem	species loss, structural disturbance, pests	cleared forest, large gaps
		individual trees	crown and bark damage, disease	uprooting, crown and bark injury, wood rot
		saplings, seedlings, other organisms	disturbance	destruction, injuries
Skidding, (yarding)	wheel/track action, sliding and sweeping logs	forest ecosystem	structural disturbance	cleared forest
		individual trees	bark damage	uprooting, bark injury, root injury
		saplings, seedlings, other organisms	disturbance	destruction, injuries
		soil	structural disturbance	structural degrading, erosion, compaction, nutrient loss
Log handling and storing	mechanical handling, storing period	logs		breaking, splitting, wood rot, insect attack
forest road making	machinery action	forest ecosystem		cleared forest
		soil		compaction, erosion

obvious from the ground (Fig. 1.2), aerial photographs of selectively logged forest may show such gaps as moderate interruptions to the vegetation cover (see Fig. 4.4 and Jonkers, 1987). The extent of damage is largely determined by the felling intensity, that is the number or volume of trees felled per hectare.

Every felled tree damages the surrounding vegetation to some extent. Consequently, intensive felling of large trees greatly affects forest dynamics. However, the allowable felling intensity cannot be determined without knowledge of ecological processes in both undisturbed and disturbed forest.

A gap has been described as an open space in the forest, partly occupied by the crown and trunk of a felled tree (see Section 1.2). A number of factors may influence the frequency, size and shape of felling gaps, such as forest composition, spatial distribution of trees, occurrence of vines and woody climbers, and gregariousness of desirable species. When tree crowns are linked bv lianas, a felled tree can easily damage neighbouring trees and may even uproot them. Large open spaces may appear in the forest vegetation as a result of the chain effect of falling trees (Fox, 1968; Putz, 1984).

Observation of gap formation during felling gives the impression that this is largely an uncontrollable process. Sound, mature commercial trees are generally large, and when felled, their bulky crowns usually determine the architecture of the chablis. At present no economically feasible means are available to prevent or restrict felling damage and gap formation.

Fig. 1.2 Gap formation

Increased light intensity and temperature in gaps accelerates most biological and biochemical processes (Schulz, 1960). In natural gaps (chablis) these processes are in balance with the stability of the ecosystem. Felling gaps expose part of the forest floor to the macroclimate. Disturbance of recycling processes may result in a loss of nutrients liberated through accelerated decomposition of organic matter (Poels, 1987; Schmidt, in press). Moreover, the stimulated growth of secondary species, lianas and climbers, will produce significant local changes in the forest structure. Logging intensities of 60 - 80 m^3/ha in the Dipterocarp forests of Indonesia and Malaysia have adversely affected regeneration, hydrology and environmental stability (BIOTROP, 1978). Such felling intensities will evidently deplete the production capacity of soils and trees of commercial species.

An acceptable level of timber harvesting is difficult to define (Vooren, 1987). It is easier to analyse destructive felling intensities than to determine the critical level for safe harvesting operations. A felling intensity of five to eight trees per hectare is considered to be sustainable for most types of tropical rain forests (Boerboom and Wiersum, 1983). The problem of an allowable felling intensity is also examined in the present study.

Skidding. After felling, trees have to be extracted from the stump area to a landing along a truck road for further transport. For this type of terrain transport, wheeled skidders and crawler tractors are widely used in lowland rain forest conditions. Skidding operations always affect the soil and forest vegetation. Firstly, there is the effect of the trail network which is part of the infrastructure of the logging area. The network comprises primary trails giving access to a section of the forest (logging compartment) and secondary or branch trails connecting the trees in the stump area.

The forest vegetation has to be cleared for the trail network. The amount of damage done in this operation will depend on the proposed logging intensity, and the planned organization of the harvesting work. A well designed and efficient trail system should not be regarded as stand damage but as a permanent part of the forest infrastructure to be used in future harvests. Removal of forest vegetation in the stump area, damage to bark and root systems of standing trees during log collection is largely unnecessary and should be considered to be stand damage.

1.3.2 Soil damage

The use of heavy mobile equipment in log extraction induces complex physical and mechanical processes in the forest soil. The visible effects are ruts or tracks formed by machine wheels and crawler tracks and by the transported load. The extent of the damage is not only determined by the equipment itself but also by the management system, soil characteristics and weather conditions.

Soil strength and bearing capacity for machines is determined by texture,

structure, density, moisture content, organic matter content of the soil as well as the rooting pattern of trees. Gross weight, wheel or track type as well as speed and steering characteristics of machinery are also important factors (Soane et al., 1981a; 1981b; Koolen and Kuipers, 1983; Beekman, 1987).

Soil compaction resulting from the use of heavy equipment is a serious problem. Loamy soils under wet conditions are more susceptible to compaction than sandy soils or soils of more stable structure. The top organic layer is rapidly removed by the rolling skidder wheels, and the soil under the wheels or tracks and the load is subjected to considerable physical forces. The soil moisture content and number of passes largely determine the degree of compaction (Moehring and Rawls, 1970). Primary trails designed to serve an entire logging compartment throughout the harvest are usually heavily compacted. Such trails may be exhausted rapidly, if deep tracks hamper machine movement. A second trail is then needed parallel to the first, thus extending the affected area. Deep tracks in the soft soil of creek crossings make further skidder movement impossible after only a few round trips.

The porosity and water penetration capacity of soils are considerably reduced by compaction. Root penetration is retarded thus slowing down vegetation growth. Compacted soils, therefore, regenerate slowly and the effects may persist for 40 years or more (Erdas, 1976). In hilly areas soil compaction may promote erosion as rainwater cannot penetrate the soil fast enough.

The high moisture content in the tropical soils makes soil damage a serious consideration in management systems for sustained timber production. A logical step would be to minimize skidder movements and to concentrate activities on the main trail (Froehlich et al., 1981; Queensland Department of Forestry, 1983). Planning and design of skid trail systems aimed to restrict soil damage is, therefore, included in the present study.

1.3.3 Damage to the harvested product

Poor working methods and techniques during felling and terrain transport lead to splitting and breaking of felled trees. Wood damage, involving serious loss of quality, can occur during positioning and collecting (bunching) of logs with the blade of a skidder. This is an indirect loss of forest area and thus an aspect of logging damage. In addition, logs may deteriorate during storage in the forest and at roadside or river landing. Both aspects of damage are examined in the present study.

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