A preliminary investigation into the effects of the thinning components of TPTI using the SYMFOR simulation model

Redhahari[1], D. Lewis[2]
P.D. Phillips[3] & P.R. van Gardingen[3]
2002

[1] Forest Planning Laboratory, Mulawaraman University, Samarinda Indonesia
[2] LTS International, Edinburgh, Scotland

Centre for the Study of Environmental Change and Sustainability (CECS)
The University of Edinburgh
John Muir Building
Mayfield Road
Edinburgh EH9 3JK
United Kingdom
Tel: +44 131 650 7860
Fax: +44 131 650 7863
Email: info@symfor.org
http://www.symfor.org/technical

DFID Department for International Development This document is an output from a project funded through the Forestry Research Programme of the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID. R6915 Forestry Research Programme.

Abstract

The ‘Indonesian Selective Cutting and Planting System’ (Tebang Pilih Tanam Indonesia – TPTI) is the formal silvicultural system used in the management of natural production forest in Indonesia. Within the TPTI regulation, thinning activities are implemented to accelerate the growth of individuals of commercial species by removing their competitors. According to the TPTI guidelines the objective of improving stand productivity is fulfilled by creating more growth space for potential crop trees (known as “*pohon binaan*”) available for the next cutting cycle, leading to a corresponding increase in commercial volume increment.

The limiting factor of any thinning assessment as a long term investment has been the lack of accurate predictive capacity. In the case study described here, a preliminary investigation is made into the effects of thinning on a stand according to TPTI, using SYMFOR to conduct simulations. Two scenarios are compared: a conventionally-logged stand, and a stand that is both conventionally logged and thinned according to TPTI.

This study has proved the concept of applying growth and yield models to evaluate the effects of silvicultural thinning activities on the stand and future yields. The results are in contrast to those published by Maman Sutisna (1996) and to the claims made about re-growth following thinning in the TPTI regulations, but suggest further developments of the concept of thinning that should be examined further. These relate to more detailed ecological and financial investigations into the viability of thinning as a silvicultural treatment for mixed tropical forest management strategies.

Abbreviations

Abbreviation	Definition
DBH	Diameter at Breast Height
ITCI	International Timber Corporation Indonesia
PSP	Permanent Sample Plot
SYMFOR	Silviculture and Yield Management for tropical Forests. (Growth and yield model framework)
TPTI	Tebang Pilih Tanam Indonesia (Indonesian Selective Cutting and Planting System)

Contents

1 Introduction

1.1 The Indonesian Selective Cutting and Planting System (TPTI)

The 'Indonesian Selective Cutting and Planting System' (Tebang Pilih Tanam Indonesia – TPTI) is the formal silvicultural system used in the management of natural production forest in Indonesia. The TPTI system was implemented through the Directorate General of Forest Utilisation decree number. 564 / KPTS / IV –BPHH / 1989, and subsequently modified by decree number 151 / KPTS / IV –BPHH / 1993. The system applies to all areas of natural forest being managed for sustainable production and is summarised as a technical guideline published by the Indonesian Ministry of Forestry (Departemen Kehutanan, 1993).

The TPTI system prescribes a series of activities specifying how natural production forest should be managed. These activities are to be implemented by forest managers through a system of forest utilisation concessions. The TPTI system is based on a fixed 35-year cutting cycle. The management activities during this period can be divided into three main groups: pre-harvest activities, harvesting activities, and post harvest activities, as detailed in Table 1.

	YEARS	ACTIVITY
Pre-harvest	- 3	Working area planning
	- 2	Pre-felling (stand) inventory
	- 1	Infrastructure establishment
Harvest	Harvesting	Felling of commercial species[1]
Post-Harvest	+ 1	Compartment re-establishment
	+ 2	Residual stand inventory
	+ 2	*Liberation treatment I*
	+ 2	Production of seedling
	+ 3	Enrichment planting
	+ 3, 4, 5	Maintenance / tending
	+ 4, 6	*Liberation treatment II & III*
	+ 10, 15, 20	*Thinning I, II & III*

Table 1 Schedule of activities prescribed under the Indonesian TPTI system. Years are specified relative to the year of harvest. Thinning activities are indicated in italics. The cutting cycle is fixed at 35 years.

1.2 Thinning activities specified by the TPTI system.

The TPTI system specifies that thinning activities are intended to accelerate the growth of individuals of selected commercial species by removing their competitors. The system specifies two general types of thinning activities: liberation cutting, and thinning. Both activities entail the removal of non-commercial and poor quality commercial competitors to ensure that two hundred "*pohon binaan*" (potential crop trees, made up of "*pohon inti*" – the "core" trees – and "*permudaan*" – the seedlings) are available for the next cutting cycle. The removal of the competitors may utilise either felling or poisoning activities.

Liberation treatments

The liberation treatments are carried out in years 2, 4 and 6 after harvesting and are often referred to as clearing activities. These activities include the removal of small shrubs and trees to promote regeneration of commercial species and facilitate other post-harvest treatments. In addition, larger competing trees are

[1] The selection of trees for harvesting depends on forest type. In full production forest, all commercial stems with a diameter exceeding 50 cm may be felled. This increases to 60 cm for areas of limited production forest and decreases to 40 cm for swamp (Ramin) forest.

removed to promote the regrowth of the commercial stand. The regulations specify that for the liberation treatment, trees under 7 cm diameter may be felled whilst trees between 10 – 50 cm should be poisoned. The regulations do not describe how trees with diameters between 7 and 10 cm should be treated.

Thinning treatments

Thinning treatments are meant to be applied in years 10, 15 and 20 following harvesting. (Dadang Fadilah, 2000) found that very few companies carry out these treatments, however. Thinning treatments are applied to trees with diameter greater than 10 cm and only utilise poisoning. There is no mention in the regulations of a maximum diameter for trees to be removed by thinning treatments, but field experience suggests that trees with diameter greater than 50 cm are rarely removed during thinning.

1.3 Previous thinning studies in Indonesia

There is only very limited information available describing the likely benefits of the thinning treatments specified under the TPTI system. In one study of data from the PT ITCI concession in East Kalimantan (Maman Sutisna, 1996), the silvicultural and economic benefits of thinning according to TPTI are strongly advocated, based on the assumption of an annual diameter increment of 1.5 cm $year^{-1}$ in thinned stands. This study was, however, only based on five years of data and made the assumption that growth rates would remain unaltered as the canopy closed and that there was no mortality of the tended trees. The ITCI study concluded 'that the profit of natural forest management without proper (TPTI) tending of logged-over forest brings only one tenth of that of the tended forest'.

These results must be questioned for a number of reasons. Firstly, the analysis assumes that a tended forest will yield almost 350 m^3 ha^{-1} compared to a maximum of 100 m^3 ha^{-1} from either primary forest or logged-over forest managed without thinning activities (van Gardingen *et al.*, 2003). Such high yields are highly unlikely when compared with a total stand volume of 400-450 m^3 ha^{-1} for all species in primary forest. Secondly, the study can also be questioned because the financial analysis fails to account for discounting in the cost-benefit analysis, which is known to be a significant factor in fast-developing countries (van Gardingen *et al.*, 2003).

A more recent financial analysis of thinning treatments (Dadang Fadilah, 2000) was developed for the PT Inhutani I Labanan concession in East Kalimantan and suggested that thinning was extremely difficult to justify. Dadang Fadilah reports that TPTI thinning activities would need to increase the timber yield by over 200 % in order to justify the costs associated with thinning. The major difference between this study and the previous (Maman Sutisna, 1996) was that the study of the PT Inhutani concession included the effects of discounting over the full 35 years of the cutting cycle. It was noted in the PT Inhutani study that the highest yield derived from primary forest on the Labanan concession is only one third of the total required to break-even for the forest management costs associated with thinning.

In both of these case studies accurate timber yield predictions were not available. The "STREK" project (Bertault & Kadir, 1998; Bertault, Sist & Nguyen-The, 1998) established a trial to quantify the benefits of thinning treatments in logged over forest (Sist & Abdurachman, 1998). These studies demonstrated a short-term increase in the growth rates of individual trees in the residual stand of thinned plots, but concluded that the available data were not able to support the discussion of the effects of thinning treatments on the long-term growth of the remaining trees. Further investigation into these thinning trials with additional re-measurement campaigns verified that these data cannot support the hypothesis that thinning was beneficial to the stand (van Gardingen, 1999; van Gardingen, 2000).

The lack of reliable predictions of future yield used in the analyses of thinning has led to highly significant differences between the results and recommendations of previous studies. In the absence of long-term field data to describe the effects of thinning, simulation modelling is the only valid approach to predict the likely increase in timber yield resulting from thinning activities. The current study aims to use this approach to make a comparison of timber yield with and without thinning activities.

1.4 The SYMFOR framework.

SYMFOR (Silviculture and Yield Management for tropical Forests) is a software framework for individual-based, spatially explicit models of the natural and management processes affecting trees (Phillips and van Gardingen, 2001). The framework contains data describing the diameter at breast height (1.3 m, DBH), location (*x* and *y* co-ordinates), ecological species group and commercial species group of each tree in a plot with DBH greater than a minimum (typically 10 cm). These data are modified by the models during a simulation. Ecological models of forest growth, recruitment and mortality simulate the natural processes affecting trees in the forest (Phillips & van Gardingen, 2000; van Gardingen *et al.*, 2001; Phillips & van Gardingen, 2001). Forest management models simulate the effect of forest management operations in terms of their effect on individual trees. The mortality of trees during forest management activity influences the structure and composition of the stand, which in turn changes the competition faced by remaining trees. The ecological model uses competition in calculation of the growth and ingrowth rates of trees in the residual stand, thus linking the effects of management to subsequent ecology. SYMFOR can output data describing the individual live or dead trees at any point during a simulation, which may be analysed to give information on the structure and composition of a forest stand.

The ecological model for East Kalimantan (Phillips *et al.*, 2002) was calibrated using data from the "STREK" (Bertault and Kadir, 1998) permanent sample plots (PSP) of PT Inhutani I at Labanan, East Kalimantan. This model simulates the processes of tree growth, recruitment and mortality based on the species, size and position (relative to other trees) of each individual tree in the stand, which is typically 1 ha.

SYMFOR management models simulate the effect of forest management operations in terms of their effect on individual trees. The processes of tree selection, felling, felling damage, skidder-damage, damage caused by pulling the stem into line with the skid-trail, and damage caused by creation of the skid-trail are modelled. In addition, due to the individual-based and spatial data stored in a SYMFOR simulation, it is possible to model the effects of other processes that affect trees, such as thinning operations. Stem quality is of importance to forest managers and tree fellers, but data describing it are rarely collected for permanent sample plots (PSP). When tree data are input to the simulation, or when a new tree is created by a simulation, each tree is assigned a value of stem quality from a uniform distribution between 0.0 and 1.0, and this value remains constant for the life of the tree.

1.5 Aims of the study

This study represents the first application to analyse the likely benefits of thinning treatments for Indonesian forests through the application of growth and yield modelling. The specific aims of the study were to:

- Estimate the additional harvested volume likely to result from thinning treatments as specified under the TPTI system.
- Demonstrate the application of growth and yield modelling to predict the effects of thinning on selectively logged tropical forests.
- Discuss the policy implications of these results for the application of the TPTI system in Indonesia.
- Suggest possible improvements to the TPTI system based on this analysis that might increase the benefits derived from post-harvest management (silvicultural) treatments such as thinning.

2 Methods

2.1 Simulation design

The study compared the results from simulations of two management strategies. The "conventional treatment" implemented harvesting of stems, based on the TPTI prescriptions (Departemen Kehutanan, 1993), with no silvicultural activity. This treatment was compared with a "thinning treatment", identical to the "conventional treatment" but with the addition of thinning activities as specified by the TPTI regulations. Each of these treatments were represented by a SYMFOR management model subsequently used in simulations.

Commercial species groups

The simulated treatments were applied to trees in the stand, having an effect that depended on the trees' diameter and commercial species group. The commercial species were defined through a classification originally developed by the Berau Forest Management Project based on commercial timber characteristics, as shown in Table 2.

Group	Status	Name	Typical Species or Genera
1	Major commercial	Meranti (Dipterocarps)	Most *Shorea* species
2	Major commercial	Fast growing Dipterocarps	*Dryobalanops* and *Hopea*
3	Major commercial	Slow growing Dipterocarps	*Dipterocarpus*
4	Minor commercial	Non Dipterocarps	*Madhuca*, *Palaquium* and *Agathis*
5	Minor commercial	Minor commercials	*Diospyros* and *Beilschmiedia* sp
6	Protected species	Protected	*Durio* sp and *Shorea pinanga*
7	Non-commercial	Non commercials	Wide range

Table 2 Commercial species groups used in this study. These groups were developed by the Berau Forest Management Project based on timber marketing in East Kalimantan (Rombouts, 1998).

Conventional Treatment model

The management model in SYMFOR was configured to simulate harvesting of stems with DBH exceeding 50 cm for the major commercial species (groups 1-3). In practice, field operations do not extract all trees that are above the specified diameter limit for various reasons including bad stem form, defect, or the position of the tree. For this reason, the model was configured to simulate extraction of only 70 % of the potentially harvestable stems (from primary forest) by setting a minimum stem quality of 0.3. The relevant settings for the SYMFOR simulation are shown in Table 3.

Thinning Treatment model

The thinning treatment combined conventional harvesting with a series of post-harvest thinning treatments.

For this study, a model of thinning was developed that was able to simulate the process as specified in the TPTI regulations. The model simulates a set of thinning treatments specified by the number of years following harvesting when the first thinning treatment is made, the number of thinning treatments and the number of years between each treatment. During a thinning treatment, all trees in competition with the "*pohon binaan*" (potential crop trees) are removed. The *pohon binaan* were identified as trees of any size and of the species groups to be felled, as defined in the felling model. Competitors were identified as trees of non-commercial species (excluding protected species) that had a crown edge less than 2 meters from the edge of the crown of a *pohon binaan*. The crown was defined from the DBH by the ecological model (Phillips et al., 2002).

The TPTI system specifies that a stand should be thinned six times in preparation for the second cutting cycle (3 liberation, 3 thinning). The "liberation" treatments should be applied in years 2, 4 and 6. Additional "thinning" treatments should be applied in years 10, 15 and 20. These two sequences were combined into two individual treatments for implementation by the model: liberation thinning treatments in years 2, 4 and 6 were simulated by a single thinning operation in year 2; the subsequent thinning treatments in years 10, 15, and 20 were simulated by another single thinning operation in year 12. This was designed to remove more trees earlier than would be the case by strictly applying TPTI, and could be expected to produce more growth response from thinning.

Pohon binaan were defined as trees of commercial species (groups 1-3). Competitors for the *pohon binaan* were defined as trees of non-commercial and non-protected species (groups 4, 5 and 7), with DBH values between 10 and 50 cm. Trees that met the description of a competitor were identified and thinned at appropriate times during the simulations. The simulated thinning treatments were applied through poisoning, as specified under the TPTI system, for all trees with DBH greater than 10 cm (the minimum DBH represented in the model). The success rate of each poisoning treatment was assumed to be 50 %, giving a cumulative success rate of 87 % over three treatments for each of the liberation phase and the thinning phase. These were implemented as the success rates for each of the treatments, simulated in years 2 and 12. The settings for the SYMFOR model are shown as Table 3.

Model Settings	Value	Conventional Harvesting Treatment	Thinning Treatment
Harvesting activities			
Minimum diameter for logging	50 cm	☑	☑
Minimum quality for logging	0.3	☑	☑
Commercial groups selected for logging (Table 2)	1-3	☑	☑
Cutting cycle	35 years	☑	☑
Thinning activities			
First thinning treatment (years)	2		☑
Thinning cycle (years)	10		☑
Number of thinning cycles per cutting cycle	2		☑
Species groups thinned (Table 2)	4,5,7		☑
Minimum size to be poisoned	10 cm		☑
Maximum size to be poisoned	50 cm		☑
Thinning success rate	87%		☑

Table 3 Settings for the SYMFOR management model simulations used in the thinning treatment.

2.2 Data

Data from the "STREK" (Bertault and Kadir, 1998) permanent sample plots (PSP) of PT Inhutani I at Labanan, East Kalimantan were used to initialise the simulations. These plots are now managed by the Berau Forest Management Project (BFMP) of the European Union. The STREK dataset contains information on tree diameter increment for 72 ha of lowland tropical rainforest, including five measurement campaigns over 10 years. The data originate from two adjacent regions of forest. One set of plots (24 ha, "RKL 1") comes from a forest compartment originally harvested in 1979. These plots were used in an investigation of the effects of experimental thinning treatments applied in 1992 (Bertault and Kadir, 1998). The second set of plots (48 ha, "RKL 4") was in an area of primary forest at the start of the study (1991) and subsequently logged using conventional and reduced-impact techniques in 1992. Both sets of plots were used to develop and calibrate the ecological model used for East Kalimantan in the SYMFOR framework.

Data from the first measurement of twelve 1 ha plots in RKL 4, representative of primary forest, were used to initialise simulations. The data described the size (DBH), location (*x* and *y* co-ordinates), ecological species group and commercial species group of each tree in the plot with DBH greater than 10 cm. The ecological species grouping relevant to this area (Phillips *et al*., 2001) described the characteristics of the species to be used by the ecological model. The commercial grouping (see Table 2) described the characteristics of the species to be used by the management model. The species group values were assigned to the original data using a relational database developed for permanent sample plot data management in Indonesia (Rombouts, 1997).

2.3 Simulations

The effects of each treatment were simulated within the SYMFOR framework using twenty replicate simulations over a period of 210 years for each plot. Data describing the number of stems, total basal area and volume were collated for each plot. The average of the twenty replicate simulations was calculated for each plot and these averages were used for the statistical tests of significance between treatments. Although the simulation was over a period of 210 years, results from only the first 5 harvests were considered due to the cumulative effects of systematic errors after more than 150 years (Phillips *et al*., 2002). The five simulated harvests represented the harvest of primary forest at the start of the simulation and four subsequent harvests of logged-over stands.

An advantage of using a simulation approach to alternative treatment evaluation is that same starting data can be used for both treatments. This means that the two treatments can be considered as a set of paired comparisons and the estimation of significant differences can be evaluated through a paired t-test (Sokal & Rohlf, 1981). This negates much of the variation between plots that can dominate the results of field trials.

3 Results

The predicted yield from each treatment is shown in Table 4. The predicted timber yield was significantly higher for all harvests from logged-over forest when thinning treatments were applied to the stand (harvests 2-5). The total basal area removed by each of the simulated thinning treatments is shown in Table 5. This shows that the first thinning in each cutting cycle was larger than the second. The average total basal area of living trees of competitor species (groups 4, 5 and 7) per ha over the simulated period is shown in Figure 1.

Harvest	Year	V_C (m^3 ha^{-1})	V_T (m^3 ha^{-1})	ΔV (m^3 ha^{-1})	P
1	0	108.7	108.0	0.6 ± 1.3	> 0.05
2	35	26.1	29.9	3.8 ± 1.0	< 0.01
3	70	30.4	49.9	19.5 ± 1.1	< 0.001
4	105	48.0	74.8	26.8 ± 1.8	< 0.001
5	140	37.4	65.9	28.5 ± 1.8	< 0.001

Table 4: Predicted timber yields for the conventional treatment (V_C) and the thinning treatments (V_T). The uncertainty of the difference between the means (ΔV) was calculated by adding the standard errors on the two volume values (not shown) in quadrature, since the errors on the two terms should be independent. The level of significance of the difference between the values (*P*) was calculated by a paired t-test.

Cutting cycle	Year	Basal Area Removed (m^2 ha^{-1})
1	2	3.6 ± 0.2
1	12	3.3 ± 0.1
2	37	4.7 ± 0.2
2	47	2.4 ± 0.1
3	72	2.7 ± 0.1
3	82	2.4 ± 0.1
4	107	2.6 ± 0.1
4	117	2.5 ± 0.1

Table 5 Total basal area removed by thinning treatments. Data shown are the mean and standard error from the twelve plots.

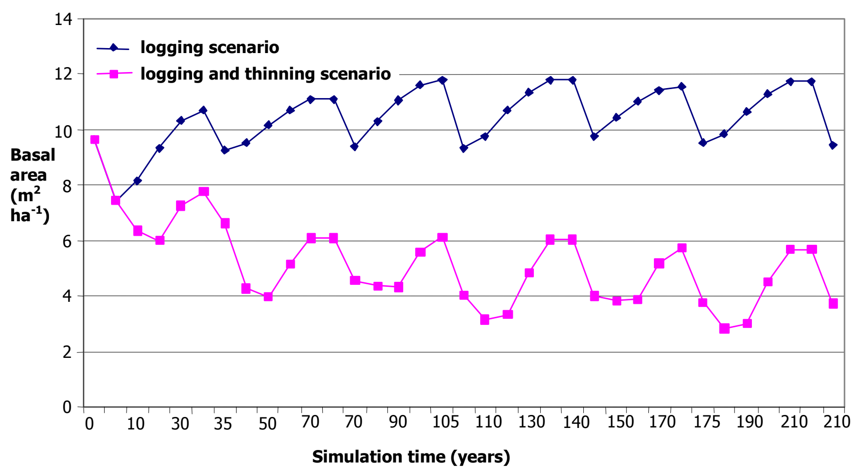

Figure 1: Mean total basal area values of competitor species for each treatment over time.

4 Discussion

4.1 An ecological explanation of the results

As the TPTI regulations do not restrict the volume or number of stems that may be removed during harvesting, the simulated harvest removed all potentially harvestable trees (i.e., those with DBH over 50 cm and stem quality over 0.3). The simulated harvest reflected the available stocking (Table 1). A large harvest from primary forest was followed by meagre returns in the second harvest under both treatments. With an initial harvest of over 100 m^3 ha^{-1}, it is not surprising that the stand cannot recover fully to achieve these harvest levels again after the 35 year cycle.

The process of thinning to increase yield is based on the idea that neighbouring trees compete for resources and that removing competitors to potential crop trees would enhance their growth. This has been observed to be the case in the simulations conducted in this study. Other studies using the same model (Phillips *et al*., 2002; van Gardingen *et al*., 2003) have shown that the damage caused by the heavy harvest of the primary forest leads to rapid ingrowth of pioneer species, which are generally not commercial or protected. It is reasonable to assume, then, that these are the primary casualties in the thinning treatment following logging. While, in the conventional treatment, pioneers best exploit the reduced competition, this is not the case when they are removed by thinning activities. Clearly this has an effect on the ecology of the forest as slow-growing species are able to grow faster in the absence of pioneers.

The primary forest contains a wide diameter-distribution of trees. This is altered by logging, such that there remain few trees above the DBH cutting limit (50 cm). In the 35 years before the next harvest, few *pohon binaan* are able to grow to above 50 cm, due to the low stocking of smaller diameter classes in primary forest. The repeated logging activity reduces competition for resources generally, leading to higher recruitment of small trees that will subsequently lead to higher stocking of the sub-50 cm DBH classes than would be observed for primary forest. Then, in a 35 year period, more trees will grow to above 50 cm and the harvest level rises. It has been observed that the smallest harvest is the second, reflecting the lower stocking in primary forest of sub-50 cm DBH classes than in logged-over forest.

4.2 Comparisons with other analyses

Despite the low volumes removed in the second cycle there is a statistically significant difference between the two treatments with more timber harvested under the thinning treatment. The additional removal of non-commercial competitors (Table 2: 3.6 m^2 ha^{-1} and 3.3 m^2 ha^{-1}) has reduced competition experienced by the *pohon binaan* that have subsequently grown faster under the thinning treatment than under the conventional treatment. This led to the slight increase in the growth of commercial species and therefore timber available in the second harvest. This does not, however, correspond to the linear recovery patterns quoted for the PT ITCI Concession (Maman Sutisna, 1994), and the second harvest yield of 29.9 m^3 ha^{-1} does not even approach the 350 m^3 ha^{-1} claimed by Maman Sutisna.

Dadang Fadilah (1999) suggested that a minimum 200 % rise in yield was necessary to make thinning activities economically viable for the PT Inhutani I Labanan Concession, due to the financial investment made to undertake thinning activities. In harvests of logged-over forest, the difference in productivity between the two treatments rose from 15 % in harvest 2 to nearly 80 % in harvest 5, but was stabilising near this value and seemed unlikely to ever reach 200 %. For a full analysis of the financial implications of thinning, a linkage between growth and yield models and financial models for forest concession operations is required (McLeish *et al*., 2002), as applied by van Gardingen *et al*. (2003) to evaluate alternative forest management strategies excluding thinning treatments.

4.3 Implications for management practice

From the results of this study that uses realistic and detailed predictions of growth following logging and thinning activities, it seems likely that the silvicultural thinning specified in TPTI regulations is not financially viable, although it does lead to some increase in yield in subsequent harvests. A full investigation, involving growth and yield modelling linked to financial modelling, should be conducted to establish more conclusive evidence for the viability of thinning as part of TPTI, and also for more general yield regulation of mixed tropical forest.

Individuals of commercial species are not currently considered as candidates for silvicultural thinning in TPTI, or in simulations in this study. These individuals may be important competitors for the high stem quality individuals, however, and including them in silvicultural thinning may result in higher yields. It should be noted that ecological issues not included in SYMFOR models may become important if all commercial species are removed either for logging or as part of thinning. Generally, it is the large trees that bear flowers and fruit, allowing the species to reproduce and continue existence. If all large trees are removed, logging of those species will last only one generation, since their recruitment will cease.

The extraction of timber from trees killed during thinning activities is not considered under TPTI. Currently the concessionaire must wait until the next cutting cycle to gain any financial return on the investment in thinning activities. Allowing such extraction would increase the returns from investment, and would do so immediately. This could be considered in a financial analysis of the effects of thinning.

4.4 Opportunities for further analysis

This analysis was intended to be preliminary; an exploration of the opportunities for using a simulation approach to evaluating silvicultural alternatives. We have identified several possible improvements and extensions to the current study that may lead to more compelling evidence of the financial and ecological non-viability of silvicultural thinning as part of a management plan in mixed tropical forest. These are identified as:

- SYMFOR could be modified to allow the simulation of all six individual thinning treatments specified by TPTI within each cutting cycle. This would negate the necessity for the simplification of six thinning treatments to two, as used in the current study.
- In this preliminary study initial extraction rates were very high concurring with traditional TPTI. It is important to investigate the effects of thinning coupled with alternative forest management practices where, for example, stems numbers per hectare are regulated, directionally felling and skid-trail planning is implemented, thinning is conducted by felling rather than poisoning, or both, and alternative thinning cycles are used.
- The yield results from SYMFOR could be linked to a financial model of forest concessions (McLeish *et al*., 2002) to examine the financial viability of thinning.
- The ecological species groups could be used in a study of the species composition changes in the forest as a result of a logging strategy, and how that differs from a strategy involving thinning. This could confirm the validity of the discussion points raised above.

5 Conclusions

Thinning by poisoning according to the TPTI has positive effects on the stand by reducing competition around potential crop trees through the removal of individuals of non-commercial species, thus enhancing the growth of commercially desirable species. The difference between management strategies with and without thinning was examined over several cutting cycles. The yields at the second harvest were significantly different from a statistical viewpoint, but only marginally beneficial from a forest manager's perspective as the increase in timber available for harvesting is small. When this minor return is compared to the investment in thinning activities and the associated discount factor which reduces the value of future returns, the financial balance of thinning is negative.

This study has proved the concept of applying growth and yield models to evaluate the effects of silvicultural thinning activities on the stand and future yields. The results are in contrast to those published by Maman Sutisna (1996) and to the claims made about re-growth following thinning in the TPTI regulations, but suggest further developments of the concept of thinning that should be examined further. These relate to more detailed ecological and financial investigations into the viability of thinning as a silvicultural treatment for mixed tropical forest management strategies.

Acknowledgements

The authors would like to acknowledge the staff of P.T. Inhutani 1, BPK Samarinda and the European Union Berau Forest Management Project for the provision of the data necessary for this work, assistance in data processing and their comments on this manuscript.

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