YIELD REGULATION OPTIONS FOR LABANAN

A financial and economic analysis of Yield Regulation options for logged over forest at PT Inhutani I, Labanan Concession.

Report by the Yield Regulation Development Group
Berau Forest Management Project, Tanjung Redeb
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EXECUTIVE SUMMARY

Many HPHs in Indonesia are currently planning to return to areas of forest which have previously been logged. For the first time they will be harvesting from an area which is not primary forest. This has two implications; for the sustainability of the forest and for the profitability of the commercial operation. Logged over forests are less rich in commercial timber than virgin areas, and are in many ways a much more delicate system. If it is truly expected that these forests will yield a third harvest in the future, it is vital that the yield from today's second harvest is regulated to a level which will allow the forest to recover.

This report explains the concept of Yield Regulation, and evaluates potential alternatives to current TPTI for logged over forest at PT Inhutani I, Labanan, East Kalimantan. The tool used to investigate the effects upon forest growth, composition, structure and yield of alternative Yield Regulation systems is a computer based forest growth model called SYMFOR (Silvicultural and Yield Management for Tropical Forests). The forest data used is that collected in the STREK plots, now managed by BFMP. All growth simulations start with data that describes the condition of the RKL I plots in 1991. These plots are located in an area which was relatively lightly logged in 1979.

Throughout the report it is assumed that (for a commercial operation interested in sustainable forest management) the aim is to maximise the secondary benefits from forested lands, subject to the achievement of a primary goal - producing a sustainable timber yield.

Sustainable Forest Management requires that yield is regulated so that the volume of timber harvested from an area does not exceed the productive and regenerative potential of that area – any system of Yield Regulation should aim to ensure this. The current TPTI system contains only very crude elements of Yield Regulation – namely a minimum felling size and a list of protected species which are not to be harvested.

Effective Yield Regulation will reduce fluctuations in timber production, with benefits for production and financial planning. It can also be used to optimise the economic benefits to be gained from the existence of forest areas. The following definitions are used

Financial benefits / costs are those which are marketed and to which a price / monetary value can readily be attached. Timber is the prime example of such a benefit. Financial benefits and costs tend to be experienced by private individuals or companies.

Economic benefits / costs are those which are generally not marketed and to which a price cannot easily be attached. These are often known as 'non-market' benefits or 'intangible' benefits. A prime example of an economic benefit of forests is biodiversity. Such benefits and costs tend to be social, ie they impact upon wider society.

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Forest resource use decision-making in Indonesia has traditionally considered only financial factors and has ignored the related economic aspects; this report presents the results of full economic analyses of current TPTI and two alternative Yield Regulation systems. The analysis of each Yield Regulation system is split into 3 elements

Timber Yield Analysis: looks primarily at gross commercial standing volume, but also at the number of stems felled and their average size
Financial Analysis: looks at the balance of production costs with income from timber sales, using the 'Minimum forest management unit size' model, developed by BFMP. The profitability of each system is analysed over a 20 year period, using alternative discount rates and log prices.
Residual Stand (Ecological and Economic) Analysis : The objective of analysing the residual stand is to determine the degree to which its structure and composition changes as a result of the harvesting interference. Both factors have a great influence upon the economic benefits which the forest can yield.

It should be noted that this analysis is based upon only one strata of forest at Labanan. It is known that the data used is not representative of the concession as a whole. This work will therefore need to be extended using data from the BFMP network of permanent inventory plots, which cover all forest strata in the concession.

The results of the case studies are summarised as follows

Case Study 1: Current TPTI

The timber yield falls from 70 m^3 in the first simulated harvest to 40 m^3 in the second, and levels out at approximately 43 m^3 thereafter, on a 35 year cycle. The TPTI system extracts on average 10 stems in each harvest, at a dbh of approximately 60 cm. This high number of stems harvested per ha has implications for future felling and skidding costs, whilst the small size of these stems will influence the price they can be sold for.

The financial analysis shows a healthy IRR of 28.4% and strongly positive NPV of $1 580 611. This means that a continuation of the current TPTI system in the logged over areas at Labanan will be financially profitable over the next 20 years. The analysis shows profitability for all discount rate and log price combinations. This is due to the high timber yield of 37.1 m^3 ha^{-1} (net).

The residual stand analysis shows an initial rise in the number of stems in the stand, from 500 at the time of the first logging to 600 before every subsequent harvest. This means that the stand contains less large trees. There is little variation in the number of stems per species group over the analysis period. The BA of the stand rises from an initial 25 m^2 ha^{-1} to a relatively constant 27 m^2 ha^{-1} over the 6 cycles. All these facts suggest that a continuation of the TPTI system will not cause a long term irreversible change in the relative structure or composition of the stand.

Case Study 2: maximum extraction 45 m^3 ha^{-1}

The timber yield shows a very sustainable level of approximately 43 m^3 per harvest over 7 cycles. The first harvest yields significantly less than the first TPTI harvest, the second harvest slightly more, with subsequent harvests giving slightly lower yield. The number of stems felled per harvest rises slowly from 5 to 7 over the 7 cycles. Their average dbh falls from approximately 80 cm to 70 cm. The 45 m^3 Yield Regulation system therefore harvests fewer stems /ha, implying lower harvest costs, whilst these stems are on average 10 cm larger dbh, which means they are likely to sell for more.

The financial analysis shows an IRR of 16.37% and an NPV of $ -591 333. This means that at current (1996) operating costs, a net yield of 23.85 m^3 ha^{-1} is not profitable. Whilst the NPV is negative, it is not irretrievably so. Analysed simply, $600 000 over 20 years equals a deficit of $30 000 per year. This loss could be overcome by improvements in efficiency; for example reducing operational costs or increasing log recovery rates.

The picture for the residual stand analysis is very similar to that shown for the TPTI system, except that the equilibrium level (of 600 stems per ha) is reached sooner. This system also shows a minimum 'immediately after logging' level of 500 stems per ha, compared with 400 for TPTI – showing that this system causes less disturbance to the residual stand as a result of logging – this is an economic benefit.

Case study 3: 40 year cycle length

There is a relatively constant timber yield of approximately 47 m^3 over 7 cutting cycles. There is a slight drop in yield from the first to the second harvest, and a very slight increase in the subsequent 3 harvests. The yield remains between 45.5 and 48 $m^3 ha^{-1}$ throughout the analysis period. The average number of stems harvested rises from 6 to almost 8 over the 7 cycles, whilst the dbh of these stems falls from 80 cm to just above 70 cm. Compared with the second case study (maximum extraction 45 $m^3 ha^1$), the 40 year cycle shows a consistently higher yield – approximately 4 m^3 in every harvest.

The financial analysis shows that on a 40 year cycle the IRR is 17.47% and the NPV is $-356 203. This shows an improvement over the previous case study – due to a higher net timber yield (25.44 $m^3 ha^{-1}$) and lower annual operating costs (the area harvested each year is smaller on a 40 year cycle). However over the 20 year analysis period the longer cycle has an NPV of $1 225 000 lower than the TPTI case study, and is still an unprofitable operation financially. But the financial loss amounts to only $ 17 500 pa, which could easily be overcome by improvements in efficiency (see Section 11).

The residual stand picture is similar to that in case study 2, and similar in its differences with case study 1. The main difference seen here is with total stand BA – it falls less during the cycle and recovers to a higher level (30 $m^2 ha^{-1}$) than is seen under either of the other systems. The average BA of the RKL 4 plots in a virgin state was 31.5 $m^2 ha^{-1}$, showing that under this system the forest comes very close to recovering a virgin BA. The implication is that this Yield Regulation system causes fewer fluctuations in the structure of the remaining stand, thus yielding economic benefits in terms of watershed protection and biodiversity.

Conclusions

In terms of purely financial, short term considerations, a continuation of the current TPTI system is the only profitable option for PT Inhutani I at Labanan. The financial analysis over a 20 year period shows this option to have a NPV of US$ 1 580 611. This compares with an NPV of $ -591 333 for the 45 $m^3 ha^{-1}$ case study and an NPV of $ - 356 203 on the 40 year cycle. However, the longer term financial viability of the TPTI system doubtful, due to a fall in timber yield in the second harvest, and fluctuating yields thereafter.

In terms of economic considerations, the 40 year cycle is the most desirable. Although none of the case studies show any significant long term negative changes in the structure or composition of the remaining stand, the 40 year cycle leaves a BA in the stand which recovers within the cycle to very closely resemble that of virgin forest. This suggests that the economic benefits which can be provided by forests (such as watershed protection, habitat provision, biodiversity) will be maximised under this system.

It is also significant that the 40 year cycle (as with the 45 m3 case study) harvests fewer stems (5-7) than are harvested under the TPTI system (9-11). These stems have a 10 cm larger dbh on average. Both these factors have implications for future harvesting/skidding costs, as well as for the prices that the logs will fetch. Neither of these factors are captured in the current financial analysis.

Improvements in efficiency are essential to ensure the long term financial sustainability of the logging operation at Labanan. Improving the log utilisation from the current rate of 0.53 to a rate of 0.75 will transform a loss making system into a profitable one.

Recommendations

It is therefore recommended that the optimal Yield Regulation system for logged over areas at Labanan is a maximum harvest of 50 $m^3 ha^{-1}$ on a 40 year cycle. Both the productive and protective functions of the forest are maximised and this system gives long term sustainability in terms of timber yield and forest integrity.

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1 AIMS OF THIS REPORT

1.1.1 The aims of this report are as follows

- To explain the concept of Yield Regulation, its objectives and tools for implementation.
- To evaluate potential alternative yield regulation systems for logged over forest in the PT Inhutani I Labanan concession, by assessing their sustainability from a financial and economic viewpoint.
- To illustrate the implementation of the concept of ‘Adaptive Management’.
- To recommend a yield regulation system for logged over forests in the Labanan concession.

2 WHAT IS YIELD REGULATION?

2.1.1 There is a range of forest management practices that can be used, in conjunction with each other, to achieve forest management objectives. Yield Regulation is one of these practices, and must be determined in the light of management objectives. It is a method of controlling the amount, type or volume of timber which can be removed from a given area of forest, over a given time period. Timber yield is controlled (regulated) through imposing upper (and lower) limits upon the volume and/or number of stems and/or basal area (BA) of timber harvested from each size class and species class (see section 4). The Yield Regulation system chosen in any particular case will depend upon the management objectives for the forest area in question.

2.1.2 A vital prerequisite for Sustainable Forest Management is that the volume of timber harvested from an area does not exceed the productive and regenerative potential of that area, within a given time period (usually the cutting cycle). Therefore, in order to achieve a sustainable timber yield (which is generally the prime objective for production forest), the yield of timber should be regulated with strict reference to the actual condition of the forest, and an informed prediction of its regenerative capacity. The matching of harvest intensity to actual forest condition is a central tenet of Adaptive Management.

2.1.3 The TPTI system currently practiced in production forests in Indonesia employs a crude method of Yield Regulation by imposing a minimum dbh for felling and stipulating a number of protected species which are not to be felled. However because the TPTI prescriptions are the same for virgin and logged over areas[1], and are related to the expected rather than the actual condition of the forest, they contain no element of adaptive management.

[1] The TPTI system gives an almost uniform prescription for all areas of forest across the whole country. There is only a slight differentiation for swamp forest.

3 WHY EMPLOY A YIELD REGULATION SYSTEM ?

3.1 PRODUCTION AND ECOLOGY

3.1.1 Yield Regulation should be used to meet forest management objectives. In production forests the primary aim should be the achievement of a sustainable timber yield. This yield should ideally be constant (fluctuating within an acceptable range) over time, and is derived from the condition and regenerative capacity of the forest. A secondary aim is that by matching the level of extraction to the forest condition, the ecological and conservative values of the forest are maximised – achieving environmental benefits within a productive system. Secondary aims can therefore be summed up by the phrase 'the maximisation of the ecological benefits of production forest'. Thirdly, an adaptive Yield Regulation system will ensure that 'forest' areas are always covered in forest, with all the resultant benefits (see section 3.3).

3.2 PRODUCTION PLANNING

3.2.1 The sustainable timber yield achieved through Yield Regulation has benefits for management and planning. Machinery and manpower requirements will be known in advance, allowing more efficient planning of harvesting and management activities. From a financial point of view, a more secure and regular timber yield facilitates improved financial planning and investment.

3.2.2 The concept of a 'Minimum Economic Harvest' has been talked about by DFID (Final Report, 1999) and the Berau Forest Management Project (BFMP). This is the minimum amount of timber (in m^3 ha^{-1}) which must be removed per unit area in order to make the logging operation economically viable. DFID (1999) suggest that it depends upon many factors, including royalties and other charges, and currently lies at around 60 m^3 ha^{-1} (gross standing volume, assuming a 50% reduction factor). BFMP defines the minimum economic harvest as " the minimum harvestable volume that needs to be present in a strata in order to have economically viable exploitation". The minimum harvestable volume is the "effective volume extracted to the collection point" (ie the volume of timber which is actually sold). BFMP go on to suggest that the minimum economic harvest is 40 m^3 ha^{-1} standing, 21.2 m3 at the collection point (using a utilisation factor of 0.53).

3.2.3 Any individual concession will be able to determine their own minimum economic harvest, dependant upon the cost and efficiency of machinery use, their log recovery rate and overall spatial and silvicultural planning.

3.3 Costs and Benefits: Financial and Economic

3.3.1 The multiple functions of tropical forests are well documented, and are discussed here only briefly in order to demonstrate the different types of benefit which flow from different forestry regimes, and the range of stake holders to which they accrue.

3.3.2 Function, benefits and beneficiaries can be classified as follows

Forest Function	Example of benefit	Stakeholder Group / Beneficiary / Scope of benefit
Ecological	Biodiversity protection Habitat conservation Soil conservation Carbon storage	Potentially global Potentially global Potentially global, nearby communities Global
Protective	Watershed protection Climate regulation Lifestyle maintenance	Regional communities Global Forest dwellers, forest edge communities
Productive	Timber NTFPs	Logging companies, local communities Potentially National Government Local communities
Recreation	Ecotourism	Local people, tourists, local income
Community / Livelihood	Agroforestry NTFPs Hunting	Local communities Local communities Local communities

Table 1: Functions and beneficiaries of forests

3.3.3 All costs and benefits arising from forests can be classified as either financial or economic (Leslie, 1987).

- **Financial benefits / costs** are those which are marketed and to which a price / monetary value can readily be attached. Timber is the prime example of such a benefit. Financial benefits and costs tend to be experienced by private individuals.

- **Economic benefits / costs** are those which are generally not marketed and to which a price cannot easily be attached. These are often known as 'non-market' benefits or 'intangible' benefits. A prime example of an economic benefit of forests is biodiversity. Such benefits and costs tend to be social, ie they impact upon wider society.

3.3.4 This difference between financial and economic aspects is important when performing cost / benefit type analyses. In a conventional financial analysis of any system only the financial costs and benefits are taken into account, with the economic ones excluded. This leads to decisions being based purely upon financial considerations.

3.3.5 A full economic analysis takes into account all of the above benefits and costs, and therefore decisions are made with input from a much wider base of information. Economic analyses are potentially very different from financial analyses. An economic analysis may, for example, sanction an activity that is wholly unprofitable from a financial standpoint.

3.3.6 The following table lists the potential financial and economic benefits and costs under two forest management scenarios. The first scenario represents TPTI as currently practiced in Indonesia; the second represents a forest management system with fewer interventions, stricter yield regulation and a greater capacity for adaptability. Comparisons within the TPTI section of the table are made with reference to virgin forest; those within the Yield Regulation section refer to the TPTI system.

	Financial		**Economic**	
	Costs	Benefits	Costs	Benefits
TPTI	-planning -harvesting -subsequent management -low yield after first cut	-large initial income	-decrease in forest integrity -loss of biodiversity -impaired watershed functions	-some form of forest cover and function is retained
Stricter and more adaptive Yield Regulation system	-increased planning and research -increased harvest cost -decreased subsequent management costs -lower initial income	-certain of achieving min economic harvest on regular basis -steadier income -demand led (provide what market wants)	-as above but to a less extreme extent	- forest form and function closer resembles that of virgin forest ie has greater biodiversity, and watershed value than above

Table 2: Financial and Economic costs and benefits of alternative management systems

3.3.7 Table 2 illustrates that there is a degree of trade-off between the financial and economic benefits of having or keeping forest areas. For example, where the financial benefits are highest, the economic ones are lowest. In a more extreme case, if financial benefits were to be maximised by felling all timber, the economic benefits of this management option would become zero (as there would be no forest left). In addition, the associated economic costs would be very high.

3.3.8 The objective of a sustainable forest management system should be to optimise financial and economic benefits. This requires managing the trade-off so that all secondary benefits are maximised subject to the achievement of a primary goal. If the objective of national forest policy in Indonesia is to maintain the remaining area of natural forest (this has been stated by the government, if not documented), then the primary goal for production forest management is sustainable timber production at a level that maintains the structure, composition, function and expanse of natural forests.

3.3.9 This report proposes a number of alternative Yield Regulation systems for logged over forest in the Labanan concession. For three of these a full financial analysis is performed (sections 8-10). The potential economic costs and benefits are also considered for each of the selected case studies. A full economic analysis within which values/prices are derived for all economic factors is not attempted. Assigning values to all economic functions is time consuming, controversial and beyond the scope of this report.

3.4 ASSUMPTIONS

3.4.1 The assumption that sustainable timber production is the primary aim in production forest guides the remainder of this report. The Yield Regulation alternatives proposed are aimed at achieving a sustainable yield which meets the minimum economic harvest criteria, whilst maximising other potential benefits in accordance with this central aim.

3.4.2 In order to plan and analyse options within any system of forest management (or Yield Regulation), certain assumptions have to be adopted. This report assumes that the following conditions prevail

- The forest area under management remains constant into the future
- There is no illegal logging, ie adequate forest protection measures are employed
- There are no fires, ie adequate fire protection measures are employed
- The forest management company holds secure, enforceable and renewable harvesting/land rights which facilitate longer term planning

4 METHODS OF YIELD REGULATION

4.1 TOOLS FOR YIELD REGULATION

4.1.1 The following parameters can be used to regulate the timber yield from a forest stand

- **maximum harvest per ha ($m^3 ha^{-1}$)**
- **maximum number of stems to be felled per ha**
- **minimum dbh harvesting limit -** this is influenced by what is available and what is demanded by the processing industry
- **selection of species for harvesting -** this is influenced by which species are considered as commercial and which are not at any point in time
- **length of felling cycle**

4.1.2 In order to achieve the management objectives for which the Yield Regulation system is being employed it is necessary to use a combination of the above parameters to meet the individual economic, ecological and technical objectives of forest management. The use of a range of tools allows the management system to be more adaptable to the observed condition of the forest.

4.1.3 Both silvicultural and harvesting systems overlap with Yield Regulation, as shown in Figure 1 below. The three systems are distinct but influence each other.

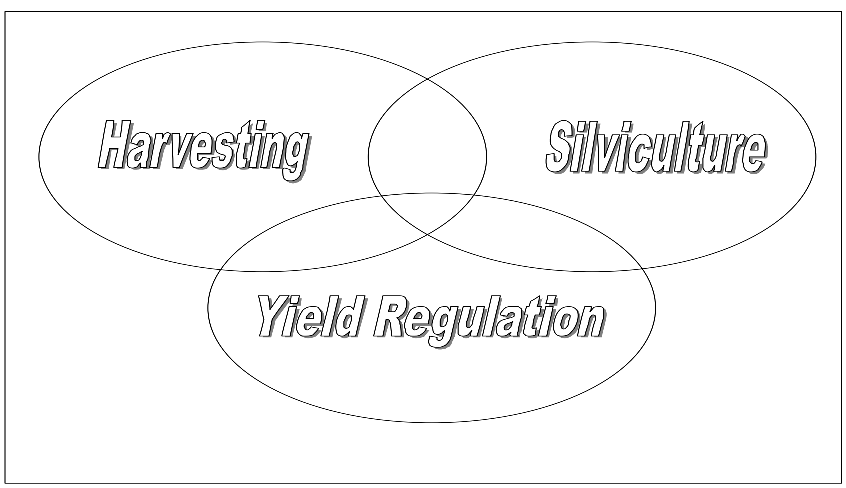

Figure 1: The overlap of harvesting, silvicultural and Yield Regulation methods in influencing the condition, growth and yield of the forest

4.1.4 The differences between the three can be defined as follows

- The yield regulation system controls how much timber is harvested
- The harvesting system dictates how this timber is felled and extracted
- The silvicultural system influences how this timber is produced (grown)

4.2 SETTING OBJECTIVES

4.2.1 A yield regulation system should be determined with reference to any of the following (or a combination of more than one)

- **Yield Flow Policy in operation –** the desired timing of product flow (in the conversion of primary to logged over forest and beyond)
- **(Sustainable) Timber yield** – the system can be designed to ensure a constant, unfluctuating timber yield each year, regardless of the effect upon the residual stand.
- **Residual stand –** the system may require that the residual stand is left with certain characteristics (eg a minimum BA) after harvesting. Timber yield is therefore dependent upon what is available subject to meeting this requirement.
- **Future forest structure –** there may be a requirement to have a forest of specified status (with regards to BA, Volume, number of stems per hectare or species composition) at some point in the future

4.2.2 Which of these options is chosen will depend upon individual management objectives, and the wider forest policy environment.

5 MODELLING FOREST GROWTH, SILVICULTURE AND YIELD

5.1 SILVICULTURE AND YIELD MANAGEMENT FOR TROPICAL FORESTS (SYMFOR)

5.1.1 SYMFOR is a computer-based model of forest growth, which has been developed for lowland dipterocarp forest in Indonesia. The model simulates tree growth according to the species, size and position of each individual tree in the stand (usually 1 ha). Ecological forest processes such as recruitment, competition and mortality are also simulated and thus the net balance between all these factors is accounted for. The model can therefore be used to give information on the structure and composition of a forest at any point in the future. In addition to simulating natural processes, management and silvicultural practices (such as harvesting) can be simulated. The removal of trees during harvesting will change the structure and composition of the forest directly, as well as through causing damage, this in turn changes the competition faced by remaining trees. All these aspects of harvesting are represented, altering the subsequent rate and style of forest growth.

5.1.2 The model has been developed using data from the STREK PSP plots of PT Inhutani I at Labanan, East Kalimantan, which are now managed by BFMP. The STREK dataset contains information on tree diameter increment for 72 ha of lowland tropical rainforest, stretching back over 5 measurement campaigns (10 years). Several of the plots have been subjected to silvicultural experiments, and the influence of these upon forest growth subsequently recorded.

5.1.3 SYMFOR requires input data on the dbh, species and position of each tree (of >10 cm dbh) in the stand. Within the model each tree is assigned to one of 10 Species Groups – all species within the same group have similar growth characteristics. BFMP have developed a set of 7 Commercial Groups – each tree is also assigned to one of these 7 groups depending on the commercial desirability of that species.

5.1.4 Forest growth is shown by changes in stem numbers, BA or volume over time. The main growth model components are diameter increment, ingrowth/recruitment and mortality. SYMFOR is a growth and yield model designed to assess and evaluate silvicultural systems ecologically and not an economic forest concession model. Combined growth and yield models, economic models and an environmental framework should be used for overall concession management planning.

5.1.5 Forest management with different silvicultural systems will have different impacts upon the current and future condition of the residual stand. SYMFOR can be used as a forest management tool to provide comparisons of silvicultural treatments by predicting forest growth and yield over the next cycle. It can also be used to look at the number of trees in any species group, and their size, to investigate how this changes as a result of any particular management system.

5.2 INPUT DATA USED

5.2.1 This report looks at yield regulation options for logged over forest at Labanan. For all the SYMFOR simulations presented in this report, the PSP data from RKL 1 was used. This area was logged (relatively lightly) in 1979. Data was first collected in 1991, before any silvicultural experiments took place. There are two important facts which should be noted here

- *All the SYMFOR runs start with PSP data collected in 1991, in logged over forest. Therefore the first harvest in the results subsequently presented is the first simulated harvest. This predicts what will be the yield in the second actual harvest of this area.*
- *Because this RKL was logged only lightly in 1979, it is likely to have a stocking of commercial timber which is higher than the average for all logged over areas at Labanan[2].*

5.2.2 In all the SYMFOR simulations performed, data from the same 20 1ha plots was used. Each plot was grown for approximately 200 years, and this was repeated 5 times. This gave 100 sets of results for each yield regulation treatment, used for subsequent statistical analysis.

5.3 ASSUMPTIONS AND LIMITATIONS

5.3.1 In all simulations, analysis and calculation of subsequent results, the following

- RIL is used, except in the TPTI case study
- Harvesting is the only silvicultural practice performed (ie no other TPTI activities - thinning, replanting etc)
- A utilisation factor of 0.53 is used to convert gross timber volume in the forest to net volume sold

[2] Comparison of the 24 RKL I plots with data from the newly established PIP network (which covers all strata within Labanan) will quantify this.

6 RESULTS OF INITIAL YIELD REGULATION SCENARIOS

6.1.1 The aims of this section are

- To demonstrate the use of the full range of Yield Regulation tools available within SYMFOR
- To demonstrate the effects upon timber yield of using these tools
- To formulate different systems which give a sustainable timber yield, before going on to examine these in detail in sections 8-10.

6.1.2 General principles of all the following simulations are

- The time period simulated is 210 years
- 30 % of eligible stems are deemed to be of non-commercial quality and are therefore not harvested
- BFMP commercial groups are used throughout
- All simulations use RIL techniques
- All simulations had a 50 cm dbh minimum felling limit

6.2 SCENARIO I : SYSTEM RIL, MAX EXTRACTION 70 M^3 HA^{-1}

6.2.1 Specific details

- 35 year felling cycle
- harvesting Commercial Groups 1-3
- Maximum harvest of 70 m^3 ha^{-1}

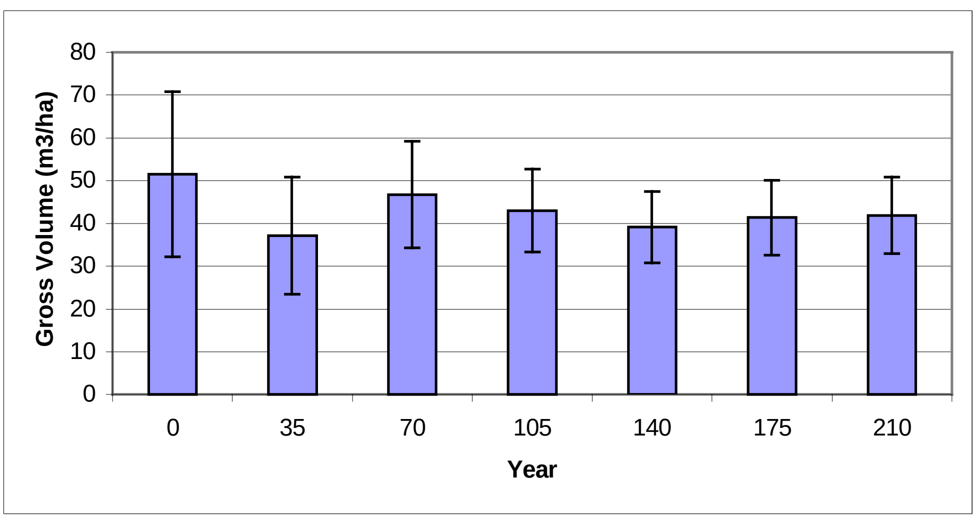

Figure 2: Gross Commercial Timber Yield using RIL, max 70 m^3 ha^{-1}

6.2.2 The above figure shows the timber yield, whilst the table below gives the details for each harvest

Harvest Number	Year	Gross Volume m^3 ha^{-1}	No of Stems ha^{-1}	dbh (cm)
1	0	52 ± 19	7.0 ± 2.2	76 ± 8
2	35	37 ± 14	6.9 ± 1.9	65 ± 5
3	70	47 ± 12	9.1 ± 2.0	65 ± 2
4	105	43 ± 10	9.0 ± 2.0	63 ± 1
5	140	40 ± 8	8.8 ± 1.9	62 ± 0
6	175	41 ± 9	9.3 ± 2.0	62 ± 1
7	210	42 ± 9	9.4 ± 1.9	62 ± 1

Table 3: Average gross timber volume harvested, number of stems and dbh using RIL max 70 m^3 ha^{-1}. Data are reported as the mean ± 1 standard error.

6.2.3 This system shows the timber yield to fluctuate between 52 and 37 m^3 ha^{-1}. Imposing a maximum harvest of 70 m^3 ha^{-1} had no effect, as the forest cannot produce a timber yield this high when only groups 1-3 are harvested.

6.3 SCENARIO II : RIL ADVANCED SYSTEM (DUAL HARVEST)

6.3.1 Specific details

- 35 year felling cycle
- harvesting groups 1-3 in the first harvest, 1-4 in harvests thereafter
- there is no upper limit placed upon the volume extractable

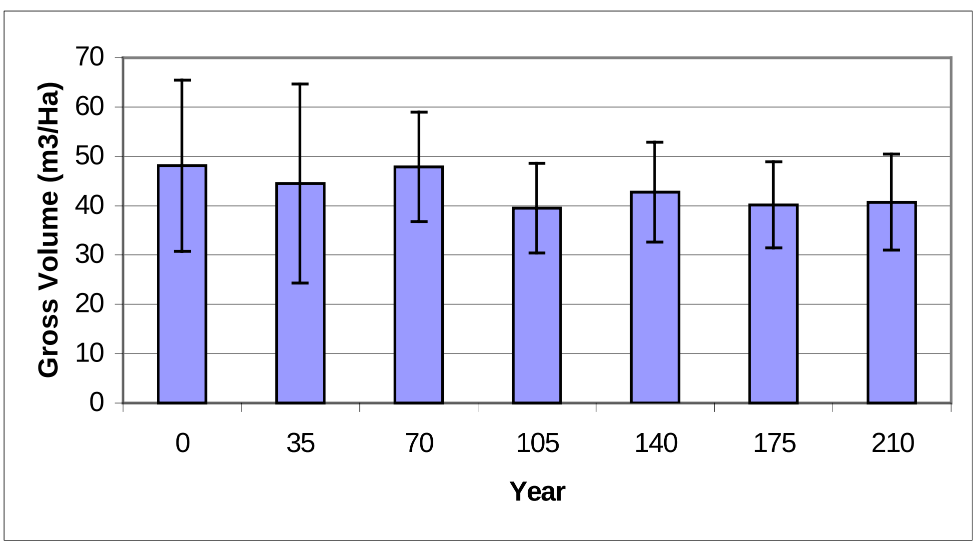

Figure 3: Gross Commercial Timber Yield under RIL Advanced system

6.3.2 The above figure shows the timber yield, whilst the table below gives the details for each harvest

Harvest Number	Year	Gross Volume $m^3\ ha^{-1}$	No of Stems ha^{-1}	dbh (cm)
1	0	48 ± 17	6.5 ± 2.0	76 ± 7
2	35	44 ± 20	8.6 ± 3.0	65 ± 3
3	70	48 ± 11	10.1 ± 2.3	63 ± 2
4	105	40 ± 9	8.9 ± 2.0	62 ± 1
5	140	43 ± 10	9.7 ± 2.3	61 ± 1
6	175	40 ± 9	9.5 ± 2.0	60 ± 1
7	210	41 ± 10	9.4 ± 2.2	61 ± 1

Table 4: Average gross timber volume harvested, number of stems and dbh using System RIL Advanced. Data are reported as the mean $\pm$ 1 standard error.

6.3.3 This system gives a less fluctuating timber yield than the previous one – with a minimum yield of 40 $m^3\ ha^{-1}$. As all other simulation settings were the same, the differences have to be due to the increased number of commercial groups harvested from the second harvest onwards.

6.4 SCENARIO III : SYSTEM RIL MAX 50 $M^3\ HA^{-1}$

6.4.1 Specific details

- 35 year felling cycle
- harvesting commercial groups 1-3 only
- Maximum harvest 50 $m^3\ ha^{-1}$

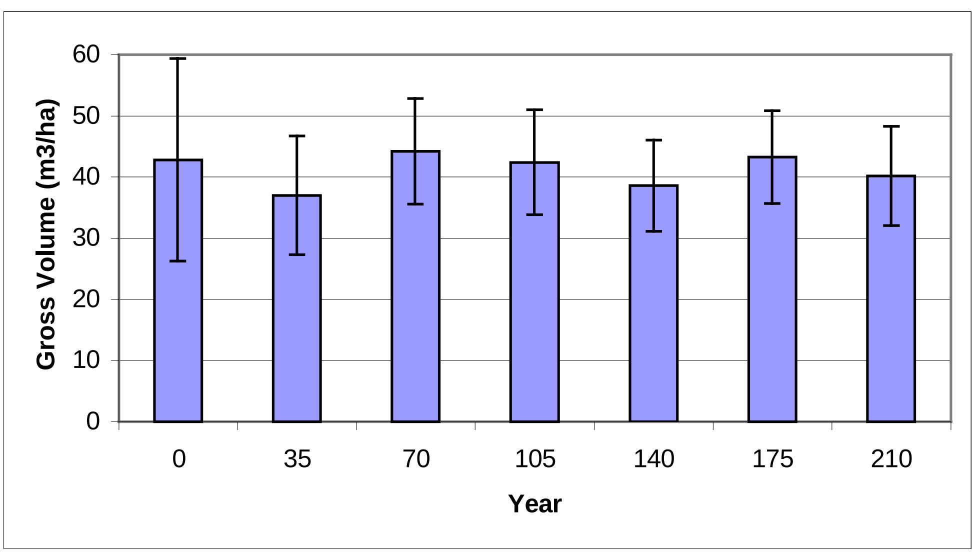

Figure 4: Gross Commercial Timber Yield under System RIL maximum 50 $m^3\ ha^{-1}$

6.4.2 The above figure shows the timber yield, whilst the table below gives the details for each harvest

Harvest Number	Year	Gross Volume m^3 ha^{-1}	No of Stems ha^{-1}	dbh (cm)
1	0	43 ± 17	5.6 ± 1.9	77 ± 9
2	35	37 ± 10	6.2 ± 1.5	70 ± 6
3	70	44 ± 9	7.8 ± 1.5	68 ± 3
4	105	42 ± 9	8.1 ± 1.3	65 ± 2
5	140	39 ± 7	7.8 ± 1.5	64 ± 2
6	175	43 ± 8	8.9 ± 1.5	64 ± 1
7	210	40 ± 8	8.2 ± 1.7	64 ± 1

Table 5: Average gross timber volume harvested, number of stems and dbh using System RIL max 50 . Data are reported as the mean ± 1 standard error.

6.4.3 As with scenario 1, the upper volume limit had no effect, as there was not enough potential in the forest to yield this maximum. This system however, gives a yield which shows no decline over time, and fluctuates less than the previous two.

6.5 SCENARIO IV : SYSTEM RIL 40 YEAR CYCLE

6.5.1 Specific details

- 40 year felling cycle
- Harvesting commercial groups 1-3
- Maximum harvest of 70 m^3 ha^{-1}

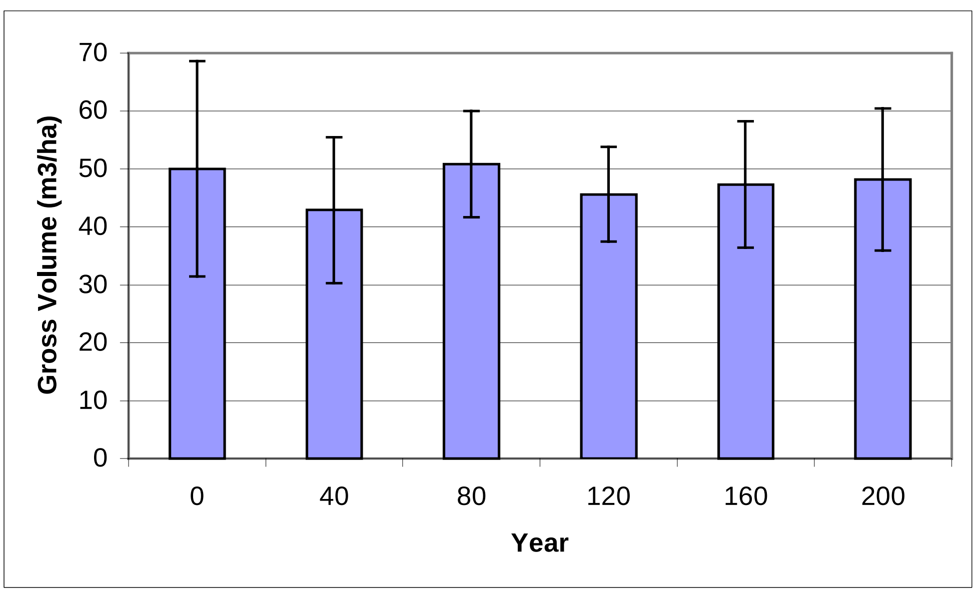

Figure 5: Gross Commercial Timber Yield on a 40 year cycle

6.5.2 The above figure shows the timber yield, whilst the table below gives the details for each harvest

Harvest Number	Year	Gross Volume $m^3\ ha^{-1}$	No of Stems ha^{-1}	dbh (cm)
1	0	50 ± 19	6.9 ± 2.0	75 ± 7
2	40	43 ± 13	7.8 ± 2.0	66 ± 3
3	80	51 ± 9	9.6 ± 1.7	66 ± 2
4	120	46 ± 8	9.2 ± 1.6	64 ± 1
5	160	47 ± 11	9.7 ± 2.3	64 ± 1
6	200	48 ± 13	10.0 ± 2.4	64 ± 1

Table 6: Average gross timber volume harvested, number of stems and dbh under 40 year cycle. Data are reported as the mean ± 1 standard error.

6.5.3 The 40 year cycle gives a higher yield than the previous scenarios in every harvest. Again the upper limit placed upon volume harvested is ineffective, as the forest does not contain this much commercial timber. This is a weakness in the design of the analysis procedure.

6.6 SCENARIO V : SYSTEM RIL 45 YEAR CYCLE

6.6.1 Specific details

- 45 year felling cycle
- harvesting commercial groups 1-3
- maximum harvest of 70 .

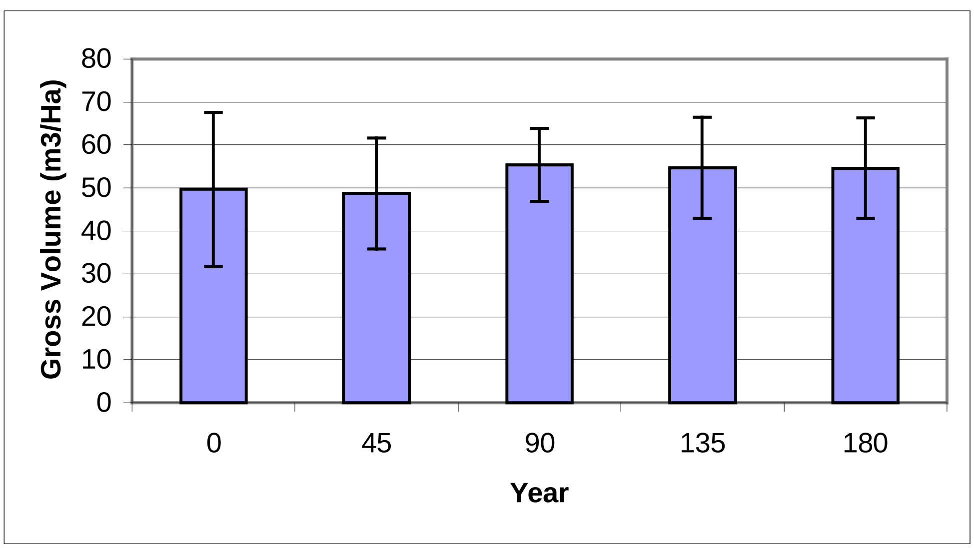

Figure 6 : Gross Commercial Timber Yield on a 45 year cycle

6.6.2 The above figure shows the timber yield, whilst the table below gives the details for each harvest

Harvest Number	Year	Gross Volume m^3 ha^{-1}	No of Stems ha^{-1}	dbh (cm)
1	0	50 ± 18	7.2 ± 2.1	73 ± 6
2	45	49 ± 13	8.5 ± 2.0	67 ± 3
3	90	55 ± 8	9.9 ± 1.6	68 ± 2
4	135	55 ± 12	10.3 ± 2.2	66 ± 2
5	180	55 ± 12	10.4 ± 2.3	66 ± 2

Table 7 : Average gross timber volume harvested, number of stems and dbh on a 45 year cycle. Data are reported as the mean ± 1 standard error.

6.6.3 The 45 year cycle gives a consistently higher timber yield than any of the proceeding scenarios. It is also the only system which shows the yield to reach a relatively constant level which is above that of the first harvest. Waiting an extra 10 years between harvests appears to yield approximately an additional 10 m^3 ha^{-1} per harvest.

6.7 SCENARIO VI : SYSTEM RIL 30 YEAR CYCLE

6.7.1 Specific details

- 30 year felling cycle
- harvesting commercial groups 1-3
- maximum harvest of 70m^3 ha^{-1} .

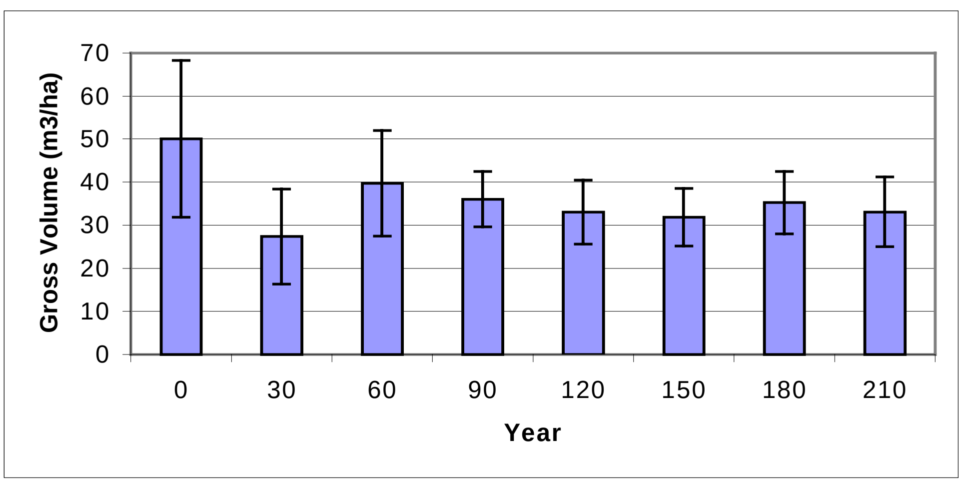

Figure 7: Gross Commercial Timber Yield on a 30 year cycle

6.7.2 The above figure shows the timber yield, whilst the table below gives the details for each harvest

Harvest Number	Year	Gross Volume $m^3\ ha^{-1}$	No of Stems ha^{-1}	dbh (cm)
1	0	51 ± 18	7.1 ± 2.0	75 ± 7
2	30	30 ± 13	5.8 ± 1.5	64 ± 4
3	60	41 ± 11	8.6 ± 2.0	62 ± 2
4	90	35 ± 8	8.1 ± 1.8	61 ± 1
5	120	33 ± 7	7.8 ± 1.6	60 ± 1
6	150	33 ± 7	7.8 ± 1.8	60 ± 1
7	180	35 ± 9	8.4 ± 2.1	60 ± 1

Table 8 : Average gross timber volume harvested, number of stems dbh on a 30 year cycle. Data are reported as the mean ± 1 standard error.

6.7.3 The 30 year cycle shows significantly lower yields than the other scenarios, after the initial harvest. The yield appears to reach a stable level of approximately 32 $m^3\ ha^{-1}$ from 120 years onwards. This and the previous two scenarios demonstrate clearly the increased yield offered under longer felling cycles.

6.8 SELECTION OF DETAILED CASE STUDIES

6.8.1 The above scenarios show the results of using the different yield regulation tools within SYMFOR. The following lessons were learned from this exercise

- The RKL I forest cannot produce a yield of 70 $m^3\ ha^{-1}$, therefore imposing a maximum yield of 70 $m^3\ ha^{-1}$ was ineffective. The highest yield seen in the first harvest of any of the above scenarios is approximately 50 $m^3\ ha^{-1}$, therefore the yield is limited to this level and below in the following case studies.
- A longer felling cycle gives a greater yield
- Increasing the number of commercial groups that are to be harvested in the second and subsequent harvests is an effective way of sustaining the timber yield. This is also a realistic practice as species currently regarded as marginal are likely to become more commercially desirable in the future. The commercial groups to be harvested were therefore increased in the following case studies[3]
- Imposing a maximum number of stems that can be harvested per ha (not used above) would be a 'safety net' method of limiting the yield when the maximum volume constraint was not reached. The 'maximum number of

[3] A further reason for doing this was to make the work more complimentary to parallel work being carried out using YSS. This work harvested commercial groups 1-5 in all harvests.

stems' limit is also useful in controlling damage to the residual stand and is therefore used in sections 9 and 10 below.

- In all the above scenarios the first simulated harvest is performed in year 0 of the simulation. Since the input data was collected in 1991 the first simulated harvest actually depicts what yield would have been available in 1991 (22 years after the actual RKL I harvest took place). This is effectively useless information – we need to know what is the likely yield today (year 2000). For this reason, the following case study simulations grow the forest for 9 years before performing the first harvest. We can therefore predict the yield potential of RKL I today in the year 2000[4].

6.8.2 The following case studies were derived from the scenarios and lessons learned above. Scenarios II and I both give relatively stable timber yields and so were merged to become the 'Maximum Extraction 45 m^3 ha^{-1} ' case study (section 9). This demonstrates the effect of limiting the yield and increasing the number of commercial groups available for harvest.

6.8.3 Scenario IV gives a relatively sustainable yield on a 40 year cycle. It is desirable to demonstrate the effect of increasing the felling cycle and therefore this (with modifications) becomes the '40 year cycle length' case study (section 10)[5].

6.8.4 The TPTI case study (section 8) depicts a continuation of the status quo. It is necessary as a yardstick against which to compare the Yield Regulation alternatives proposed.

[4] If the 'first harvest' yields in the 6 scenarios are compared with the 'first harvest' yield in the TPTI case study (Section 8), the latter is seen to be higher. This is partially because commercial groups 1-4 are harvested, but also because this harvest effectively takes place 9 years later (ie in the year 2000 rather than in 1991).

[5] Scenario V shows a sustainable (and increasing) yield on a 45 year cycle, but was not selected for further analysis as a 5 year extension of the TPTI cycle is regarded as more realistically achievable in the current climate, despite the benefits of the 45 year cycle.

7 APPROACH TO ANALYSIS

7.1.1 The aims of this report have already been stated in section 1: To evaluate potential alternative yield regulation systems for the PT Inhutani I Labanan concession by assessing their sustainability from a financial, ecological and economic viewpoint. The approach taken towards each of these analyses is detailed below.

7.1.2 The objective throughout is to find a system which gives a stable timber yield from logged over forest, asses the financial viability of this level of production, and to observe changes in the residual forest stand to determine overall ecological sustainability and the resultant economic costs and benefits. The final analysis brings all these elements together.

7.2 TIMBER YIELD ANALYSIS

7.2.1 The aim is to maximise production at a harvest level, which can be sustained over the analysis period. Whilst the gross commercial standing volume is the most important factor, the number of stems felled and their average size have important ecological and financial implications.

7.3 FINANCIAL ANALYSIS

7.3.1 Realistically, as can be seen from section 6, Yield Regulation results in yield limitation (during the first harvest at least). In primary forest yield has often been unofficially 'regulated' through the practice of 'High Grading', which has not adversely affected profit levels due to the richness of the virgin stand. In secondary forest the available commercial yield is lower in any case, and this report shows that it must be further regulated (limited) to achieve long term sustainability aims. The financial analyses undertaken determine whether or not the regulated yield will allow the concession to continue to operate profitably. The procedure is a simple comparison of income from timber sales with expenditure incurred, discounted at a rate of 20% and 16%.

7.3.2 BFMP has developed a spreadsheet model (**Model for Minimum Forest Management Unit** size) which balances concession productivity with related costs, and discounts all income and expenditures over a 20 year period (the length of time which harvesting rights are usually granted for, ie the investment period), to calculate a Net Present Value (NPV). An operation is profit-making if the NPV is greater than zero. The min-FMU model also calculates the Financial

Internal Rate of Return (IRR) of the concession, which allows a comparison of the profitability of alternative concession management systems.

7.3.3 The min-FMU model operates on a 20 year timescale. This means that the financial benefits gained from regulating the yield (ie steady and arguably higher second cycle yield than in the no regulation scenario) are not represented in an analysis using this model. There appears to be a mismatch between the SYMFOR modelling covering 200+ years and the financial analysis, which considers only 20 years. This is explained in three ways

- at any significant discount rate, income flows occurring beyond a certain number of years in the future are rendered insignificant by discounting. For example, the PV (year 2000 value) of $1 in the year 2020 discounted at 20% is $0.02. Because the immediate income flows carry the greatest weight, extending the analysis to greater than 20 years would have an insignificant impact upon the result.
- This problem inherent in financial analysis and discounting is what necessitates an ecological analysis of the residual stand, from which economic conclusions can be drawn. The financial aspects of a Yield Regulation system cannot be represented beyond 20 years into the future, but the structure of the forest can be predicted using SYMFOR, from which economic costs and benefits can be derived. Essentially, the economic analysis replaces the financial analysis beyond 20 years.
- Yield Regulation is part of a system of Adaptive Management. This requires that future harvest levels are explicitly linked to the observed state of the forest at the time of harvest. Thus we cannot be certain of the timber yield in future harvests, so are not certain of income and costs. This argument could also be applied to the ecological and economic analyses, but carries less weight as future harvest levels should be dictated by what the stand can support, rather than achieving a set yield no matter what the impact upon the forest.

7.3.4 In order to represent the Yield Regulation, forest management and harvesting methods (RIL) which are being modeled in SYMFOR, the min-FMU model requires the following input data

- **Concession size**
- **Current year, the first year of harvesting and the cycle length** (this determines if the timber harvested is coming from virgin or logged over forest in any given year)
- **Net timber yield per Ha from virgin and logged over areas**. This information comes directly from SYMFOR and depends upon the Yield Regulation system being investigated. The gross to net utilisation factor used is 0.53 (Kuru, 1999).
- **Current log price**
- **Exchange rate**
- **Discount rate**

- **Management costs**. The total of all management costs can be inflated or reduced to represent the management system in place. Alternatively the costs of individual activities can be altered one by one. For example, in the SYMFOR simulations no silvicultural activities (eg liberation, thinning) were performed. Their cost in the financial analysis model must therefore be adjusted to zero.

7.3.5 For the analysis of all three alternatives (see sections 8, 9 and 10), the following figures have been used. All prices used are 1996 prices. Government levies and fees are also at 1996 levels.

Factor	**Figure**	**Note**
Concession size	53 000 ha	total of the 7 current RKL s (productive area)
Current year	2000	
First year of logging	1965	makes year 2000 the first harvest on L/O area
Cycle length	35 years	(except in 40 year case study)
Net timber yield	-	depends upon Yield Regulation system
Log Price (US $/m^3)	90 and 100	logs assumed to be sold on international market
Exchange Rate $1 =	Rp 2350	1996 exchange rate used – see appendix I
Discount Rate	16 % and 20%	Current rate on a deposit account in Indonesia is 16%. The higher figure of 20% reflects the increased risks inherent in forestry.
Management Costs		See appendix I

Table 9: Figures used in Financial Analysis

7.3.6 The primary measure of financial profitability reported is the NPV. The IRR is also reported for each Yield Regulation scenario. As this is a study of the profitability of Yield Regulation alternatives, rather than the distribution of costs, no further financial aspects are reported.

7.4 RESIDUAL STAND (ECOLOGICAL AND ECONOMIC) ANALYSIS

7.4.1 The objective of analysing the residual stand is to determine the degree to which its structure and composition changes as a result of the harvesting interference. Because the analysis starts with a forest stand which has already been logged over, we do not expect to see as significant a change in the post-logging stand as that which is observed when comparing a virgin forest with a newly logged over forest.

7.4.2 **Structure** is defined with regard to the physical properties of the stand. It can be measured by volume or Basal Area (BA) per ha.

Composition describes the relative presence of individual species (groups) in the stand. This can be measured by the number of stems, the volume or the BA of that species (group). For a more detailed analysis this should ideally be broken down by size class. However, this is not possible with the data analysis tools used in producing this report.

7.4.3 A secondary objective is to observe the pattern of change in structure and composition. Does it continue to change throughout the analysis period, or does the structure and composition reach a new equilibrium level? Any new equilibrium may be linked to a sustainable timber harvest.

7.4.4 Table 10 shows the elements of the residual stand which are analysed in sections 8-10. All analysis uses the seven BFMP Commercial Groups. A more in-depth ecological analysis should use the ten SYMFOR Species Groups. Time constraints prevented this for the present analysis.

Factor of residual stand analysed	**Relates to ..**	**Information sought and links to Economic Analysis**
Total number of stems in stand	structure	Larger number of stems means smaller average size, implications for NTFPs, habitat, biodiversity (example - Koompasia)
Total number of stems broken down by commercial group	composition	Changes in biodiversity, NTFP availability, option value
Total BA	structure	Changes in BA over time Information on physical functions of forest Ability of forest to perform watershed functions Habitat provision
BA broken down by commercial group	composition	Rate and pattern of change in composition, is an equilibrium reached? biodiversity

Table 10: Linkage of Ecological and Economic analysis

7.4.5 The total volume of timber left in the residual stand is not analysed here, as it is calculated directly from the BA using species-specific volume equations. Its analysis would therefore give little additional information.

7.4.6 A full economic analysis requires that the ecological benefits (and costs) of any system are accounted for. Ecological functions should as far as possible be given a parallel in economic magnitudes – this requires counting ecological functions as economic functions. Table 10 (above) shows how this has been attempted in the analysis.

7.4.7 The quantification of economic benefits and costs in exact financial terms (ie giving them a price) is laborious and controversial, and is beyond the scope of this report. Stating that such benefits and costs exist, and comparing their likely magnitude relative to other case studies is the limit of the following analysis.

8 CASE STUDY 1: CURRENT TPTI

8.1 YIELD REGULATION USED

- 35 year cutting cycle using conventional logging techniques
- 50cm dbh minimum cutting limit
- the first cycle harvests commercial groups 1-4, subsequent cycles harvest groups 1-5
- there is no imposed maximum to the number of stems or the volume that can be harvested per ha
- the first logging is performed in year 9 of the simulation (input data collected in 1991, forest grown for 9 years to give present yield in the year 2000)[6]
- 30% of eligible stems are deemed to be of non-commercial quality and are therefore not harvested

8.2 TIMBER YIELD PROFILE

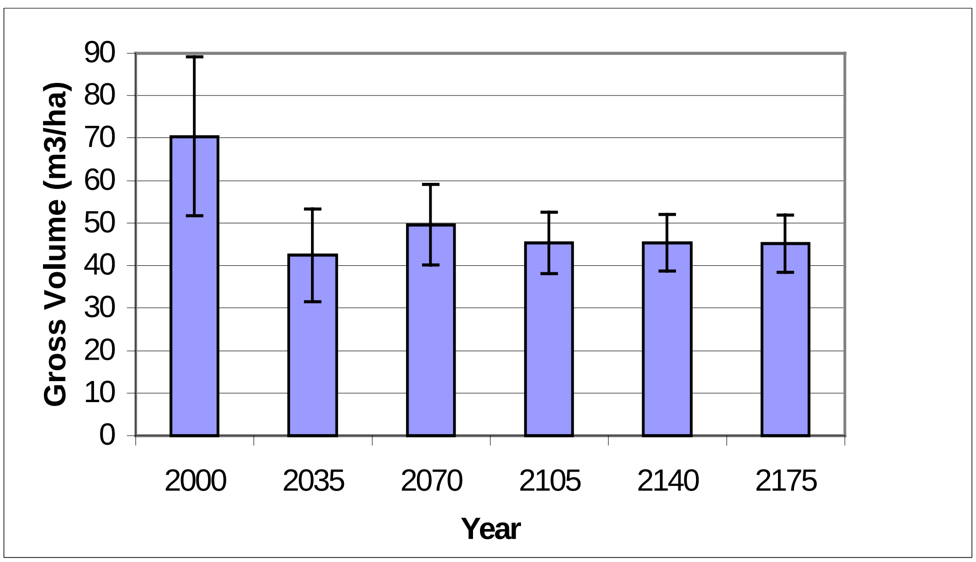

Figure 8: Gross Timber Yield under TPTI system

[6] This case study therefore predicts the commercial timber yield if this area was logged today. The area was logged for the first time in 1979 and according to current planning is not due for a second logging until 2014.

8.2.1 Figure 8 shows a high first harvest of 70 m^3 ha^{-1}, which falls sharply in the second harvest and then balances out at around 45 m^3 ha^{-1} from the fourth harvest onward. After the initial fluctuations which take approximately 70 years to settle, a relatively sustainable yield is achieved.

8.2.2 The number of stems harvested and their average diameter (Table 11) are two factors worth looking at in addition to the total yield. The TPTI system extracts on average 10 stems in each harvest, and these are mostly at a dbh of approximately 60 cm. This high number of stems harvested per ha has implications for future felling and skidding costs, whilst the small size of these stems will influence the price they can be sold for.

Harvest Number	Year	Gross Volume m^3 ha^{-1}	No of Stems ha^{-1}	dbh (cm)
1	2000	70 ± 19	11.1 ± 2.7	71 ± 4
2	2035	42 ± 11	9.4 ± 2.3	61 ± 1
3	2070	50 ± 10	10.6 ± 2.1	63 ± 1
4	2105	45 ± 7	10.4 ± 1.5	61 ± 1
5	2140	45 ± 7	10.4 ± 1.5	61 ± 1
6	2175	45 ± 7	10.3 ± 1.5	61 ± 1

Table 11 : Average timber volume, number of stems and diameter under TPTI system. Data are reported as the mean ± 1 standard error.

8.3 FINANCIAL ANALYSIS

	Discount Rate 16%		Discount Rate 20%	
	Log Price $90	*Log Price $100*	*Log Price $90*	*Log Price $100*
IRR	**22.39%**	**28.4%**	**22.39%**	**28.4 %**
NPV	**$1 623 459**	**$3 214 829**	**$445 349**	**$ 1 580 611**

Net timber Yield (year 2000) = 37.1 m^3	Gross yield in year 2000 harvest (70 m^3) * 0.53 = net

Table 12: IRR and NPV figures for four discount rate and log price combinations. Column 5 (shaded) is taken as the most realistic.

8.3.1 The above table shows a healthy IRR of 28.4% and strongly positive NPV of $1 580 611 in the shaded area. This means that a continuation of the current TPTI system in the logged over areas at Labanan will be financially profitable over the next 20 years. The analysis shows profitability for all combinations – even at a high discount rate and low log price. This is due to the high timber yield of 37.1 m^3 ha^{-1} (net)

8.4 RESIDUAL STAND (ECOLOGICAL AND ECOMOMIC) ANALYSIS

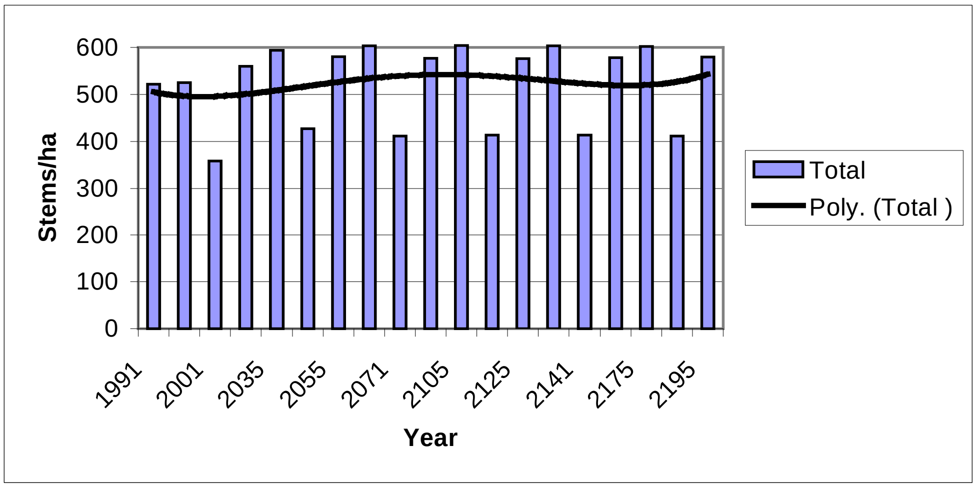

Figure 9: Total number of stems in the stand over the analysis period

8.4.1 Figure 9 shows the total number of stems in the stand to rise from just above 500 at the time of the first logging (the second column), to approximately 600 before every subsequent harvest. This increase in the number of stems suggests that the average stem dbh will be smaller than before the first harvest ie the stand contains less large trees. This has potentially negative implications for habitat provision and biodiversity functions of the forest. However, after the initial increase, the number of stems remains constant at 600 (allowing for cyclical fluctuations) suggesting that the forest reaches a new equilibrium. This appears to be correlated with the leveling out of the timber harvest under the TPTI system (Figure 8).

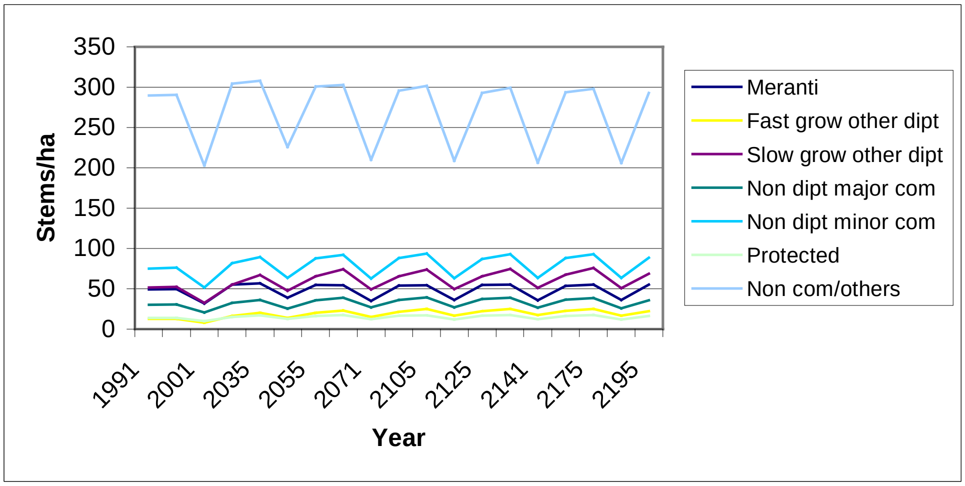

Figure 10: Number of stems in the stand broken down by commercial group

8.4.2 The above figure shows there to be very little variation in the species composition of the forest over the analysis period. The variation that is seen is related to the harvesting cycle (the number of stems of any species falling and recovering cyclically). There is no evidence of any particular species group (eg Protected species) declining terminally. This suggests that the harvesting operation does not have a detrimental effect upon biodiversity, at least in terms of the relative numbers of each species in the remaining stand.

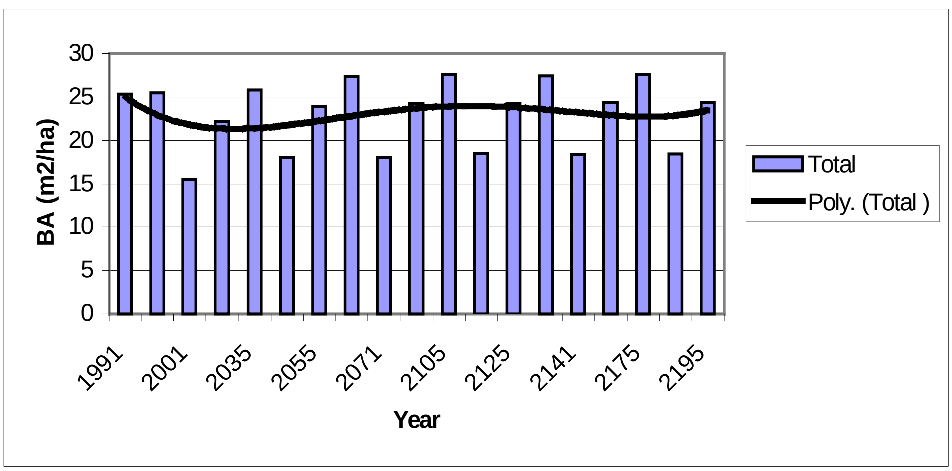

Figure 11: Total BA of the stand over the analysis period

8.4.3 Figure 11 shows the total BA of the residual stand under the TPTI system to increase slightly over the first two cycles before levelling out from the third onward (at approximately 27 m2 /ha). This shows a similar pattern to the number of stems (Figure 9), and appears to be correlated with the leveling out of the timber harvest, suggesting that a new equilibrium is reached in terms of forest structure. The fact that the total BA is constant (or increasing) is positive in terms of the physical functions of the forest such as watershed and soil protection.

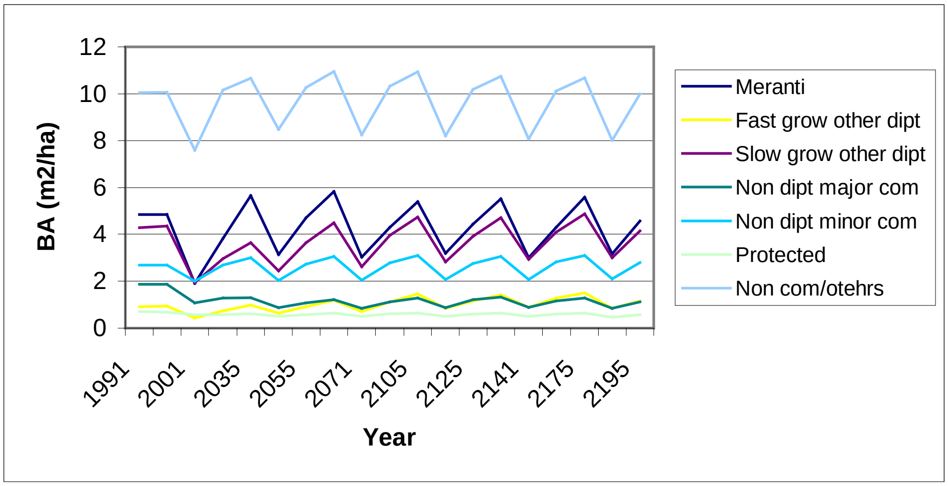

Figure 12: BA broken down by commercial group

8.4.4 Figure 12 shows a similar pattern for the BA per commercial group to that seen in Figure 10 ie there is no significant change in the species distribution. All species fluctuate with the harvest cycle, but there is no evidence of the relative numbers of any particular group declining or increasing. This suggests that the TPTI system will not cause a long term change in the relative species composition of the residual stand.

9 CASE STUDY 2: MAXIMUM EXTRACTION 45 M^3 HA^{-1}

9.1 YIELD REGULATION USED

- 35 year cutting cycle using RIL techniques
- 50cm dbh minimum cutting limit
- the first cycle harvests commercial groups 1-4, subsequent cycles harvest groups 1-5
- a maximum harvest of 45 m^3 ha^{-1} is imposed for all harvests
- a maximum harvest of 10 stems /ha
- the first logging is performed in year 9 of the simulation (input data collected in 1991, forest grown for 9 years to give present yield in the year 2000)[7]
- 30% of eligible stems are deemed to be of non-commercial quality and are therefore not harvested

9.2 TIMBER YIELD PROFILE

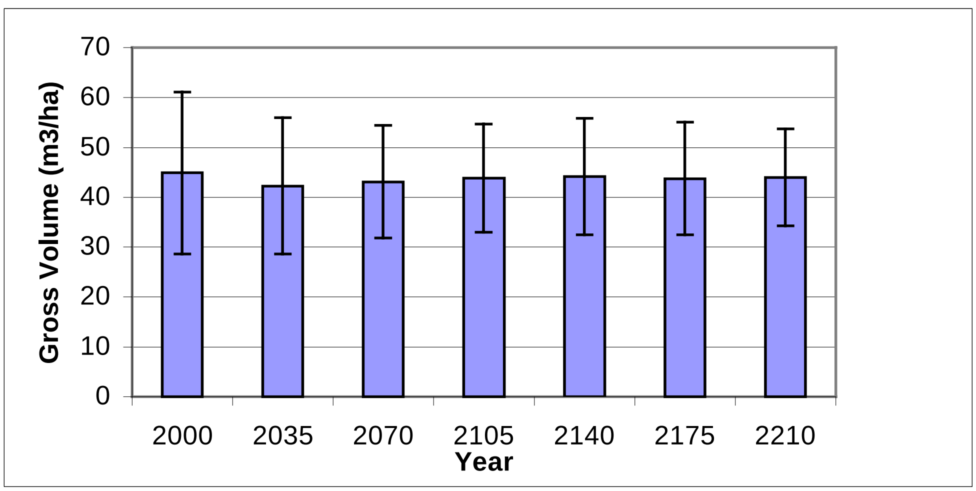

Figure 13 : Timber yield with a maximum extraction limit of 45 m^3 ha^{-1}

9.2.1 Figure 13 shows a very sustainable yield of approximately 43 m^3 ha^{-1} per harvest over 7 cycles. The first harvest yields significantly less than the first TPTI harvest, the second harvest slightly more, with subsequent harvests giving slightly lower yield (see Figure 8). This reduction in yield of approximately 30 m3 (compared with the first TPTI harvest) is what causes the financial profitability to plummet. The higher yield in the second harvest is not captured in the financial analysis.

9.2.2 Table 13 (below) shows that the number of stems felled rises slowly from 5 to 7 over the 7 cycles. Their average dbh falls from approximately 80 cm to 70cm.

[7] This case study therefore predicts the commercial timber yield if this area was logged today. The area was logged for the first time in 1979 and according to current planning is not due for a second logging until 2014.

Table 11 (above) shows the equivalent figures for the TPTI system to be 11 to 10 stems and dbh 70 to 60 respectively.

Harvest Number	Year	Gross Volume m^3 ha^{-1}	No of Stems ha^{-1}	dbh (cm)
1	2000	45 ± 16	5.2 ± 1.7	82 ± 8
2	2035	42 ± 14	6.1 ± 1.7	74 ± 6
3	2070	43 ± 11	6.9 ± 1.5	72 ± 6
4	2105	44 ± 11	7.0 ± 1.7	73 ± 6
5	2140	44 ± 12	7.0 ± 1.8	72 ± 5
6	2175	44 ± 11	7.4 ± 1.9	71 ± 4
7	2210	44 ± 10	7.4 ± 1.6	71 ± 3

Table 13: Average timber volume harvested, number of stems and diameter with 45 m^3 ha^{-1} maximum extraction. Data are reported as the mean ± 1 standard error.

9.2.3 The 45 m^3 ha^{-1} Yield Regulation system therefore harvests fewer stems /ha implying lower harvest costs, whilst these stems are on average 10 cm larger dbh, which means they are likely to sell for more[8]. Neither of these advantages is captured in the financial analysis.

9.3 FINANCIAL ANALYSIS

	Discount Rate 16%		**Discount Rate 20%**	
	Log Price $90	*Log Price $100*	*Log Price $90*	*Log Price $100*
IRR	**10.23%**	**16.37%**	**10.23%**	**16.37 %**
NPV	**$ -1 231 320**	**$81 487**	**$ -1 555 416**	**$ -591 333**
Net timber Yield (year 2000) = 23.85 m^3	Gross yield in year 2000 harvest (45 m^3) * 0.53 = net			

Table 14: IRR and NPV figures for four discount rate and log price combinations. Column 5 (shaded) is taken as the most realistic.

[8] The increased sale price of larger stems is potentially great, as tropical hardwoods (and particularly those of larger dbh) become increasingly scarce over the next 200 years.

9.3.1 Table 14 shows an IRR of 16.37% and an NPV of $ -591 333 in the shaded column. This means that at current (1996) operating costs, a net yield of 23.85 $m^3\ ha^{-1}$ is not profitable. This yield is only just profitable at a low discount rate and a high log price.

9.3.2 Whilst the NPV is negative, it is not irretrievably so. Analysed simply, $600 000 over 20 years equals a deficit of $30 000 per year. This loss could be overcome by improvements in efficiency; for example reducing operational costs or increasing log utilisation rates.

9.3.3 Forest concessions in Indonesia have been notoriously inefficient in the past, when virgin forests offered massive profits and few incentives to improve the efficiency of the operation. With the reduced timber yield offered by logged over forest it is natural that concessions should have to improve their efficiency in order to remain profitable. There is plenty of scope for this (eg improving upon the low recovery rate of 0.53), and the above analysis shows that the annual loss ($30 000) which must be wiped out at Labanan is not insurmountable.

9.4 RESIDUAL STAND (ECOLOGICAL AND ECOMOMIC) ANALYSIS

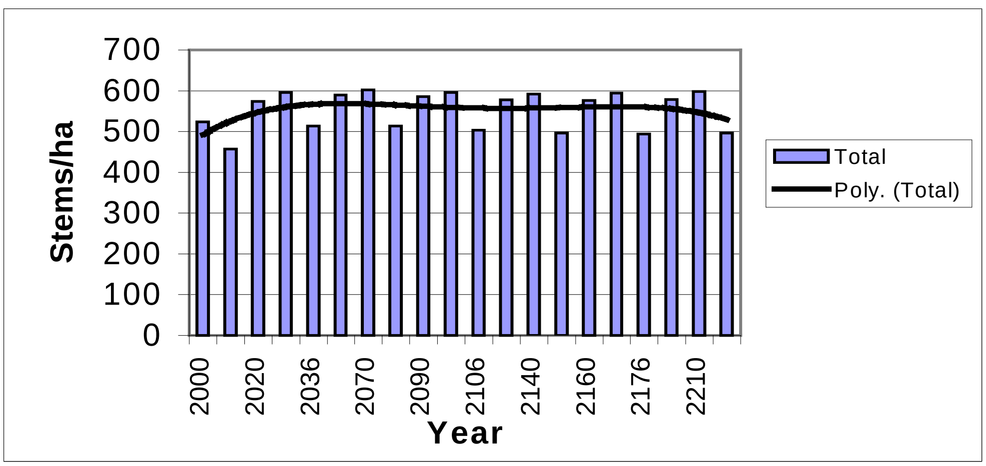

Figure 14: Total number of stems in the stand over the analysis period

9.4.1 The above simulation result shows the number of stems to reach a remarkably constant recovery level of 600 after the first harvest. The picture is very similar to that shown for the TPTI system (Figure 9), except that the equilibrium level is reached sooner. Another difference is that the ‘immediately after logging’ columns (2, 5, 8, 11, 14, 17, 20) show there to be around 500 stems left in the stand – this figure falls to approximately 400 in the TPTI system (probably as a result of the conventional logging techniques). What this means is that the 45 $m^3\ ha^{-1}$ system causes less disturbance to the residual stand as a result of harvesting. This could be seen as an economic benefit. All fluctuations are related to harvesting and the number of stems recovers by the end of each cycle, suggesting that this is a sustainable system.

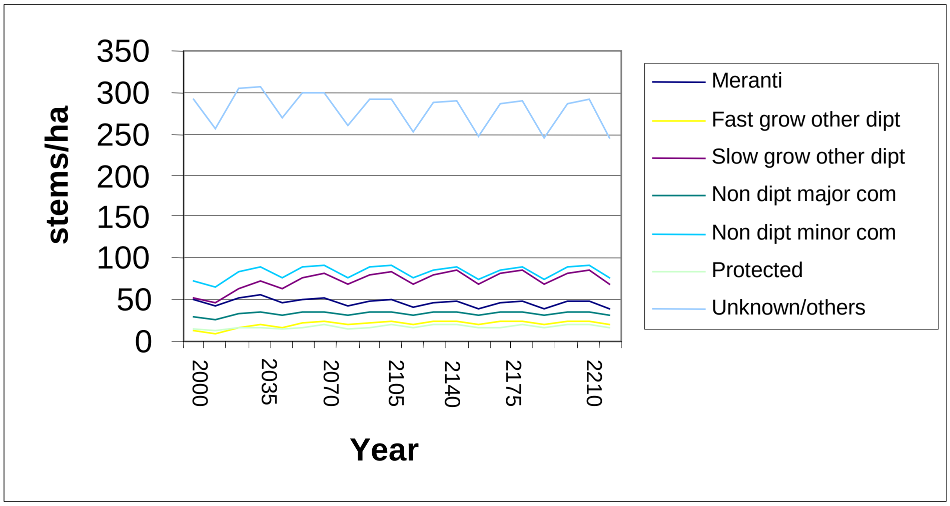

Figure 15: Number of stems in the stand broken down by commercial group

9.4.2 The above figure shows the number of stems per commercial group to be remarkably constant over the analysis period. This indicates no long term change in the composition of the forest as a result of harvesting. The variation that is seen is related to harvesting, although fluctuations are smaller than under the TPTI system (Figure 10).

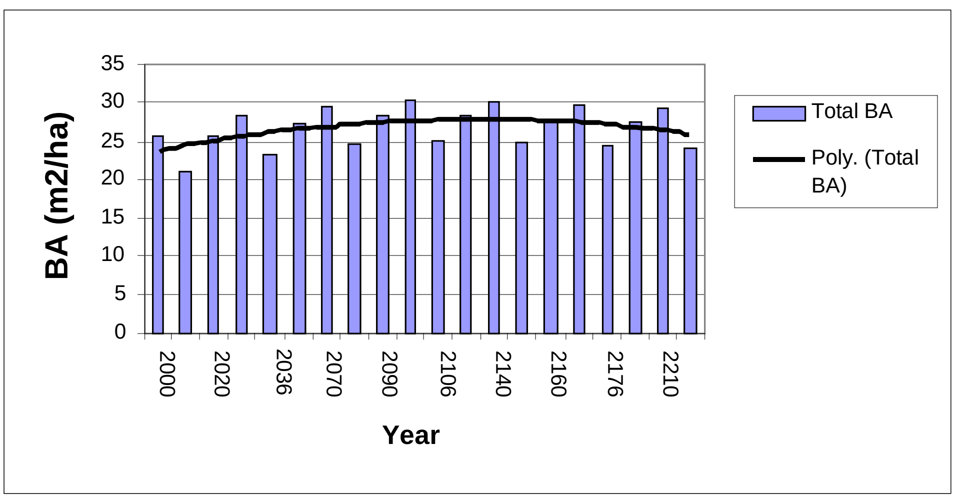

Figure 16: Total BA in the stand over the analysis period

9.4.3 Figure 16 above shows the BA of the residual stand to increase, reaching an equilibrium level of approximately 30 m2 before the third harvest (column 7). This equilibrium level of BA is 3 m2 greater than under the TPTI system (Figure 11). This shows that by limiting the yield to 45 m^3 ha^{-1}, this Yield Regulation system allows the BA of the residual stand to closer resemble that of virgin forest[9]. This is likely to augment ability of the forest to perform protection and biodiversity functions, thus yielding economic benefits.

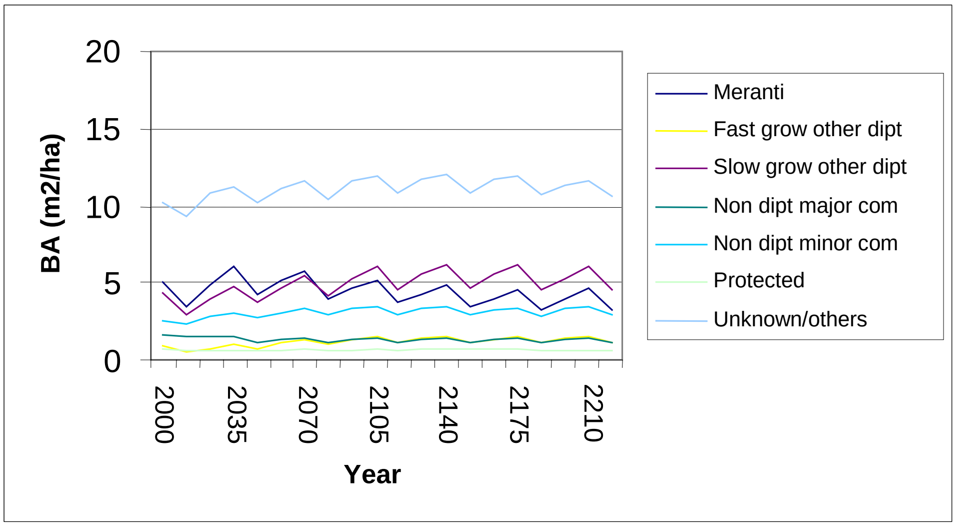

Figure 17: BA broken down by commercial group

9.4.4 Similar to Figure 15, Figure 17 shows there to be no long term changes in the composition of the residual stand. The relative BA of each commercial group remains constant, showing that this Yield Regulation system causes no long term changes in biodiversity.

[9] For comparison, the average BA of the RKL 4 plots at first measurement (ie in their virgin state) was 31.5 m^3 ha^{-1}.

10 CASE STUDY 3: 40 YEAR CYCLE LENGTH

10.1 YIELD REGULATION USED

- 40 year cutting cycle using RIL harvesting methods
- 50cm dbh minimum cutting limit
- the first cycle harvests commercial groups 1-4, subsequent cycles harvest groups 1-5
- a maximum harvest of 50 $m^3 ha^{-1}$ is imposed for all harvests (this is increased from 45 $m^3 ha^{-1}$ due to the longer cycle length)
- a maximum harvest of 10 stems /ha
- the first logging is performed in year 9 of the simulation (input data collected in 1991, forest grown for 9 years to give present yield in the year 2000)[10]
- 30% of eligible stems are deemed to be of non-commercial quality and are therefore not harvested

10.2 TIMBER YIELD PROFILE

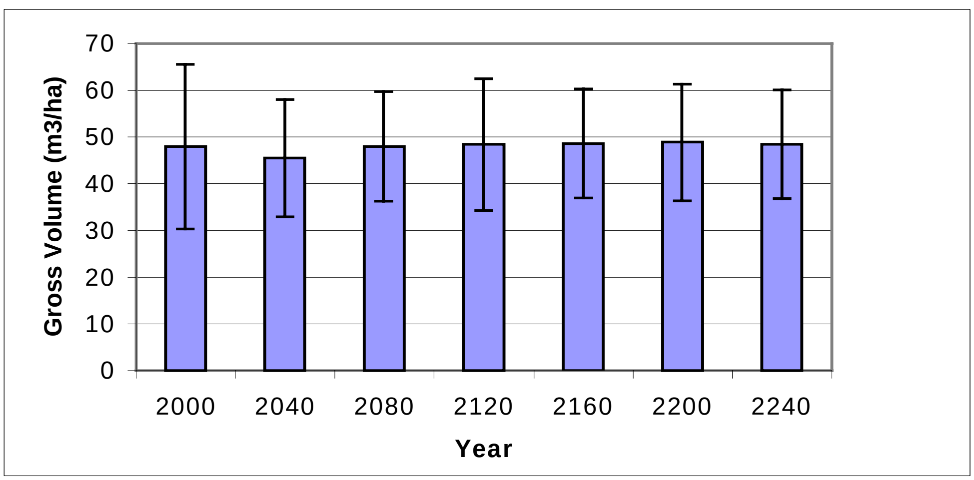

Figure 18: Commercial Timber Yield on a 40 year cycle

10.2.1 The above graphic (Figure 18) shows a relatively constant yield of approximately 47 $m^3 ha^{-1}$ over 7 cutting cycles. There is a slight drop in yield from the first to the second harvest, and a very slight increase in the subsequent 3 harvests.

10.2.2 Table 15 (below) shows that despite the slight drop in yield from first to second cycle, the yield remains between 45.5 and 48 $m^3 ha^{-1}$ throughout the analysis

[10] This case study therefore predicts the commercial timber yield if this area was logged today. The area was logged for the first time in 1979 and according to current planning is not due for a second logging until 2014

period. The average number of stems harvested rises from 6 to almost 8 over the 7 cycles, whilst the dbh of these stems falls from 80 cm to just above 70 cm.

Harvest Number	Year	Gross Volume $m^3\ ha^{-1}$	No of Stems ha^{-1}	dbh (cm)
1	2000	48 ± 18	6.0 ± 2.0	80 ± 7
2	2040	46 ± 13	6.7 ± 1.7	73 ± 5
3	2080	48 ± 12	7.3 ± 1.9	74 ± 5
4	2120	48 ± 14	7.3 ± 1.9	74 ± 5
5	2160	49 ± 12	7.6 ± 1.8	73 ± 3
6	2200	49 ± 12	7.9 ± 2.0	72 ± 3
7	2240	48 ± 12	7.7 ± 1.9	72 ± 3

Table 15 : Average timber volume, number of stems and diameter on a 40 year cutting cycle. Data are reported as the mean ± 1 standard error.

10.2.3 In comparison with the TPTI system the initial yield is much lower, as expected (48 $m^3\ ha^{-1}$compared with 70 $m^3\ ha^{-1}$). Subsequent yields are generally higher, with the exception of that in the 3rd harvest. Compared with the second case study (45 $m^3\ ha^{-1}$ max), the 40 year cycle shows a consistently higher yield – approximately 4 $m^3\ ha^{-1}$in every harvest. This confirms expectations that a longer cycle will give a greater yield – in this case an extra 5 years yields approximately an extra 4 $m^3\ ha^{-1}$.

10.2.4 In terms of the number of stems harvested and the average dbh of these stems, the two Yield Regulation systems are very similar. In both cases the number of stems harvested varies between 5 and 7 over the 7 cycles, and their dbh falls from approximately 80 cm to 70 cm. The 40 year cycle is therefore very similar to the 45 $m^3\ ha^{-1}$ max system in its differences with the TPTI. The initial timber yield is much lower, but fluctuates much less over the analysis period, whilst fewer stems are harvested and these are larger.

10.2.5 In terms of timber yield the only significant difference between the 45 $m^3\ ha^{-1}$ max system and the 40 year cycle is the consistently higher volume yielded by the longer cycle.

10.3 FINANCIAL ANALYSIS

	Discount Rate 16%		Discount Rate 20%	
	Log Price $90	*Log Price $100*	*Log Price $90*	*Log Price $100*
IRR	**11.64%**	**17.47%**	**11.64%**	**17.47 %**
NPV	**$ -820 006**	**$ 278 614**	**$ -1 174 608**	**$ -356 203**
Net timber Yield (year 2000) = 25.44 m^3	Gross yield in year 2000 harvest (48 m^3) * 0.53 = net			

Table 16: IRR and NPV figures for four discount rate and log price combinations. Column 5 (shaded) is taken as the most realistic.

10.3.1 Table 16 shows that on a 40 year cycle the IRR in the shaded column has a value of 17.47% and the NPV is $-356 203. This shows an improvement over the previous case study (Table 14) – due to a higher net timber yield (25.44 m^3 ha^{-1}) and lower annual operating costs (the area harvested each year is smaller on a 40 year cycle). However over the 20 year analysis period the longer cycle has an NPV of $1 225 000 lower than the TPTI case study, and is still an unprofitable operation financially.

10.3.2 Over the 20 year period, the financial loss amounts to $ 17 500 pa. This is a low figure that could be easily overcome by improvements in efficiency, making the 40 year cycle a financially profitable proposition at Labanan (see Section 11).

10.3.3 Financial profitability is seen at a low discount rate and a high log price, (column 3 in Table 16 above) where this Yield Regulation option shows an NPV of $278 614. Again, improvements in efficiency could make column 3 a very attractive proposition financially.

10.4 RESIDUAL STAND (ECOLOGICAL AND ECOMOMIC) ANALYSIS

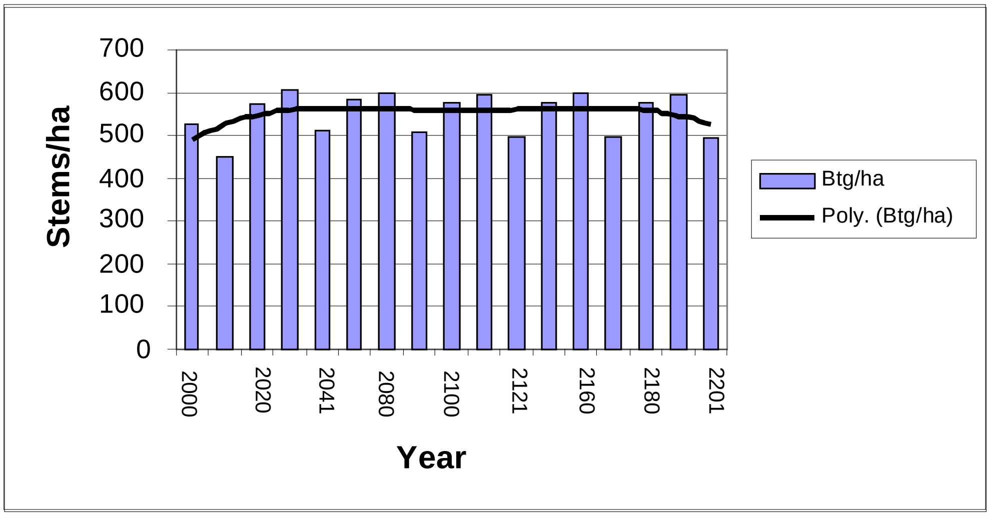

Figure 19: Total number of stems in the stand over the analysis period

10.4.1 Similar to the equivalent graphics for the TPTI and 45 m^3 ha^{-1} systems (Figure 9 and Figure 14 respectively), Figure 19 shows the number of stems in the residual stand to reach a constant 600 before the second harvest (column 4). The number of stems never falls below 500 (after the initial harvest), indicating less disturbance to the forest at each harvest. All fluctuations are related to harvesting and the number of stems recovers by the end of each cycle, suggesting that this is a sustainable system.

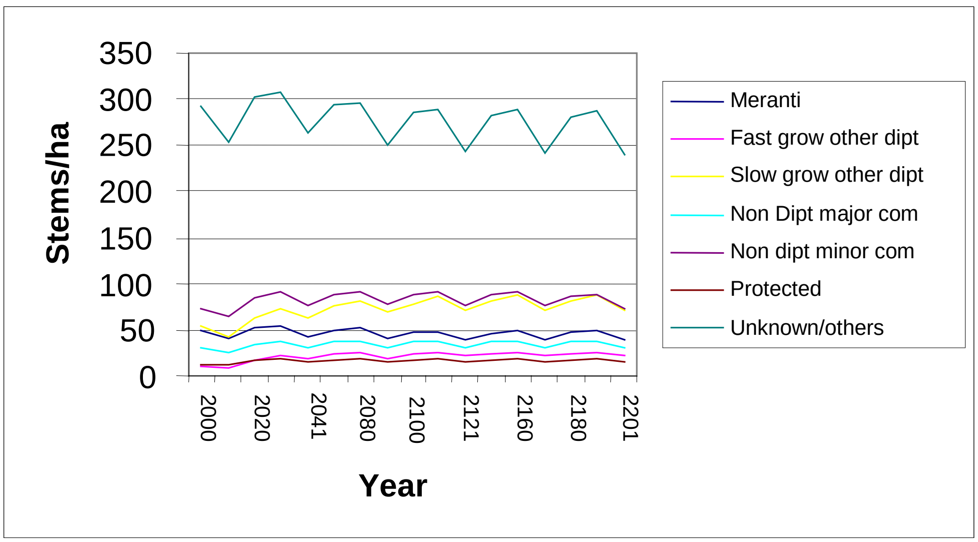

Figure 20: Number of stems broken down by commercial group

10.4.2 Figure 20 shows the species composition of the remaining stand to fluctuate little with harvesting and to show no long term changes over the analysis period. This is similar to the equivalent figures for the TPTI and 45 m^3 ha^{-1} systems.

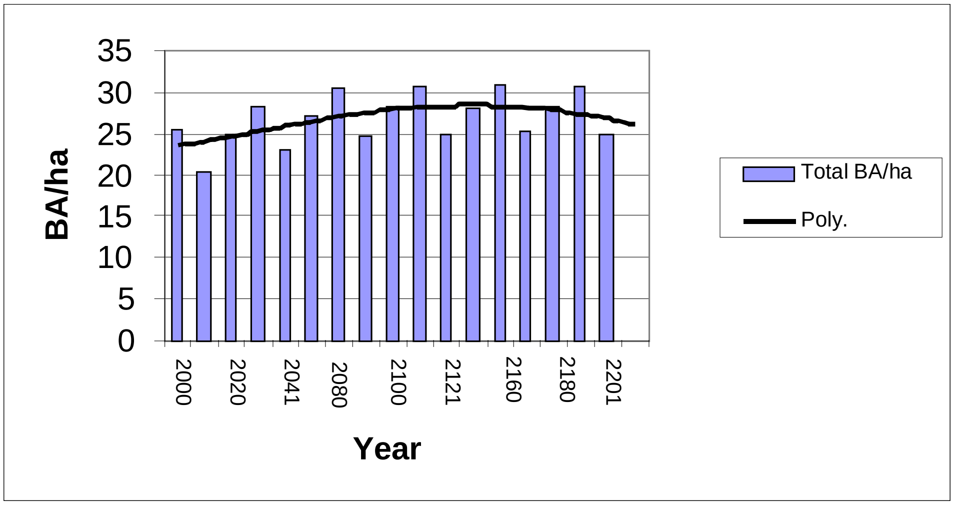

Figure 21: Total BA in the stand over the analysis period

10.4.3 The above figure shows the total BA to increase over the 200 years of analysis. After the second harvest it reaches a relatively constant 31 m^2 ha^{-1} (ignoring variation related to harvesting). This level is slightly higher than the BA of 30m2 observed in Figure 16 for the previous case study. The average BA of the RKL 4 plots in a virgin state was 31.5 m^2 ha^{-1}, showing that under this system the forest comes very close to recovering its virgin BA. The BA also reaches a constant minimum of 25 m2 from the third harvest onward – this minimum is slightly higher than that for the previous case study (and much higher than the constant minimum of 18m2/ha seen in the TPTI system). The implication is that this Yield Regulation system will cause fewer fluctuations in the structure of the remaining stand, thus yielding economic benefits in terms of watershed protection and biodiversity.

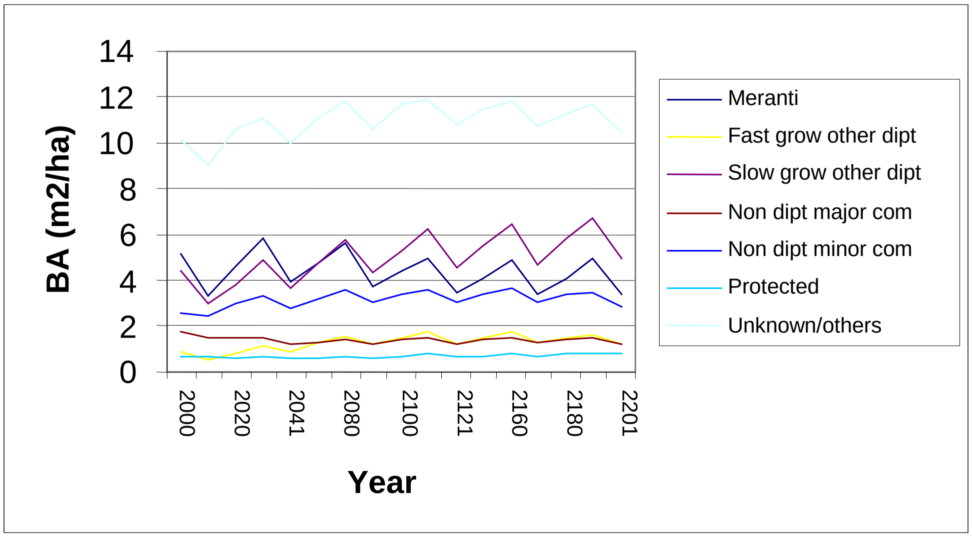

Figure 22: BA broken down by commercial group

10.4.4 Figure 22 shows there to be very little long term change in the species composition of the forest under the 40 year Yield Regulation system. This indicates a sustainable system in terms of the biodiversity function of the forest.

11 EFFECT UPON FINANCIAL PROFITABILITY OF INCREASING THE LOG UTILISATION RATE

11.1.1 This section demonstrates the effect upon financial profitability of improving the efficiency of log recovery. In sections 8-10 it was assumed that 53 % of the commercial timber standing available in the forest made it to the point of sale (and was sold). Here the 40 year cycle case study is repeated, but the log utilisation rate is increased to 75% (ie 75% of the standing commercial timber is makes it to sale)[11].

11.1.2 The result of this is that the net timber yield is now 36 m^3 ha^{-1} compared to 25.44 m^3 ha^{-1}.

	Discount Rate 16%		**Discount Rate 20%**	
	Log Price $90	*Log Price $100*	*Log Price $90*	*Log Price $100*
IRR	**21.61 %**	**27.56 %**	**21.61 %**	**27.56 %**
NPV	**$ 1 219 561**	**$ 2 572 844**	**$ 256 554**	**$ 1 222 657**

Net timber Yield (year 2000) = 36 m^3	Gross yield in year 2000 harvest (48 m^3) * 0.75 = net

Table 17: IRR and NPV figures for four discount rates and log price combinations. The shaded column is taken as the most realistic

11.1.3 Table 17 (above) shows that on a 40 year cycle with a log utilisation rate of 75%, the IRR in the shaded column is 27.56% and the NPV is $ 1 222 657. This is therefore a profitable system. The analysis shows profitability for all combinations – even at a high discount rate and low log price.

11.1.4 When compared with Table 16 (above) this example shows that the increased income from log sales turns a loss making system into a profitable one. When compared with the TPTI case study (Table 12) it can be seen that this increased efficiency 40 year cycle is only $350 000 less profitable over the 20 year analysis period.

[11] This figure has been selected as DFID (1999) state that this is the best that can be achieved within the limitations of the heavy technology that is now used. Improvements beyond this would require the use of specialised equipment and new techniques.

12 DISCUSSION AND RECCOMENDATIONS

12.1.1 Sections 8-10 presented the results of each Yield Regulation alternative in terms of timber yield, financial profitability and the condition of the residual stand.

12.1.2 In terms of purely financial, short term considerations, a continuation of the current TPTI system is the only profitable option for PT Inhutani I at Labanan. The financial analysis over a 20 year period shows this option to have a NPV of US$ 1 580 611. This compares with an NPV of $ -591 333 for the 45 $m^3 ha^{-1}$ case study and an NPV of $ - 356 203 on the 40 year cycle.

12.1.3 In the longer term however, the TPTI system will not be financially profitable. This is due primarily to a low timber yield in the second cycle, with fluctuating productivity thereafter.

12.1.4 In terms of economic considerations, the 40 year cycle is the most desirable. Although none of the case studies show any significant long term negative changes in the structure or composition of the remaining stand, the 40 year cycle leaves a BA in the stand which recovers within the cycle to very closely resemble that of virgin forest. This suggests that the economic benefits which can be provided by forests (such as watershed protection, habitat provision, biodiversity) will be maximised under this system.

12.1.5 The 40 year cycle is also more attractive financially than the 45 $m^3 ha^{-1}$ system, but it is still a loss making operation. However the annual loss incurred over the 20 years of analysis amounts to $ 17 500 pa - this is a low figure and could easily be overcome by improvements in operating efficiency.

12.1.6 It is also significant that the 40 year cycle (as with the 45 $m^3 ha^{-1}$ case study) harvests fewer stems (5-7) than are harvested under the TPTI system (9-11). These stems have a 10cm larger dbh on average. Both these factors have implications for future harvesting/skidding costs, as well as for the prices that the logs will fetch. Neither of these is captured in the financial analysis.

12.1.7 The very concept of sustainability and Yield Regulation is conservative in nature, and suggests a recognition of the economic benefits of the maintenance of forest cover. It has already been stated that any system of Yield Regulation is likely to reduce the timber yield and will therefore reduce financial profitability. This report has shown that this is the case – there is a trade off between financial and economic benefits.

12.1.8 The third case study, regulating timber yield to 50 $m^3 ha^{-1}$ on a 40 year cycle, demonstrates this trade-off. The system shows a number of long term sustainable economic benefits, gained at the expense of a shorter term financial loss.

However this financial loss is avoidable. If the log utilisation rate is increased to 75% (as in section 11), this system becomes profitable.

12.1.9 It is therefore recommended that the best Yield Regulation option for logged over areas at Labanan is a maximum harvest of 50 m^3 ha^{-1} on a 40 year cycle. This system offers long term sustainability in terms of timber yield and forest integrity. Both the productive and protective functions of the forest are maximised. With a few simple and long overdue improvements in operating efficiency it will also become a financially attractive proposition.

13 REFERENCES

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14 APPENDIX I – MANAGEMENT COSTS

14.1.1 The base figures for management costs in the min-FMU model were collected in the Labanan concession, with reference to current practice (ie TPTI). The cost data in the model uses 1996 prices. These data have not been updated for this analysis, as they are a complete and accurate set. The exchange rate used is also that from 1996.

14.1.2 In addition to the figures set out in Table 9, certain elements of the base data set have been changed to reflect the differences between the alternative case studies. These are set out below

14.2 CASE STUDY 1 : CURRENT TPTI

The following forest management practices were given a cost of zero as they were not performed in the simulations

- Post felling inventory
- Liberation cutting
- Seedling production
- Enrichment planting
- Maintenance I
- Maintenance II
- Thinning I
- Thinning II
- Thinning III

This case study used conventional rather than RIL harvesting techniques.

14.3 CASE STUDY 2: MAXIMUM EXTRACTION 45 M^3 HA^{-1}

14.3.1 To account for the altered cost structure as a result of RIL, the following alterations were made

Management cost	Alteration to base data
Pre felling inventory	Basic cost inflated by 10%
Skidding	Basic cost reduced by 50%
Training	Basic cost inflated by 10%

14.3.2 The forest management practices listed in section 14.2 were all given a cost of zero for the reason stated in that section.

14.4 CASE STUDY 3: 40 YEAR CYCLE LENGTH

14.4.1 Same alterations as in section 14.3.