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# Financial analysis of sustained forest management for timber Perspectives for application of the CELOS management system in Brazilian Amazonia

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**Abstract**

Sustained management of the Terra Firme Forest in Amazonia is financially analysed for an integrated forest management and timber processing industry. Two scenarios are studied, one with reduced impact logging (RIL) and sparing of reserves without silvicultural follow-up in a 100-year harvesting cycle, and another one inclusive of silviculture after RIL, liberating reserves in a 25-year cycle. Cycle lengths are based on CELOS research in Suriname. Acquisition of land is assumed to be complete at the beginning, the 100-year cycle option needing four times as much land as the 25-year cycle option. A cash flow analysis over a 100-year period for both options with a 8% discount rate shows that the total costs in the land-intensive option (25 years) with silviculture are considerably less than in the land-extensive option; the lower cost of infrastructure, log transportation and land acquisition offset the cost of silviculture. Because the annual revenues from timber sale are the same in both options, the NPV of the intensive option is also much higher. A sensitivity analysis shows that the land-intensive option is expected to give still a positive NPV in less favourable situations. The relatively small forest area in the land-intensive option together with the organisational setting, which includes integration with the processing industry, favours a sustainable development. More intensive management gives signals to settlers that helps prevent their encroachment. In addition, the higher annual increment in this option facilitates a contribution to regional development and makes a larger area available for strict nature reserves.


*Keywords:* CELOS; Uneven-aged Terra Firme Forest management; Reduced impact logging (RIL); Cash flow analysis; Net present value; Sensitivity analysis

## 1. Introduction

Various systems for the sustained management of tropical rain forests have been developed during and since colonial times (Lamprecht, 1989), but the actual situation appears still more to be one of timber plunder and subsequent conversion to agricultural land in many places. Which conditions hinder these systems to be commonly practised?

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As land use is largely economically driven, the answer has to be partly sought in the economic conditions. In general, economists, such as Leslie (1987), Verissimo et al. (1992) and Southgate (1998), are not optimistic about sustained management opportunities for tropical rain forest. Richards (2000) concludes that financial incentives will be necessary to make sustained tropical forestry profitable. Southgate (1998) assumes in his evaluation of the prospect of environmentally sound timber production that ''sheer resource abundance discourages the sort of investment required for sustainable resource management''. Moreover, opening up forest areas has the risk of introducing settlers along the roads made for logging, and the logging companies usually can not care sufficiently about future timber harvests in coming cycles to keep such intruders out effectively. Sustained forest management appears for timber companies in such situations to be less attractive than just logging and leaving, and the companies reckon on the government to hand out new forest areas for logging when needed, or simply assume to be out of business after some period. For sustained land use and regional development these logging companies are not the right choice of enterprise. The scenario of such logging has been typified, by amongst others Vincent (1992), as ''boom and bust''.

It should be noted that the risk of introducing settlers depends on the location. Southgate (1998) has explained about the effects of the frontiers of colonisation on local forest uses; effects commonly resulting in predatory logging. He expects better results of sustained forest management in more accessible places where management is more intense. Introducing regular forest management in active frontiers of colonisation, where law and order are largely deficient, appears indeed not quite feasible, but in more settled environments the situation may differ.

Authors arguing that just logging is more profitable than sustainable management, are generally right for the short run. Adding profits from predatory logging to the credit of the follow-up agricultural use supports the view of these authors. However, agricultural use of former forestland is often not a sustainable use on the poor soils under consideration.

A reason for the meagre financial perspective of sustainable forest management in most of the traditional systems is the apparently considerable cost, mainly caused by the silvicultural interventions. The profitability of these traditional systems often was low because of the substantial long-term investment in the frequent pre- and post-harvesting interventions they prescribed (Lamprecht, 1989). Even if the profitability would be sufficient, the lack of funds for forest management could be a hinder for the introduction of these systems. Because of uncertainty about future tenure private companies have not a strong incentive to make the required silvicultural investments. Governments in many tropical countries also lack these funds, which situation ''results not so much from low international timber prices as from the failure of governments to capture the existing stumpage value'' (Vincent, 1992).

An alternative option, preached by some conservationists, would be to preserve the untouched forest or log it lightly once to reduce pressure on the resource and then fence it off as a nature preservation area (Reid and Rice, 1997). Permanent job establishment of any extent cannot be expected with such an option, which is therefore, usually even less acceptable for regional public authorities than is the regular predatory logging. In addition, this strategy is not effective at all against illegal logging that occurs so frequently now in many countries.

In the case discussed in this article, the above conditions that hinder the introduction of sustained forest management could be, at least partly, avoided. The objective in this article is to assess in such a situation the financial perspective of applying silviculture in sustainable management of Amazonian Terra Firme Forest. We will try to find out whether the effectiveness and the low cost of the CELOS management system (CMS) found in small-scale research situations in Suriname (De Graaf, 1986) generates also useful opportunities in a real life situation on enterprise level.

This article is organised as follows. First we describe the case of the enterprise that by integration of forest management with timber processing creates favourable conditions for application of sustained forest management. Next, we describe the way CMS is applied in the forest enterprise. Then, we provide the method and the data used in the financial analysis and we present the research findings. The last section reflects on method and findings and the implications of these findings.

## 2. The case of Mil Madeireira Itacoatiara

In the following case, several conditions for application of sustained forest management appear more favourable than in other parts of Brazil. The enterprise of the case study here presented, *Mil Madeireira Itacoatiara* (MMI) is located in the heart of the Amazon, in the Manaus region, north of where the Rio Madeira enters the Rio Amazonas. Its mission as a subsidiary company of Precious Woods is to be a leader in sustainable management of tropical forests, with ecological and social contexts to be well balanced with financial aspects. The associated trade company Precious Woods Amazon concentrates on producing and selling quality lumber and other wood products from certified forest, in a set-up where log processing is strongly integrated with sustained forest management. The forest management plan of MMI is based on the CMS (see further). The capital needed largely was provided by European sources that wanted to invest in environmentally and socially just industries.

The sawmill has an annual capacity of 60,000 $m^3$ roundwood, and lies adjacent to the managed, and privately owned, Terra Firme Forest area. This forest is largely untouched apart from the rosewood oil exploitation in the past age that under the former owners has nearly eradicated the *Aniba rosaeodora* (Lauraceae). The forest area managed for timber production was originally planned to be 50,000 ha net productive area in a total estate area of about 80,000 ha, but extension is expected to complete the area needed for sustained yield. The integration of forest management and processing industry provides a more safe position for both. The enterprise employs about 350 people and has had its activities FSC-certified several years already. Export lumber is sold to environmentally conscious customers in Europe and elsewhere at competitive prices.

It is generally known in the Manaus region that both the climate and soils in the region are mostly not suitable for large scale and sustained agricultural activities and ranching, except maybe for some forms of agroforestry and horticulture. The chemically very poor Latosols often have a very high clay percentage and a high aluminium saturation. Rainfall is about 2200 mm annually, with about 4 months water deficit. Until now problems with respect to security of land ownership did not occur and still a lot of unlogged forest is available for purchase, so land prices are reasonable though not low anymore. A few asphalt roads have partly opened up the region, but this region is not a frontier area in the sense of raw untamed development with lack of law and order. Clearing for slash and burn cultivation is still done in the traditional way along rivers and streams and also along the roads when permitted, but this last form is quite kept under control by landowners and the authorities. The government has recognised the advantages of forest and landscape conservation for the tourist industry, but also wants some further economic development and diversification of land use and industry, as Manaus probably cannot be kept a free trade zone forever.

## 3. Silvicultural system

The CMS, developed in Suriname in the 80s (De Graaf, 1986, Hendrison, 1990), showed the additional cost of RIL and of follow-up silvicultural management to be reasonable as compared to cost of traditional logging methods and management systems. The CELOS system as used by MMI has recently been described by De Graaf (2000). In brief, its silviculture is a domestication approach in which a mild timber harvest, with strictly controlled (reduced impact) logging and sparing of reserves (potential crop trees (PCTs)), is followed by an effective liberation of the PCTs and of some advance regeneration, to be done either with a refinement or a drastic liberation thinning. Structure and standing volume of the forest is largely retained, and the system results in natural-looking stands. Actually at MMI no use of herbicides is planned; trees are tried to be killed or mortally weakened merely by deep girdling. Silviculture was found in CELOS research to have low cost, some 0.5–1 man-day/$m^3$ standing wood of commercial species, which is quite different from most colonial silvicultural systems (for this see Lamprecht, 1989). Transformation of the original rain forest structure and composition into a form more fit to human uses is assumed to be necessary for sustained yield.

For cycle length the increment after selective harvesting is the decisive factor. Managers should not be optimistic about the increment of valuable timber species in Amazonian high Terra Firme Forest after selective logging without further release. In experiments recorded during a decade and more in Suriname (De Graaf, 1986) the only net increment (per diameter class) in exploited, and further untreated, stands was on trees above 45 cm dbh, which indicates that competition still was strong. Many trees of commercial species of this size left over, were of low quality or were second class species. Increment of the whole stand was largely on non-commercial species, and the net increment percentage for the left over tree population of commercial species was estimated to be around 1% annually. Mortality was found to be close to 2% annually for all sizes of trees and was settled with these net increment data given above. In situations, such as in the forests of MMI, where a residual stock of commercial species (above 50 cm dbh, and of sufficient quality to serve as PCTs for the next harvest) is found of 20–30 $m^3$/ha, this 1% means a meagre 0.2–0.3 $m^3$ net annual increment per hectare. It will take 100 years to reach the stock level of 40–50 $m^3$ needed for a second harvest of good quality logs of about 20–25 $m^3$/ha. Experience confirms that a lower minimum standing stock level is not realistic for profitable logging. Actual diameter limits for trees to be harvested in the enterprise discussed are above 65 cm dbh, and only a low percentage of hollow and rotten wood is acceptable.

With silvicultural treatment of the residual stand such as prescribed in CMS, the net increment of the standing volume of commercial species will considerably increase, up to an estimated 4%, maybe 5%. This results under the given conditions into an annual net increment of 0.8–1.2 $m^3$ or even 1.5 $m^3$, and the minimum stock level of 40–50 $m^3$/ha is reached within 25 years. De Graaf (1986) found in his experiments in Suriname even higher increment percentages for the most intensive treatments. Thus, in a cutting cycle of 25 years in CMS, the same timber volume per hectare can be harvested as in a cutting cycle of 100 years without any volume increment stimulation. To harvest annually the same total timber volume, the forest area needed in the land-extensive option (without silviculture) has to be four times that in the land-intensive option (with silviculture).

So application of silvicultural treatments has advantages in a situation of integrated sustained forest management and timber processing, and one of the advantages is that with more intensive silviculture a by far smaller area of forest land is needed. Investment in land and roads apparently can be considerably less than for sustained yield with no silviculture. This smaller area also means that the log transport distance can be shorter over a whole cycle. Since cost of transport is an important part of the total cost of timber production, such a reduction of transport cost can help offset the extra cost of silvicultural treatments.

Another advantage is that forest in the region not needed for timber production thus, can be reserved for nature preservation purposes, while the managed areas under CMS can form a buffer zone around valuable natural core areas with high interest for conservation.

## 4. Method of analysis

The starting point is that the owner of the sawmill wants to secure the supply of raw material, be it from simple (but sustainable) forest exploitation or from forest management with silviculture. Supply of raw material is secured by acquisition of all the needed forestland at the start of the mill.

Based on annual increment estimates, it is here assumed that the cutting cycle can be 25 years with silvicultural treatments, and has to be 100 years without silvicultural help that stimulates increment. Both cycles use comparable harvesting systems and intensities, and it is also assumed that the assortment and quality of the logs harvested in the second cycle is equivalent to that in the first. It probably will not be exactly the same, as the average diameter will be somewhat smaller and species composition may differ too.

In the following, a cash flow analysis will be made of the management without silvicultural treatments—further indicated as the land-extensive option—as well as of the management with application of CMS, further indicated as the land-intensive option. The cash flow analysis covers in both options a period of 100 years. In the land-extensive option every compartment—which is a forest area of a given constant size that will be harvested in one year—can be harvested once, in the land-intensive option, every compartment will be harvested four times in the 100-year period. This highly regular schedule is of course theoretical. The first harvest is in pristine forest.

Because of a lack of detailed observations, some uncertainty exists on the accuracy of the current labour and machine productivity, growth and yield as well as of prices of inputs and timber. Also the development in time of these variables is uncertain. Therefore, a sensitivity analysis, which measures how sensitive the financial viability of the options is to a change of one of these variables, is carried out. We have made a financial analysis, that is to say an analysis from the point of view of the forest enterprise, and not an economic analysis which is an analysis from the point of view of society.

## 5. Data

Most data are from a study of the enterprise (Huesca Santos, 2000) and therefore, containing locally gathered information. Since in this study a harvest volume of 30 $m^3$/ha has been assumed, and a correspondingly annual harvested area, the data have been revised according to new information. Another source of information is the FAO study (1997) done at the enterprise, and additionally some information from personal communication with MMI functionaries is used. Because of a lack of observations, various data had to be taken from studies in other areas. One of the sources is the study of Barreto et al. (1998) in Paragominas.

The monetary units used in this article are July 1999 US$ with an exchange rate of 1 US$ = 1.61 R$ (Brazilian real). Some of the figures in this study concern monetary units from the early 90s. It has been assumed that the price increases since the early 90s are set-off by the productivity increase since then.

To find out the right discount rate is very difficult. Hence, in the base calculations the discount rate used in other Brazilian studies, e.g. Barreto et al. (1998), will be applied (8%), but in the sensitivity analysis other rates will be used as well. Because constant prices are used, the discount rates are supposed to be real rates.

### 5.1. Annual cut and forest area

The harvest level in our case study in both the land-intensive and land-extensive option is set at 20 $m^3$/ha. This harvest level is quite high for the forest concerned, and the level will be reached only in the near future when more volume in lesser used species will be taken, as planned by MMI. The actual harvest is lower, and lies around 15 $m^3$/ha, and consequently a larger area has to be harvested at the moment, but this is not the stable long-term situation envisaged. A cut of 20 $m^3$/ha every 25 years in the land-intensive option implies that annually a compartment of 3000 ha has to be harvested to feed the sawmill with 60,000 $m^3$ and that the enterprise has to acquire a productive forest area of 75,000 ha. In the land-extensive option, with a cut of 20 $m^3$/ha every 100 years, the enterprise has to acquire an area of 300,000 ha.

### 5.2. Log price

For this study, the log price at the mill gate is relevant. A difficulty in determining this price is the large number of tree species that is found in the Brazilian Amazon forest, of which many species are used by the sawmills: Verissimo et al. (1995) report 300 species. The log prices of these species vary considerably: Verissimo et al. (1995) report roundwood prices in Pará State—where 65% of Brazil's roundwood is produced—for mahogany of US$ 220/$m^3$, for logs of medium-value species US$ 80/$m^3$ and for the other species on average US$ 40/$m^3$. Mahogany is not found in the MMI forests. Because the mill will also process lesser used species with a low value, a conservative estimate of US$ 40/$m^3$ will be used in the following calculations.

### 5.3. Productivity and cost

The same annual total cut and cut per hectare in both options implies that the same productivity of harvesting and the same cost per hectare and per cubic meter can be applied for a number of items in both options. Only the cost of infrastructure, log transport and silvicultural treatments differ between the options as will be shown below. Table 1 shows per hectare and per cubic meter cost. To have an idea of real per hectare and per cubic meter cost, the figures in this table include the contingent cost of depreciation of and interest on the invested capital in machines. An 8% discount rate has been used. In the cash flow analysis, however, the accounting items cost of depreciation and interest are not relevant. In that analysis, the cost of depreciation and capital does not appear explicitly, but comes to expression via the recurrent expenses for machines. Per hectare costs have to be multiplied with

Table 1
Productivity and cost per hectare and per m$^3$ of forest management at Mil Madeireira Itacoatiara (MMI) in Amazonas, Brazil. An explanation of the data can be found in the Appendix A

| Activity | Productivity | Cost | | Source |
|---|---|---|---|---|
| | | US$/ha | US$/m$^3$ | |
| Management plan | | 0.9 | 0.045 | Per hectare cost from Barreto et al., 1998 |
| Extraction plan | | 13.44 | 0.67 | Per hectare cost from Barreto et al., 1998 |
| IBAMA supervision[a] | | 1.60 | 0.08 | Per hectare cost from Barreto et al., 1998 |
| Survey and tree mapping | | | | |
| UTM blocks[b] | 100 ha per team-day | 1.28 | 0.06 | Huesca Santos, 2000 |
| Plot demarcation | 24.29 ha per team-day | 8.38 | 0.42 | Huesca Santos, 2000 |
| Forest inventory | 15.75 ha per team-day | 10.21 | 0.51 | Huesca Santos, 2000 |
| Infrastructure | | | | |
| Layout + marking roads | 33.3 ha per team-day | 1.54 | 0.07 | Productivity from Barreto et al., 1998 |
| Layout + marking landings and trails | 3.6 ha per team-day | 15.09 | 0.75 | Productivity from Barreto et al., 1998 |
| Construction of permanent roads | | 106.66 | 5.33 | Pers. Comm. manager MMI |
| Construction of temporary roads | | 31.70 | 1.59 | Pers. Comm. manager MMI |
| Construction of landings | 4 landings per team-day | 2.81 | 0.14 | Pers. Comm. manager MMI |
| Road maintenance | See Appendix A | | – | Pers. Comm. manager MMI |
| Felling operations | 103.6 m$^3$/team-day | 16.36 | 0.82 | Huesca Santos, 2000 |
| Log extraction | | | | |
| Opening skid trails | 720 m/h | 5.91 | 0.30 | Pers. Comm. manager MMI |
| Pre-concentration | 38.6 m$^3$/h | 30.34 | 1.52 | FAO, 1997, Huesca Santos, 2000 |
| Skidding | 33.7 m$^3$/h | 35.97 | 1.80 | Productivity from Barreto et al., 1998 |
| Log transportation | | | | |
| Truck loading | | 20.77 | 1.04 | Huesca Santos, 2000 |
| Transport (in first cycle) | | 66.69 | 3.33 | Huesca Santos, 2000 |
| Silvicultural treatment (first) | 5 ha per team-day | 18.96 | | Pers. Comm. manager MMI |

[a] IBAMA is the Brazilian Institute for the Environment and Renewab Resources, also with the function of a Forest Service.
[b] UTM blocks are the regular administrative land mapping units 4 km × 4 km.

the number of hectares in a compartment to achieve the annual cost.

An explanation of the items of Table 1 is given in the Appendix A.

## 6. Results

A summary of the cash flow tables, that is to say the present value of costs and revenues (timber sale) over the whole period of 100 years is given in Table 2. As already has been noted, depreciation and interest are not explicitly included in this table. The table shows that total costs in the land-intensive option are considerably less than in the land-extensive option. This is largely the result of the lower cost of land acquisition, but also the investment in machinery and some items of the compartment cost are lower, namely the cost of infrastructure and transportation. Cost of land acquisition are in the land-extensive option with about 30% an important part of the total discounted cost. In the land-intensive option this part is only about 10%. In the section on the silvicultural system it has already been briefly described how costs are related. In the land-intensive option the cost of land acquisition is lower as well as the cost of infrastructure, and the shorter log transportation distance implies lower direct cost as well as lower investment in machinery. In the land-intensive option, we have cost of silvicultural treatments, but the lower cost of other items significantly

Table 2
Present value of a 100-year period in the land-extensive and the land-intensive option of costs, timber sale and net present value at 8% discount rate (in US$ 100)

| | Land-extensive option | Land-intensive option |
|---|---|---|
| Land acquisition[a] | 59973 | 14993 |
| Machinery | 31771 | 31165 |
| Compartment cost[b] | 102328 | 108097 |
| Management plan | 422 | 422 |
| Extraction plan | 5038 | 5038 |
| IBAMA supervision | 648 | 648 |
| Survey and tree mapping | 8045 | 8045 |
| Infrastructure | 58570 | 54056 |
| Felling operations | 5908 | 5908 |
| Log extraction | 10633 | 10633 |
| Log transportation | 13064 | 12187 |
| Silvicultural treatments | n.a. | 11160 |
| Total cost | 194072 | 154256 |
| Timber sale | 299864 | 299864 |
| Net present value | 105792 | 145608 |

[a] At the end of the 100-year period the value of the forest land is included in the cash flow analysis as a desinvestment at acquisition price.

[b] Depreciation and interest on invested capital not included in this and following items because purchase of machinery has been presented apart.

offset these costs of silvicultural treatments. Because the revenues are the same in both options, the NPV of the land-intensive option is considerably higher. Savings on the cost of infrastructure, transportation and machinery alone do not offset the higher cost of silvicultural treatments although they are only a relatively small part of the total compartment costs. A saving on the cost of land acquisition is necessary to achieve a higher NPV in the land-intensive option. This partly results from the application of discounting: savings on the cost of land acquisition are substantial and their importance is not diminished by discounting because they occur at the beginning of the project, but savings on the cost of infrastructure and transport are supposed to start only after the first cycle of 25 years (see Appendix A) while cost of silvicultural treatments occur already after the first harvest.

Because of that high cost of land acquisition in the land-extensive option and because they occur in the beginning of the project life, it may be expected that the financial viability of this option is more sensitive to the discount rate used. Table 3 shows that the NPV of the land-extensive option changes relatively more with a change of the discount rate than does the NPV of the land-intensive option. The NPV in the land-intensive option is still substantially above zero at a 20% discount rate, which indicates that the internal rate of return is well above this rate, even almost 55%. The internal rate of return is in the land-extensive option close to 20%.

The NPV per hectare in Table 3 gives information about the price that can be paid for forest land. The figures in this table show that at a price of US$ 20/ha—which is already included in the NPV—a substantial producers' rent remains at moderate discount rates in the land-intensive option. In the land-extensive option, this price will be about an upper limit at discount rates above 15%. Here, it has to be noted that this ratio depends on the NPV and the amount of hectares. This amount of hectares is large in the land-extensive option and a large part of the area is used only after a long time.

The annual equivalent[3] per hectare can be used to compare the outcome of forest management/exploitation with the outcome of other land-use options, such as cattle ranching or shifting cultivation, which give an annual income. The table shows that application of CMS considerably increases this ratio, which means that the land-intensive option is a much more competitive type of land use.

Table 4 shows the consequences of scenarios with lower or higher revenues from timber sale and cost overrun. It has not been specified whether the higher or lower revenues are the result of higher or lower prices of timber or of higher or lower timber production. It may be expected that costs increase/decrease if timber production increases/decreases. Also it has not been specified whether the cost overrun is the result of higher prices of production factors or of a too low estimate of the volume use of these factors. Table 4 shows that an increase of the timber sale with 10% considerably increases the NPV. A 10% decrease of timber sale revenues or a 10 and 20% increase of costs makes the land-intensive option not critical even at a discount rate of 20%. The land-intensive option is, as contrasted with the land-extensive option, at a 10% decrease of timber sale or 10% increase of cost,

[3] This ratio has been calculated with the capital recovery rate (see Gittinger, 1982).

Table 3
Sensitivity to discount rate of NPV (net present value), NPV per hectare and annual equivalent per hectare

| Discount rate (%) | NPV (US$ 100) | | NPV per hectare (US$) | | Annual equivalent per hectare (US$) | |
|---|---|---|---|---|---|---|
| | Land-extensive option | Land-intensive option | Land-extensive option | Land-intensive option | Land-extensive option | Land-intensive option |
| 5 | 206611 | 250230 | 69 | 334 | 3.47 | 16.81 |
| 8 | 105792 | 145608 | 35 | 194 | 2.82 | 15.54 |
| 10 | 71375 | 111042 | 24 | 148 | 2.38 | 14.81 |
| 15 | 24989 | 65714 | 8 | 88 | 1.25 | 13.14 |
| 20 | 1539 | 43289 | 1 | 58 | 0.10 | 11.54 |

Table 4
Sensitivity of NPV (US$ 100) to change in timber sale and total cost at different discount rates

| Discount rate (%) | Timber sale (10%) | | Timber sale + 10% | | Total cost + 10% | | Total cost + 20% | |
|---|---|---|---|---|---|---|---|---|
| | Land-extensive option | Land-intensive option | Land-extensive option | Land-intensive option | Land-extensive option | Land-intensive option | Land-extensive option | Land-intensive option |
| 5 | 158976 | 202595 | 254246 | 297865 | 179637 | 227618 | 152664 | 205006 |
| 8 | 75806 | 115622 | 135778 | 175594 | 86385 | 130183 | 66978 | 114757 |
| 10 | 47377 | 87044 | 95373 | 135041 | 54514 | 98148 | 37653 | 85254 |
| 15 | 8989 | 49714 | 40989 | 81714 | 11488 | 56286 | −2013 | 46857 |
| 20 | −10461 | 31289 | 13539 | 55289 | −10307 | 35618 | −22154 | 27947 |

financially still viable at a 20% discount rate. The sensitivity analysis shows that the land-intensive option is less sensitive to an increase in costs or a decrease of timber sale revenues than is the land-extensive option, in the sense that such a change affects the NPV of the land-intensive option less.

Table 5 gives the outcomes of another type of sensitivity analysis, namely a breakeven analysis on base of switching values. The breakeven analysis gives an answer on the question at which value an option becomes critical; that is when the NPV becomes zero (total discounted benefits equal total discounted cost). The switching values for timber sale give the percentage with which timber sale revenues can decrease before an option will be critical. According to Table 5, the timber sale revenue may decrease with 35% in the land-extensive option and even 49% in the land-intensive option at an 8% discount rate before the critical point will be reached. The switching value of cost gives the percentage with which the cost can increase before the NPV will be zero. At 8% discount rate this switching value is in the land-intensive option 94%. This breakeven analysis shows that from the point of view of uncertainty, the land-intensive

Table 5
Switching values of timber sale and cost at different discount rates

| Discount rate (%) | Switching value timber sale | | Switching value cost | |
|---|---|---|---|---|
| | Land-extensive option | Land-intensive option | Land-extensive option | Land-intensive option |
| 5 | 43 | 53 | 7 | 111 |
| 8 | 35 | 49 | 55 | 194 |
| 10 | 30 | 46 | 42 | 86 |
| 15 | 16 | 41 | 19 | 70 |
| 20 | 1 | 36 | 1 | 56 |

option is much more acceptable than the land-extensive option.

## 7. Discussion and conclusion

The land-intensive option with complete application of the CMS, thus including the CELOS Silvicultural System with only a relativily few post-harvest interventions, gives in the region of this study and under the conditions of this analysis, better financial results than the land-extensive option with only RIL. The conditions include that many data on harvesting cost had to be taken from other sources or had to be established by means of a best professional estimate. Data taken from other sources are not always related to the same circumstances, e.g. the data in the study of Barreto et al. (1998) are based on generally small-scale operations and a harvest of 38.6 $m^3$/ha which is a realistic option in the rich forests of Paragominas, but not in the forests near Manaus. The use of these data means on one hand that the productivity of skidding has been overestimated because of the smaller harvest in this case study and on the other hand has been underestimated because of the larger scale of operation. The results of the sensitivity analysis indicate, however, a substantial NPV for the land-intensive option both in an absolute sense and in comparison to the land-extensive option. The sensitivity analysis gives information about the change in NPV as result of a given change in costs or benefits, it does not inform about the probability of the change. As will be argued below, it may be expected that especially in the land-intensive option the probability of a decrease in benefits because of encroachment by settlers is smaller. A comparison with the profitability of other types of land use, such as pasture or agroforestry, has not been done.

The cycle length for both scenarios has a strong influence on the outcome of the study, and has not been based on local data but on long-term research from comparable forests in Suriname. This has been done awaiting more convincing increment studies based on local long-term research, for which a field experiment has been started in the enterprise several years ago. We still have the opinion that most preliminary and modelling studies for the region show too optimistic increment results for just-log-and-leave scenarios. To be more precise with demands on sustainability, the future harvest should not be composed with new second-quality species to replace the old assortment largely. It would mean a change (degradation) of forest productivity when first-class species now accepted were to be replaced in next harvest by lower quality wood species as yet unacceptable or acceptable only at low prices. This is not to say that it should not be acceptable as the strategy of an innovative enterprise, but it would dilute the sustainability concept as kept in this study.

The financial outcomes also are strongly influenced by the strategy that acquisition of all the needed forest land should be done at the very start of the operation to ensure the continuous supply of raw material to the mill. This strategy makes the land-extensive option rather expensive because a part of this land will be harvested only after a long time. The Brazilian law actually does not require such a secure supply and asks for the holding of much less terrain. Secure log supply for less than a decade is sufficient to obtain a licence for sawmilling. It should be noted that much sawmilling in the Amazon is with temporary mills, with consequently a low degree of industrialisation. Such industrialisation, making semi-manufactured articles from the sawn timber, appears to be profitable.

The reason why the strategy of complete land acquisition has been applied is that land use in the area is in a process of development even though MMI is not located in a frontier area. Therefore, the firm should take into account that forest land with an adequate stock will become more scarce in the future. It can be expected that additional forest land can not always be purchased on short distance to the mill and adjacent to the land already owned. This implies that the managed area would become fragmented, which makes it more difficult to control the forests, and increases the log transport distance in comparison to a coherent area. In the situation that no suitable forest land would be available at a reasonable distance, the mill could try to purchase raw material from other logging companies that then need to be certified for sustained forest management. Because a strategy of land acquisition spread in time does not guarantee sustainability it has not been analysed. In the assessment of such a strategy we have to consider that in a strategy of land acquisition spread in time it would have been realistic to take into account a real increase of the land price. Including such an increase would not change the conclusions of this research.

Application of the CMS in areas with a better site quality will result in a better response in annual increment than on poor sites of this case study, but this does not imply that financial results are automatically better on high quality sites. In both situations the same annual harvest can be achieved with a smaller forest area and a shorter cycle can be obtained. The financial results will depend on the price that has to be paid for forest land on this site. Further, the benefits of savings on cost of infrastructure and log transportation will be smaller on the smaller forest area. Research might be done to know the relation between site quality and the financial results of application of the CMS.

In Section 1, we have already pointed at the environmental implications of application of the complete CMS: a larger forest area in the region would be available for reservation as strict nature reserve and the conditions have been created that prevent degradation in managed timber-producing forests. The land use option with CMS is not merely expected to be sustainable because of its silvicultural characteristics but also because of its organisational setting. This setting includes integration with the timber processing industry implying the acquisition of land at the very beginning to secure raw material supply. The more intensive management on a relatively small area gives signals to settlers that may help prevent their encroachment.

The social aspect is another implication that has to be recognised. Application of CMS as compared to traditional harvesting systems and mere RIL involves the increase of employment, not only because of the additional silvicultural treatments but also as a result of the higher annual increment. Employment in the processing industry will be favourably affected. The creation of regional development opportunities may help avoid the non-optimistic scenario in the paper of Laurance et al. (2001) on processes of deforestation and degradation in the Brazilian Amazon, to become reality. Because of the expected positive effects on several national objectives, the proposed land-intensive option seems to generate a win–win situation. The perspectives on sustainable forest management this option offers, should therefore, encourage further research of several aspects, including the way incentive mechanisms—inclusive of institutional incentives—can stimulate its adoption by private forestry and the opportunities for a balance between timber production, strict nature reserves and agriculture.

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## Appendix A. Explanation to productivity and costs of Table 1

### *A.1. Unit costs*

Labour cost includes social taxes (65%), food cost (US$ 2 per man-day), administrative cost (US$ 1.1 per man-day) and other overhead costs 10% of the basic wage rate and additional labour costs. Total labour cost per day amounts to: chainsaw operator US$ 21.70; crew leader US$ 44; assistant US$ 16.94; crew leader (forester) US$ 76.00; machine operator and truck driver US$ 23.65.

Cost of trucks, frontloaders and skidders includes depreciation (purchase price-residual value/life-time), interest on average invested capital (8% of (purchase price-residual value)/2), diesel and oil use (US$ 0.7 and 2.8/l respectively), insurance 3% of purchase price annually and maintenance (US$ 36 per day). Tracked skidder: purchase price US$ 160,000, zero residual value after 6 years, insurance US$ 4800 per year, diesel and oil use 78.4 and 1 l per day respectively; wheeled skidder (purchase price US$ 170,000, zero residual value after 6 years), insurance US$ 5100 per year, diesel and oil use 78.4 and 1 l per day respectively; truck and trailer with 30 $m^3$ capacity (purchase price US$ 131,000, residual value after 4 years US$ 39,300), insurance US$ 3930 per year, diesel use 0.5 l per km, oil use 3 l per day; front loader (purchase price US$ 193,000, zero residual value after 6 years), insurance US$ 5790 per year, diesel and oil use 70 and 3 l per day, respectively; chainsaw (purchase price US$ 700, residual value US$ 140 after 3 years), lubrication use 1.8 l per day, maintenance US$ 400 per year. Filling station (purchase price US$ 6500, no residual value after 10 years). The costs of the filling station are included in cost of trucks, skidders and frontloader on base of diesel use.

### A.2. Management plan

Before a project will be approved by IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources) a general management plan has to be submitted. To draw up such a plan, an inventory of some plots throughout the forest area has to be done to have a base for the harvest plan, cutting cycle etc. It has been supposed that every 5 years such a management plan will be drafted by a forest engineer for the area to be managed in the coming 5 years, i.e. 15,000 ha.

### A.3. Extraction plan

IBAMA requires after approval of the management plan also an extraction plan, which includes maps with location of the roads, landings, skid trails, silvicultural activities, etc. A forest engineer with an assistant is responsible for the design of this extraction plan.

### A.4. IBAMA supervision

IBAMA has to approve the said plans and to monitor the implementation. A tax has to be paid to cover the cost of this supervision.

### A.5. Survey and tree mapping

Each UTM block (of 4 km × 4 km) is subdivided by line cutting into 10 ha management units (*talhoes*), oriented east–west. UTM blocks are permanently marked. Access lines are cut every 50 m along the 400 m plot borderline; pickets are placed every 50 m along the access lines. A team consists of a crew leader and five assistants. Cost includes US$ 1/ha material costs.

Trees of commercial species with a diameter at reference height larger than 40 cm are spotted and noted on a map. Tree parameters are assessed. All information is computerised in the office, to produce felling maps. A team includes a crew leader and four assistants. Cost of inventory includes US$ 1/ha material cost.

### A.6. Infrastructure

The forest company does layout and marking of roads, trails and landings. Layout and marking of roads are carried out by a team that consists of three assistants. A contractor does permanent and temporary road construction in the year of extraction of the compartment. Permanent roads are gravelled with a 10–15 cm gravel layer and have a track width of 5 m. Permanent road density is 7.16 m/ha and construction cost US$ 14 906/km.

The average permanent road length per annual cut of 3000 ha is taken to be 22 km. Temporary road density is 4.64 m/ha and construction cost US$ 6832/km. Maintenance for the intensive option is using the grader every two years for about US$ 440 per turn of 22 km, which makes US$ 20/km. For the incidental removal of stems from the permanent roads, when a vehicle passes by, no cost is reckoned. Permanent roads can also be used for silvicultural treatments in the land-intensive option.

A number of 84 landings per compartment of 3000 ha is constructed, each with a size of 40 m × 40 m. A team consists of a machine operator with a crawler tractor. Cost of layout and marking roads includes US$ 1.5/km material costs and cost of layout and marking of landings and trails includes US$ 1/ha material costs.

Temporary roads will be opened up again after 25 years for half the construction cost.

In the land-extensive option, the length of the permanent roads that will be maintained is gradually extended to a maximum of 100 km in 10th year. A part of this length has the function of main road and will be permanently maintained over the full 100-year cycle. The rest of the permanent road system is only temporarily maintained and is assumed to be reconstructed in the next 100-year cycle at full cost.

### A.7. Felling operations

Trees to be felled are indicated on a computer printed felling map. Felling is carried out by crews trained in directional felling, in a way that winching and skidding from the stump is easiest. Fellers have to give priority to avoidance of damage to PCTs. Logs are numbered with plastic tags directly after felling and a list is kept. A team consists of a crew leader/chainsaw operator, a chainsaw operator and an assistant and they have two chainsaws available. Three teams operate in the compartment.

### A.8. Log extraction

Opening skid trails—27.6 m/ha is done by a team consisting of a machine operator with a tracked skidder.

The distance between adjacent skid trails is on average 100 m, so that the winching distance is at maximum 50 m. If possible, and this is nearly always so, a log is fully winched from the stump to the skid trail with the tracked skidder. On the skid trail the logs are picked up by a wheeled skidder with a skidder-mounted grapple and subsequently transported to the landing where a worker organises stacking of the logs and fills out a form to have statistics on work progress and timber stock. Pre-concentration is implemented by a team consisting of a machine operator with tracked skidder, a chainsaw operator with chainsaw and an assistant. Skidding is done by a machine operator with a wheeled skidder, furnished with a grapple.

### A.9. Log transportation

Loading of trucks on the landings is done by one operator with a front-end loader. Bucking at the landings is restricted to logs that exceed the capacity of the trailer. Truck transport is done by a truck and trailer with a driver.

It has been assumed that the forest land that is harvested is the same in both options during the first 25 years. As a result, the distance from the landings to the sawmill does not differ between the options during this period. After this period, the average distance in the land-extensive option is supposed to be twice that in the land-intensive option, 50 and 25 km respectively, although the forest area in the land-extensive option is four times that in the land-intensive option. The shorter distance in the land-intensive option means not only that the direct costs of transport (such as that of diesel) decrease, but that also a saving on investment can be achieved because only two in stead of three trucks and trailers are needed.

### A.10. Silvicultural treatments

Treatments in the land-intensive option include a selective liberation thinning with an effective reduction of the competition for PCTs. To that end about 14 large trees per hectare are girdled in the first treatment just after logging. The next treatments are carried out in years 9 and 16. These less intensive treatments take only two third of the time of the first treatment. This scheme was derived from intensive research done in Suriname in the 80s, and is more intensive than actually will be needed to execute in the enterprise. A team consists of a crew leader and three assistants.

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