Sustainable forest management for smallholder farmers in the Brazilian Amazon: The experience of the Pedro Peixoto Settlement Project

Marcus V.N. d'Olveira[1] , M.D. Swaine[2] , David F.R.P. Burslem[2], Evaldo M Bráz[1], Henrique J.B. de Araujo[1]

Abstract

The paper describes a forest management system to be applied on smallholder farms, particularly on settlement projects in the Brazilian Amazon. The proposed forest management system was designed to generate a new source of family income and to maintain forest structure and biodiversity. The system is new in three main characteristics: the use of short cycles in the management of tropical forests, the low harvesting intensity and environmental impact, and the direct involvement of the local population in all forest management activities. It is based on a minimum felling cycle of ten years and an annual timber harvest of 5-10 m^3 ha^{-1}.

Keywords: *forest management, timber harvesting, silviculture*

Manejo florestal sustentável para pequenos agricultures na Amazônia brasileira: A experiência do Projeto de Colonização Pedro Peixoto

Resumo

Este trabalho tem o objetivo de apresentar um sistema de manejo florestal para ser aplicado em pequenas propriedades rurais, especialmente em projetos de assentamento da Amazônia Brasileira. O sistema proposto foi desenhado para gerar uma nova fonte de renda familiar e manter a estrutura e biodiversidade das florestas manejadas. O sistema é novo em três características principais: o uso de ciclos curtos no manejo de florestas tropicais, a baixa intensidade de corte e baixo impacto ambiental e o direto envolvimento das populações locais em todas as atividades do manejo florestal. O sistema é baseado em um ciclo de corte mínimo de 10 anos e um corte anual de madeira de 5 a 10 m^3 ha^{-1}.

Palavras chaves: *manejo florestal, exploração florestal, silvicultura*

Introduction

Timber harvesting in the Brazilian Amazon, as still practiced today, is a predatory activity. The formal management system as prescribed by IBAMA, the Brazilian Institute for the Environment and Natural Resources, is only possible on large properties where investment potential is high, and even then is only occasionally viable when strictly applied (EMBRAPA 1996). A change in the dominant paradigm governing forest management is required if the small producers, such as colonists and rubber tappers, are to become involved. This change is needed to allow the implementation of techniques and levels of intervention appropriate to the scale of the production and the availability of investment capital.

According to the Brazilian Forest Code, 50% (later set up to 80%) of the area of a property (for properties with less than 100 ha) in the Brazilian Amazon must be preserved as a legal forest reserve, i.e. it cannot be converted to agricultural land or pastures. The only legal commercial uses of this land are extractivism and sustainable forest management. However, despite government efforts to control land use in the Amazon, some areas have already been converted to shifting cultivation and pastures. For instance, in 1994 the mean area deforested on farms sampled in two settlement projects in the States of Acre and Rondônia was 40% of the total area, representing a

[1] Researcher, EMBRAPA/CPAF-Acre, Rio Branco, Brazil. CEP 69901-180, Caixa postal 392
[2] Department of Plant & Soil Science, Aberdeen University, Aberdeen AB24, UK.

mean deforestation rate of natural forest of 2.4 ha yr^{-1} (Witcover *et al.* 1994). Assuming the same deforestation rate in 1999 as in 1994, average farmers on these settlement projects are reaching the limit of 50% they can legally slash-and-burn for shifting cultivation or pasture establishment. It is likely that they will not stop, or even reduce, the deforestation rate on their properties unless they can find an economic use for their forests.

In this paper we will present a forest management system designed for small farmers in settlement projects of the Brazilian Amazon, and examine its sustainability by monitoring forest harvesting operations and forest dynamics. The forest management system aims to generate a new source of household income, thereby alleviating poverty and increasing quality of life. In addition, it maintains the structure and biodiversity of the legal forest reserves, conferring more value to the forest resource than alternative forest uses (Dickinson *et al.* 1996) and increasing their importance for conservation.

Description of the proposed system

History

Traditional timber harvesting methods have been applied since the beginning of forest exploitation in the Amazon. The main characteristic of these methods is the low level of technology applied which results in low production and a low financial return, but resulting in low environmental impacts (Oliveira 1992). However, these traditional methods have not yet been formalised as a silvicultural system nor documented sufficiently to allow its broad systematic application. The model we are proposing is a formalisation of these traditional methods.

In the *várzeas* or flooded areas of the Amazon Basin "riverine" populations of small farmers have been harvesting timber for generations. In Amazonas State the production of timber by riverine populations of small farmers represents a significant proportion of total wood production (Santos 1986, Bruce 1989, Oliveira 1992). Because of the low harvesting intensity (because only a few species are utilised and because of the high diameter felling limit) the practice as a whole is considered environmentally sound (Oliveira 1992). This practice is sometimes also common in the *terra firme*, high land forest but varies in intensity according to access and market proximity. In both, i.e. *várzeas* and *terra-firme* cases, the sustainability of the system is determined by the farmers' capacity to extract wood and the opportunity that they have to sell it, due the absence of rules and control.

The extraction of timber by small producers is a seasonal activity. This permits producers to continue other essential activities (hunting, fishing, non-timber product extractivism and subsistence agriculture), which makes an integrated management system feasible and promotes sustainable production without damaging the forest ecosystem (Oliveira 1992). The existence of these traditional timber harvesting methods is proof of the ability of local people in the Amazon to implement forest management activities. Furthermore, the fact that they have been implementing these methods for generations is a strong indication that forest management can be done in a sustainable way.

Ecological basis

Selective logging creates disturbances akin to natural tree falls and canopy openings that stimulate the growth of advanced regeneration (Uhl *et al.* 1990). The conventional mechanised timber harvesting methods create a large number of gaps, all at the same time (Johns *et al.* 1996). Large gaps may take a longer period to recover than small gaps because succession starts at the pioneer phase. Pioneer plants establish and grow rapidly in response to canopy opening, but the desirable commercial species are set back in their growth because of competition with the pioneers, which imposes a longer cutting cycle and reduces yield (Hendrison 1990). Smaller gaps may be closed rapidly by the crowns of trees surviving or recovering from the felling impact (Hendrison 1990).

In addition, because mechanised logging operations are not usually planned, forest damage is greater, with the opening of unnecessary skid trails and excessive skidder manoeuvring (Uhl and Vieira 1988, Oliveira and Braz 1995, Johns *et al.* 1996). On the other hand, if the impacts of logging are distributed over time, a lower number of gaps will be created at the same time. Therefore it is likely that in a non-mechanised system the contribution of pioneer species to the natural regeneration will be lower, and the contribution of the desirable species will be greater. We suggest that the natural regeneration of desirable species is promoted by distributing the impacts over a longer time period as well as more uniform in space. Reduced competition from pioneer species might lead to a greater net yield of desirable species and lower amounts of damage to the forest ecosystem. The proposal is based on the hypothesis that low-impact disturbance at short intervals, combined with silvicultural treatments (e.g. liana cutting, refinement and natural regeneration conduction) will create gaps of different ages and permit the maintenance of a forest with a similar structure and biodiversity to that of the original natural forest. The canopy opening associated with felling will allow young trees (less than 50 cm dbh) to grow faster, some of them reaching commercial size during the period.

The management of the commercial species will be determined by their ecological and silvicultural aspects (e.g. growth rates, maximum size, distribution and seed production and dispersal). As a result the production system will have a tendency to focus on the dominant, fast growing commercial species. Harvesting at ten year intervals will allow seed production and regeneration because most of the reproductively mature trees will be retained within the residual stand, in contrast to uncontrolled long-rotation production systems in which entire populations of adult trees can be removed at harvesting. Retaining seed trees between harvesting events helps to maintain the genetic diversity of populations over time, particularly for species with intermittent reproduction and buffers the population against the possibility of stochastic disturbance events eliminating smaller size classes (Primack 1995).

Short cycles and harvesting intensities

There are many factors affecting decisions about cutting cycle length. The final choice is a balance of these factors as weighted by management objectives. The most important factors are species composition, financial needs and site. The use of short cycle avoids the larger impact caused by heavier interventions. Instead of harvesting all trees of commercial size at one time, they will be felled over three felling cycles. In general, shorter cutting cycles allow better biological control than longer cycles because diseased or infested trees can be cut more often. It is also easier to salvage dead trees, if the smaller trees are marketable. On the other hand there is the need for a minimum harvesting volume intensity to make the activity economically viable. In addition, when working with small properties the cutting cycle may be shortened so that it equals the number of annual felling compartments in order to create an annual income that allows the owner to pay taxes and forest management costs (Leuschner 1992).

Polycyclic silvicultural systems have been criticised for the damage they cause to the soil and the residual trees, because of the need to return to the forest at short intervals (Dawkins and Philip 1998), but this damage can be minimised by re-utilising old logging roads and skid trails, and through better planned and controlled logging operations (Silva *et al.* 1989, Braz and Oliveira 1995)

In the case of the PC Peixoto, the decision on cutting cycle length considered its particular characteristics such as the small forest areas (no greater than 40 ha), the short period of time to execute all operations, the limited labour availability and the use of animal traction for extraction. The small size of the felling area prevents the creation of many compartments (Figure 1) and

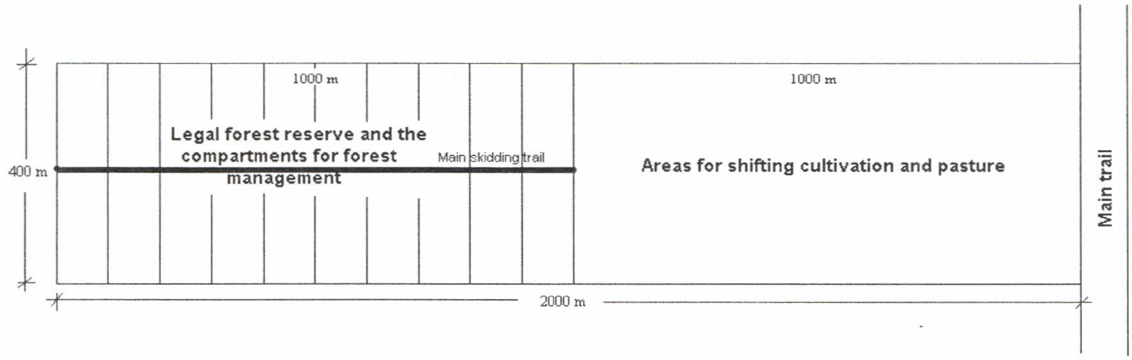

Figure 1. Layout of a typical farm on the PC Peixoto showing the distribution of agricultural land (crops and pastures) and the legal forest reserve (with the compartments and main skid trail indicated)

eliminates the possibility of using long cycles. The other characteristics also predispose the system to the use of short cutting cycles. Animal traction drastically reduces harvesting damage relative to the opening of skid trails (Dykstra and Heinrich 1992) and the limitation of time and labour reduces production.

The annual harvesting was determined on the basis of a minimum felling cycle of ten years and harvesting intensity of 5-10 m^3 of timber per hectare. A short cutting cycle has the advantage of increasing the frequency of silvicultural interventions in the forest, which diminishes the time needed for the forest to recover and decreases the risk of replacement of the forest by other agricultural activities. However, short cycles would limit production per hectare since it cannot be combined with heavy harvesting because the forest would not recover within the length of the cycle. Under short-cycle systems, harvesting operations must be well planned to minimise damage to the residual trees. Thus, the use of mechanised logging in short-cycles systems is probably limited for both economic and technical reasons. However, light mechanisation (e.g. the use of small tractors for the removal of the planks to the main skid trail) can be considered for the future.

We have based the harvesting recommendations on a conservative yield estimate of 1 m^3 ha^{-1} yr^{-1} (Silva *et al.* 1996), although we envisage that predicted yields may increase in the future following the growth studies on permanent plots. In terms of usable timber volume the net increment of a managed forest can be increased silviculturally up to 5 m^3 ha^{-1} yr^{-1} (Miller 1981, Silva *et al.* 1996). For the moment, the low yield predictions are based, in part, on the low level of silvicultural intervention that will be used. An additional harvesting rule will be applied, whereby a maximum of one third of the total commercial volume (stems of commercial species > 50 cm dbh) is taken. A similar harvesting rate was used in Osa Peninsula, Costa Rica, where all trees with dbh above 60 cm were felled in three cycles of ten years (Howard 1993). This rule guarantees that there will be at least three rotations of the management system.

The volume of commercial timber in the study site is currently around 20-30 m^3 ha^{-1}. Although the conventional forest management system in the Amazon employs a harvesting rate around 30 to 60 m^3ha^{-1} on a cutting cycle of 30 years, it does not usually exceed 30 m^3 ha^{-1} (Johns *et al.* 1996). Thus, the outcome in terms of yield will be equivalent to the standard rotation of 25-30 years established by IBAMA (the Brazilian Institute for the Environment and Natural Resources) for mechanised management. The annual felling rate should not fall below 5 m^3 ha^{-1} $cycle^{-1}$, otherwise harvesting is likely to be uneconomic returning less than the minimum salary practised in Brazil (around US$ 100). Also it is important to recognise that low harvesting rates will only work as a silvicultural system if implemented in short cutting cycles.

Techniques and basic concepts

The formalised systematic application of the forest management practices used by small farmers in the Brazilian Amazon requires the implementation of techniques for the evaluation of the production capacity of the forest, planning of harvesting activities, and monitoring (Braz and Oliveira 1996) Formalisation of these procedures helps to reduce *ad hoc* changes in the method when external conditions change, such as falls in the price of extractivist products, economic recession or third-party greed. In the absence of formal procedures, short-term changes in economic circumstances undermine the long-term perspective required for sustainable forest production by small producers and may lead to fluctuations in harvesting rates and damaging impacts on the forest.

Forest inventory. The main objective of the forest inventory is to characterise the structure and species composition of the forest and identify the potential for wood production. During 2000 EMBRAPA has planned to perform an inventory of the whole forest area of PC Peixoto (150,000 ha). This inventory will be used for future forest management planning.

Prospective forest inventory. A prospective forest inventory is performed in the compartments one year before harvesting. All trees with dbh > 50 cm are measured, marked and plotted on a map. The purpose of this inventory is to allow planing of harvesting activities, defining the trees to be treated, logged or preserved and other features when necessary (e.g. streams and topographic variation). The resulting map also allows the location of the skid trails and areas for preservation to be planned.

Tree felling and conversion of logs to planks. Trees are directionally felled to facilitate their transport and minimise damage to the forest. The logs are converted by chainsaw or one-man sawmills into planks, boards or other products according to the characteristics of the timber and market demand. After felling the tree, the conversion of logs to planks is performed in the forest. This phase is the most expensive and labour-intensive component of the entire system.

Plank skidding. In *terra firme* forests, such as at Pedro Peixoto, there is a need to saw the logs into planks or boards to allow animal traction to be used for skidding them from the forest to the secondary roads. Haulage by animals has the advantage of generating less soil compaction and modification, and less damage to residual trees, than mechanical skidding equipment (Dykstra and Heinrich 1992, Ocaña-Vidal 1990; FAO 1995). For this system, a main skid trail crossing the middle of the compartment is created, perpendicular to the direction of the nearest secondary road (see Figure 1). This trail is permanent and opened according to the need for management implementation from the first to the tenth compartment in a rate of 100 m (the width of the compartment) per year (Figure 1). The main skidding trail (around 1.5 m in width) is wide enough to allow the passage of small wagons pulled by animals. The skidding of the planks is performed in two stages, the first from the felled tree to the main skid trail with the use of a "zorra" (an implement used regionally to skid planks) and the second stage from the main skid trail to the secondary road, where the primary transport of the planks is by wagon.

Silvicultural treatments. One year before felling, climbers are selectively cut in the compartments to be harvested, at the same time as the prospective inventory is being carried out. Climber cutting has long been considered a useful silvicultural tool and, by cutting climbers sufficiently ahead of time, damage caused by felling in climber infested areas may be significantly reduced (Fox 1968, Liew 1973).

Monitoring forest dynamics. The monitoring of the forest responses to forest management is carried out through the study of forest dynamics (growth, ingrowth, recruitment, damage and mortality) in permanent sample plots (PSP). The PSPs are 1 ha each and the measurements are started one year before harvesting and will be performed at three years intervals.

The sequence of operations defining the forest management system is as follows:

1) A forest inventory one year before the first harvesting is conducted
2) Compartments are established
3) A 100 % prospective inventory of trees > 50 cm dbh and tree mapping are conducted
4) Species are selected and the felling rate determined
5) Logging is conducted
6) Desirable species are planted in felling gaps and on skid trails after logging
7) One year after logging PSP are measured (to assess logging damage and for stocking estimation)
8) Three and five years after logging the PSPs are again measured
9) Bad formed or undesirable trees are removed five years after logging
10) Ten years after logging the PSPs are measured

Methods

Site description

The PC Peixoto was created in 1977 in an original area of 408,000 ha (afterwards 378,395 ha) involving the municipal districts of Rio Branco, Senador Guiomar, and Plácido de Castro and planned for the settlement of 3000 families (Cavalcanti 1994). The forest management is carried out in two trails on the road BR363 (from Rio Branco to Porto Velho), 80 km and 90 km far away from Rio Branco. The experience involves 11 farms with 80 ha each and a forest management area of 40 ha each, thus totalling 440 ha.

The nearest meteorological station to the area is the CAPAF- Acre meteorological station at 160 m altitude, latitude 9°58'22" S and longitude 67°48'40" W. The climate is classified as Awi (Koppen) with an annual precipitation of 1890 mm yr^{-1} and an average temperature of 25°C (all data from EMBRAPA 1996a, b).

Forest inventory

The forest inventory was carried out in the 440 ha under forest management, comprising the 11 legal forest reserves of around 40 ha each. A systematic sampling design was used with plots of 10 x 100 m distributed along ten lines. There were 20 plots for each area, totalling 214 samples and a sampled area of 21.4 ha, or 4.87 % of the forest area under management. Later these lines were used as access routs for the implementation of activities prescribed in the management plan. All plants greater than 10 cm dbh were measured and identified. Natural regeneration (individuals taller than 1.5 m and less than 10 cm dbh) was sampled in 10 x 10 m sub-plots located in the first 10 m of each plot. The species were identified by "mateiros"[3] (usually local people with large experience in field identification of tree species) using vernacular names.

Timber harvesting

Tree-felling and conversion of logs to planks. The data were collected at four logging events, using trees from 45 to 97 cm dbh of three species (*Guarea pterorachis*, *Hymenolobium excelsum* and *Dipteryx odorata*). A total of 28 logs each of 2.2 m in length were processed, by a team of three men. The study considered three different phases: felling the tree, cutting the log and converting the logs to planks. The time required for each phase was measured and the efficiency of the conversion measured as the rate of the final volume in planks by the initial volume of the logs.

[3] Provided by FUNTAC, the Acre State Technological Foundation.

Planks skidding. The data were collected in five skidding events and 40 skidding cycles, where planks of four species were being skidded (*Couratari macrosperma*, *Dipteryx odorata*, *Protium apiculatum* and *Peltogyne* sp.). The skidding distances varied from 200 to 1400 m and the planks were loaded onto a "zorra" (implement used in the region to skid planks). In this study we considered a skidding cycle as: the travel unloaded from the edge of the secondary road to the felling gap in the forest, loading of the planks, the time to travel back to the secondary road and the unloading of the planks. The time need to rest the animals was considered as "wasted" time. The skidding was performed with two teams of two men working with an ox on each team. The oxen used for skidding the planks were two individuals of the Nelore breed of age five and eight years and a weight around 500 kg.

Forest management general costs and economic analysis. The costs were estimated on the basis of the minimum salary offered in Brazil in 1997 (US$ 100.00 per month), a working day of six hours, a five day working week and a team of three people for all activities except the skidding of the planks, where the team consisted of only two men. The depreciation of the chainsaw was calculated as 25 % yr^{-1}, and the useful life of the oxen 10 years. The harvesting and conversion of the logs to planks was performed with a Stihl 051 chainsaw.

Results

Forest inventory

Structure and floristic composition. The vegetation is predominantly evergreen tropical forest with some deciduous species (e.g. *Tabebuia serratifolia*, *Ceiba pentandra* and *Cedrela odorata*. The forest variees from open (low stature forest with a dense understorey and high occurrence of lianas and palm trees) to dense (taller forest with greater standing timber volume and no dense understorey), according to the drainage (streams formation and design) and topographic status of the site. In the samples of the systematic forest inventory 307 species were identified, drawn from 185 genera and 54 families. The most common family was the Caesalpinaceae, with 18 genera and 23 species sampled. The distribution of the species across the area was very irregular, with some species common (e.g. *Protium apiculatum*) whilst other rare species were sampled only once in all 214 samples (e.g. *Macrolobium acaceifolium*).

The forest had an average of 375 trees ha^{-1} (trees > 10 cm dbh), an average basal area of 22 m^2 ha^{-1} and a total volume of 180 m^3 ha^{-1}. The volume of trees below 50 cm dbh (i.e. commercial size) was 107.4 m^3 ha^{-1} and the volume of trees above 50 cm dbh was 73.1 m^3 ha^{-1} (Table 1).

Table 1. Results of the forest inventory at PC Peixoto showing mean values of tree density basal area, volume, the standard deviation and 95 % confidence interval for estimates of total volume

Total volume of timber (dbh > 10 cm) average	180.4 m^3 ha^{-1}
Standing volume (dbh > 50 cm)	73.1 m^3 ha^{-1}
Standing volume (10 cm > dbh > 50 cm)	107.4 m^3 ha^{-1}
Basal area	22.0 m^2 ha^{-1}
Volume Confidence Interval (p > 0,05)	
Minimum	171.0 m^3 ha^{-1}
Maximum	189.7 m^3 ha^{-1}
Standard deviation	71.6
Standard error (%)	4.8
Average number of trees (dbh > 10 cm) ha^{-1}	375.4

Timber harvesting

Tree-felling and conversion of logs to planks.- The efficiency of conversion (in volume terms) of logs to planks was between 61 % and 41 % for the biggest and smallest trees respectively, with an average of around 50 %. The total time to convert one cubic metre was 5.1 man-hours. For a 6-hour working day a team of three people were able to produce 3.6 m^3 of sawn timber, which represents a very low productivity even when compared with a small sawmill (around 10m^3 day^{-1}). On the other hand, as the annual potential production of these farms is only about 40 m^3 (10 m^3 ha^{-1} x 4 ha $year^{-1}$), the maximum annual labour requirement is therefore only about 18 man-days to convert this un-sawn timber into about 20 m^3 of planks (Table 2).

Table 2. Means and standard deviation of the man-hours required to complete each of the phases involved in felling trees and converting the timber into planks in the PC Peixoto

Phase	Time per tree (man-hours)	Sd	Time for 1 m^3 (man-hours)
Cutting the tree	0.5	0.20	0.1
Cutting the logs	1.0	0.07	0.2
Converting logs to planks	23.0	0.80	3.5
Chainsaw maintenance	6.0	0.88	0.9
Wasted time	1.8	0.32	0.4
Total time	32.3	1.97	5.1

Skidding the planks.- The number of skidded pieces varied between one to four per ox per trip, according to their shape and weight. The load therefore varied from around 0.19 m^3 (*Dipteryx odorata*) to 0.39 m^3 (*Couratari macrosperma*) with an average of 0.28 m^3. The loading and unloading of the "zorra" was also strongly affected by the shape and specific weight of the wood. The pace of the oxen was approximately 4 km hr^{-1} and was kept constant even when the skidding distance increased from 200 to 1200 m. However, when the distance increased to 1400 m the time required to load and unload the zorra was not long enough to rest the animals for continuous operation. The total volume skidded in one day by a team of two men and one ox varied according to skidding distance, from 1.14 m^3 (skidding distance 1400 m) to 3.36 m^3 (skidding distance 250 m) (Table 3).

Table 3. Breakdown of the performance and volumes skidded by two teams of two men with one ox per team over three skidding distances (200, 1200 and 1400 m) in the managed forest of the PC Peixoto

Skidding distance (m)	200	Sd.	1200	Sd.	1400	Sd.
Effective work day average (men $hour^{-1}$)	13.7		11.00		12.30	
Total wasted time per day (men $hour^{-1}$)*	0.5		1.0		2.00	
Average time for complete cycle (men $hour^{-1}$)	1.1	0.19	1.7	0.13	1.10	0.45
Number of cycles per day	12		6		6	
Average volume skidded per cycle (m^3)	0.28	0.07	0.28	0.04	0.19	0.07
Average volume skidded per hour (m^3)	0.43		0.26		0.13	
Total volume skidded by day (m^3)	3.36		1.68		1.14	

*The time to rest the animal was accounted as wasted time

Costs and economic analysis of the proposed forest management system.- The production costs were between US $ 33.5 and U$ 35.5 per cubic metre of sawn planks at the road-side before transport to the market (Figure 2). Considering the costs of transportation at around US $ 15 m^{-3} the total costs would be around US$ 50 m^{-3}.

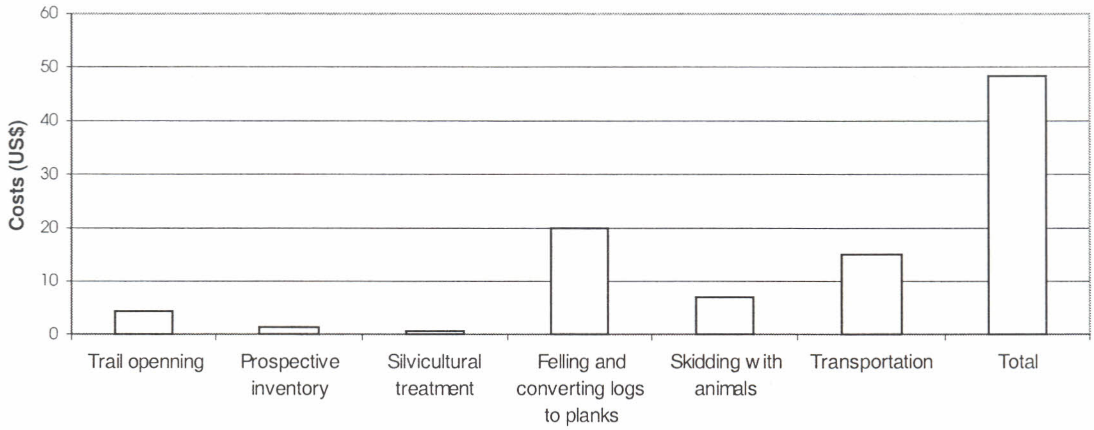

Figure 2. Mean and total costs of each phase of the forest management system per cubic metre of harvested timber (US$) in PC Peixoto

Discussion

Timber harvesting

For the management system proposed here the short cutting cycle should provide for continuing benefits of enhanced growth of the residual trees. Nevertheless, additional silvicultural treatments should be considered, such as the elimination of badly formed trees, refinements (of undesirable species), crown liberation (for commercial species) and gap liberation. The proposed system will facilitate the application of silvicultural treatments, which are planned as part of the conventional system but (due their high labour demand and costs) are usually not executed. The implementation of liana cutting, directional felling and skid trail planning reduce the damage caused by logging and extraction and contribute to the maintenance of forest productivity (Pinard and Putz 1996). In the future, with more data on forest dynamics, new silvicultural techniques should be applied to improve yields. The use of the "zorra" over long distances reduces the productivity of this phase. Alternatively, a small wagon pulled by one ox has been tried for the primary transport of the planks from the main skid trail to the edge of the secondary roads. Under this scenario the skidding by "zorra" is limited to the distance from the felled tree to the main skid trail, or a maximum journey of 200 m, which will not compromise the productivity of the overall operation.

Market, economic and social benefits

There is a potential market for plywood species (e.g. *Ceiba* spp.), which was not considered due to the low prices in the local market for the wood sold in logs. The group of commercial species is changing quickly. The constant restrictions on the availability of timber of certain highly valued species, combined with international pressure for preservation of some of these species, has created a strong incentive for the introduction of new species to the market. The price of timber is likely to increase in the future because of the rise in the demand for tropical timber worldwide and the restriction in supply, especially of the more valuable timbers. Therefore, the current standing stock of timber represents an investment rather like a savings account. This may be true even for stems of species which are not highly valued at present. The current market price for this kind of wood in Rio Branco varies between US $ 100 and US $ 150 m^{-3}, according to species and the quality of the planks. Even with the low-level of technology and experience available to the farmers for this activity, it was possible to achieve ratio of benefits to costs of around 2:1 (Figure 2). In similar conditions (small-scale forest management for timber production, animal traction, and conversion of logs to planks by chainsaw) Castañeda *et al.* (1995) in Nicaragua found a return of U$ 47 per workday and production costs around U$ 43 to U$ 65 per cubic metre.

However, it must be recognised that the system has a low profitability when compared with the yields obtained by mechanised forest management. A low profitability is to be expected for a system designed to be applied in communities with a shortage of investment capital. In this case the social benefits obtained by returning low profits to the colonists rather than higher profits to forestry companies, can be used to justify the application of the system. On the other hand, the other available land use options for small farmers and colonists (shifting cultivation, extractivism and small-scale cattle ranching) also usually return low profits. Furthermore, the aggregation of producers into larger units may facilitate the acquisition of new technologies (e.g. one-man sawmills, oxen and small tractors), result in increased prices in local markets and reduced costs of overheads such as transport. Collective working might generate a substantial increase in the yields from forest management and our expectation is that within a short time the profits generated by forest management as proposed here will increase significantly.

Small-scale forest management provides an opportunity to fill a gap in land use in the Amazon, by allowing small farmers to use the forest reserves on their properties in an economic and sustainable way. Forest management will help to maintain and preserve these reserves, which are currently under strong pressure to be converted to pastures and shifting cultivation. However, for the consolidation of this proposal some changes to forest legislation will be necessary and policies must be implemented to enforce and promote these changes. A specific legislative framework covering inspection and implementation of management plans on small properties was approved in 1998. This legislation established the use of short cycles and animal traction by IBAMA agencies.

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