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Revisiting the Palcazu Forest Management Model and its sustainability for timber extraction in the tropics

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SUMMARY

The Palcazu Forest Management Model was introduced to the tropics in the 1980s to incorporate social, ecological and economic considerations for the development of the Palcazu Valley, Peru. The development of the Yanesha Forestry Cooperative was the social benefit; the use of strip clear-cutting to promote rapid regeneration of timber species was the ecological benefit; and the complete use of timber from the clear-cut strips was the economic benefit. The sustainability of the Palcazu forest management model is discussed based on the interaction of factors that affected its performance. Apart from adverse social and economic policies, there was no social inclusion of the Yanesha to the project, limited knowledge of strip clear-cutting in the tropics, and low timber productivity, along with low profits and high costs in its first harvest. As originally proposed, the Palcazu forest management model is not sustainable, but several modifications could make this model financially viable.

Keywords: Natural forest management, community forestry, Peru, Amazonia

Révision du modèle de gestion forestière du Palcazu et sa durabilité pour l'extraction de bois dans les tropiques

X.J. RONDON, D.L. GORCHOV et F. CORNEJO

Le modèle de gestion forestière du Palcazu a été introduit dans les tropiques dans les années 1980 pour incorporer des considérations sociales, écologiques, et économiques au développement de la vallée du Palcazu au Pérou. Le développement de la coopérative forestière yanesha correspondait au bénéfice social, l'utilisation de la coupe rase pour promouvoir la rapide régénération des espèces forestières était le bénéfice écologique, et l'utilisation complète du bois issu de la coupe rase était le bénéfice économique. La viabilité du modèle de gestion forestière du Palcazu est discutée en fonction de l'interaction des facteurs qui ont affecté sa performance. En plus de politiques sociales et économiques adverses, les Yaneshas n'ont pas étaient inclus au projet, les connaissances sur la coupe rase étaient limitées dans les tropiques, et la production en bois était faible avec peu de profit et des coûts élevés lors de la première coupe. Comme il a été proposé à l'origine, le modèle de gestion forestière du Palcazu n'est pas durable mais plusieurs modifications pourraient le rendre financièrement viable.

Revisión analítica sobre la sostenibilidad de el Modelo de Manejo Forestal el Palcazú para la extracción de madera en los bosques tropicales

X.J. RONDON, D.L. GORCHOV y F. CORNEJO

El Modelo de Manejo Forestal el Palcazú fue aplicado por primera vez en el Valle del Palcazú, Perú, a principios de 1980, incorporó aspectos sociales, ecológicos y económicos para el desarrollo y el manejo forestal del valle. A través de este proyecto se creó la Cooperativa Forestal Yanesha y se utilizó la tala rasa en fajas en la extracción de madera, el cual prometía una rápida regeneración de especies maderables y un aprovechamiento integral del recurso. En este artículo se analiza la sostenibilidad del modelo Palcazú, examinando los factores más determinantes que influyeron en su rendimiento. En aquel tiempo los proyectos forestales enfrentaban adversas políticas económicas y sociales. En el proyecto no se fomentó la inclusión social de los Yanesha y se tenía un conocimiento muy limitado sobre la ecología de la tala rasa en fajas, especialmente en los bosques tropicales. La fase operativa del proyecto fue afectada por la baja producción de productos maderables, bajos ingresos económicos y altos costos en la primera extracción. Concluimos que el modelo de manejo forestal el Palcazú, como fue propuesto originalmente, no es sostenible, sin embargo ciertas modificaciones podrían hacerlo económicamente viable.

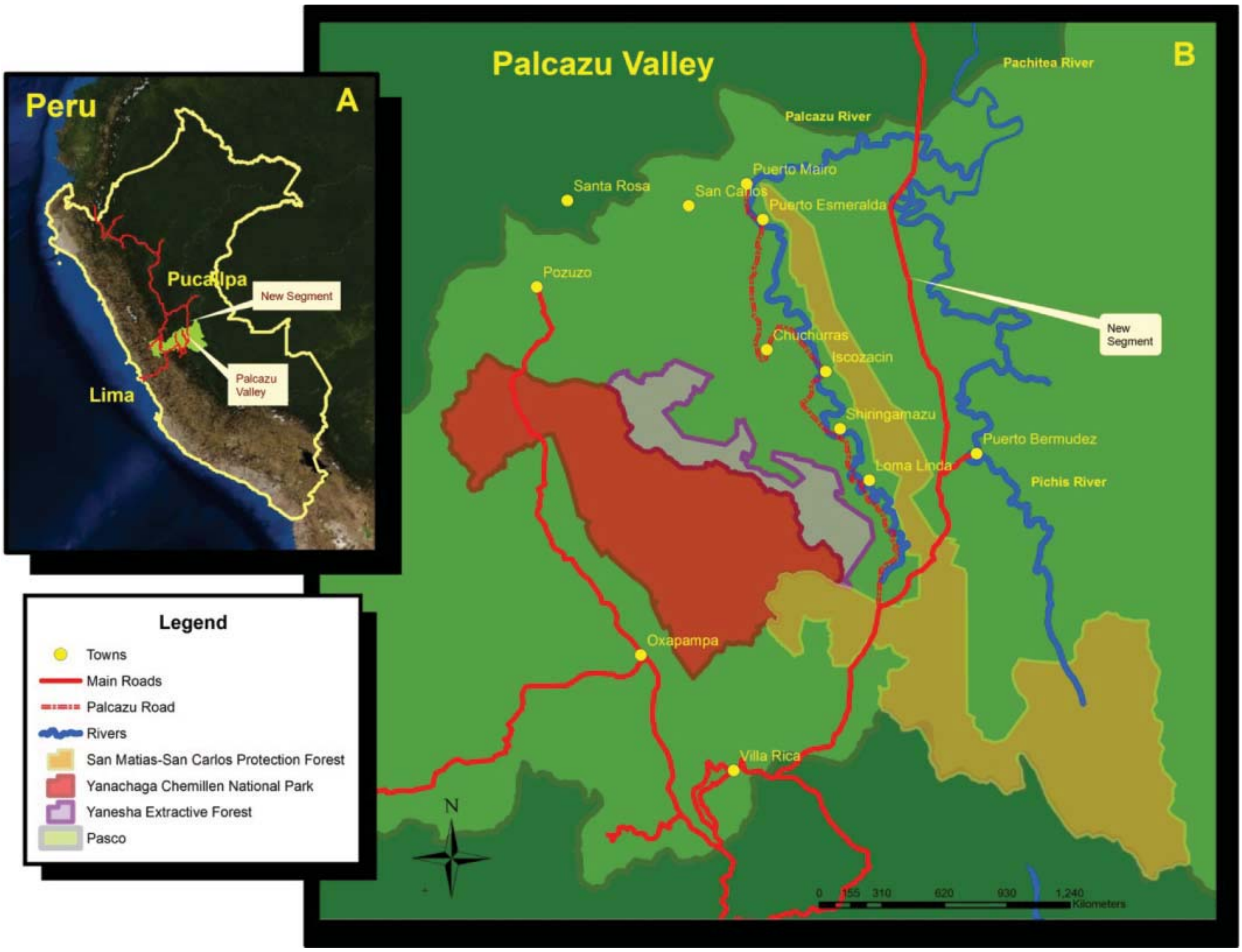
INTRODUCTION

The construction of the Marginal Highway system (*Carretera Marginal*) in Peru began in the mid-1960s, aiming at promoting geographic and economic integration of the Andean foothills of the Amazon to the rest of the country (Brack 1981, Horna 1976). This policy gave rise to 'special projects in the Amazon' (*Proyectos Especiales en Selva*), designed to assist in infrastructure construction, colonization and developmental programs (Brack 1981, Horna 1976).

The Pichis-Palcazu Special Project (PEPP) was one of the projects designed to contribute to the development of the central region of the Peruvian Amazon (*Selva Central*) (Figure 1A). PEPP intended to open the Pichis and Palcazu valleys for colonization and advancement of the agricultural frontier. The project called for the improvement and extension of fair-weather feeder roads to connect the main road starting in Villa Rica and ending at the junction of the Tingo María-Pucallpa Highway with the Marginal Highway system (Figure 1B) (Hartshorn 1981). Additional feeder roads were to connect the Pichis and Palcazu valleys to the main road (Figure 1B).

To finance PEPP, President Fernando Belaunde of Peru requested funds from several foreign developmental aid agencies (Hartshorn and Pariona 1993). A feasibility study, however, found the land unsuitable for agricultural development; consequently, the World Bank denied funding support for the colonization aspect of the Palcazu-PEPP component (Rich 1983). Despite the World Bank's lack of support, the U.S. Agency for International Development (AID) agreed to finance a pilot project in the Palcazu valley to test the suitability for sustained productivity without colonization, based on newly conducted assessments (JRB 1981, Tosi 1982). These assessments created a life zone map, preliminary inventories of flora and fauna, and studies of the sustainability of local crop and livestock production systems (JRB 1981). Moreover, USAID assessments confirmed the unsuitability of valley for agricultural development, but suggested the use of forestry production and protected areas (Tosi 1982).

FIGURE 1 *Location of the Palcazu Valley and the northern section of the Marginal Highway system (Carretera Marginal) going through Pasco (A), and the Palcazu Valley with the addition of a new road segment from Villa Rica to the Tingo Maria-Pucallpa Highway (B)*



Eventually, USAID and the Peruvian government decided to fund the Central Selva Resource Management project (CSRM) in the Palcazu Valley (Hartshorn 1981, Tosi 1988). Begun in 1981, CSRM was an environmental and resource management project with three main components: protection forest, agroforestry-based agriculture and forestry (Staver 1990, Tosi 1982). USAID and the Nature Conservancy assisted with protection component of CSRM and created the Yanachaga Chemillen National Park and the San Matias-San Carlos Protection Forest (Hartshorn and Pariona 1993) (Figure 1). The Yanesha Communal Reserve was established as a buffer between the Yanesha native communities and the park (Hartshorn and Pariona 1993). The agroforestry component focused on pasture land for livestock, tree crops and food crops for home consumption (Staver *et al.* 1994). The Tropical Science Center (TSC) in Costa Rica was contracted to design the Palcazu forestry component, introducing strip clear-cutting to harvest timber in the tropics (Hartshorn 1989a, Tosi 1982). TSC designed a vertically integrated forest management plan, where the Yanesha, organized into a cooperative, harvested and processed timber locally in the valley (Hartshorn 1989a, Tosi 1982).

In this review article, we assess the sustainability of the forestry component of the CSRM, the Palcazu Forest Management Model (PFMM), focusing on the interaction of social, ecological and economic factors that made this system fail in its first harvest and potentially fail in its second harvest. In the first section, a description of the Palcazu Valley is presented. The second section describes the PFMM. Results from the application of PFMM in the Palcazu Valley and in other sites are reported in the third section. The sustainability of PFMM is discussed in the fourth section.

THE PALCAZU VALLEY

The Palcazu Valley is located in the Andean foothills of southwestern Amazonia in Oxapampa, Pasco, Peru (Figure 1A). The Palcazu basin is bordered by the San Matias (2 000 meters) and the Yanachaga mountain ranges (4 000 meters). The Palcazu river-basin is part of the Pachitea river-basin, where the Pachitea River is a major tributary of the Ucayali River and originates at the junction of the Palcazu River and the Pichis River (Figure 1B). According to the Holdridge classification system, 85 percent of the Palcazu Valley consists of tropical wet forest, premontane wet forest and transition to tropical wet forest (Bolaños and Watson 1981). Only 15 percent of the valley consists of tropical moist forest, suitable for agriculture (Bolaños and Watson 1981). Rainfall is > 6 000 millimeters per year with a rainy season in November-May and a relatively dry season in July-August (Staver *et al.* 1994). Soils are acidic (pH 3.8- 4.5) with a high aluminium content, with exception to the alluvial floodplains along the valley floor, the most fertile land in the valley (Bolaños and Watson 1981, Staver *et al.* 1994). The plant families with the highest densities in primary forests on red clay, high terrace soils are Fabaceae, Sapotaceae, Myristicaceae, Moraceae and Lauraceae (Tosi 1982).

The population of the Palcazu Valley is made up of Yanesha communities, families of European immigrants, and descendants of Andean and coastal immigrants. In 1986 there was a population of 5 350, of which 50 percent were Yanesha (Stocks and Hartshorn 1992). The Yanesha have been in this region since 4 000 B. P., practicing floodplain and fallow agriculture supplemented by fishing and hunting (Hamlin and Salick 2003, Salick 1989, Smith 1977). In the late 1800s, the rubber boom attracted European colonists to the valley, making the Yanesha high demand workers for cattle ranching, collecting rubber and working in the coffee farms (Stocks 1988). As the cultivated lands of European families expanded, Andean workers were required to work in the farms every year (Stocks and Hartshorn 1992). The families of European immigrants ran extensive cattle ranching operations (> 100 hectares) while other immigrants ran smaller operations (25–50 hectares) (Stocks 1988). The Yanesha also participated in cattle ranching (Hartshorn 1981, Stocks and Hartshorn 1992). Although most of the southern half of the Palcazu Valley consisted of primary forest, the main environmental concern was the conversion of forests into pastures by the influx of colonists and loggers (Hartshorn 1981).

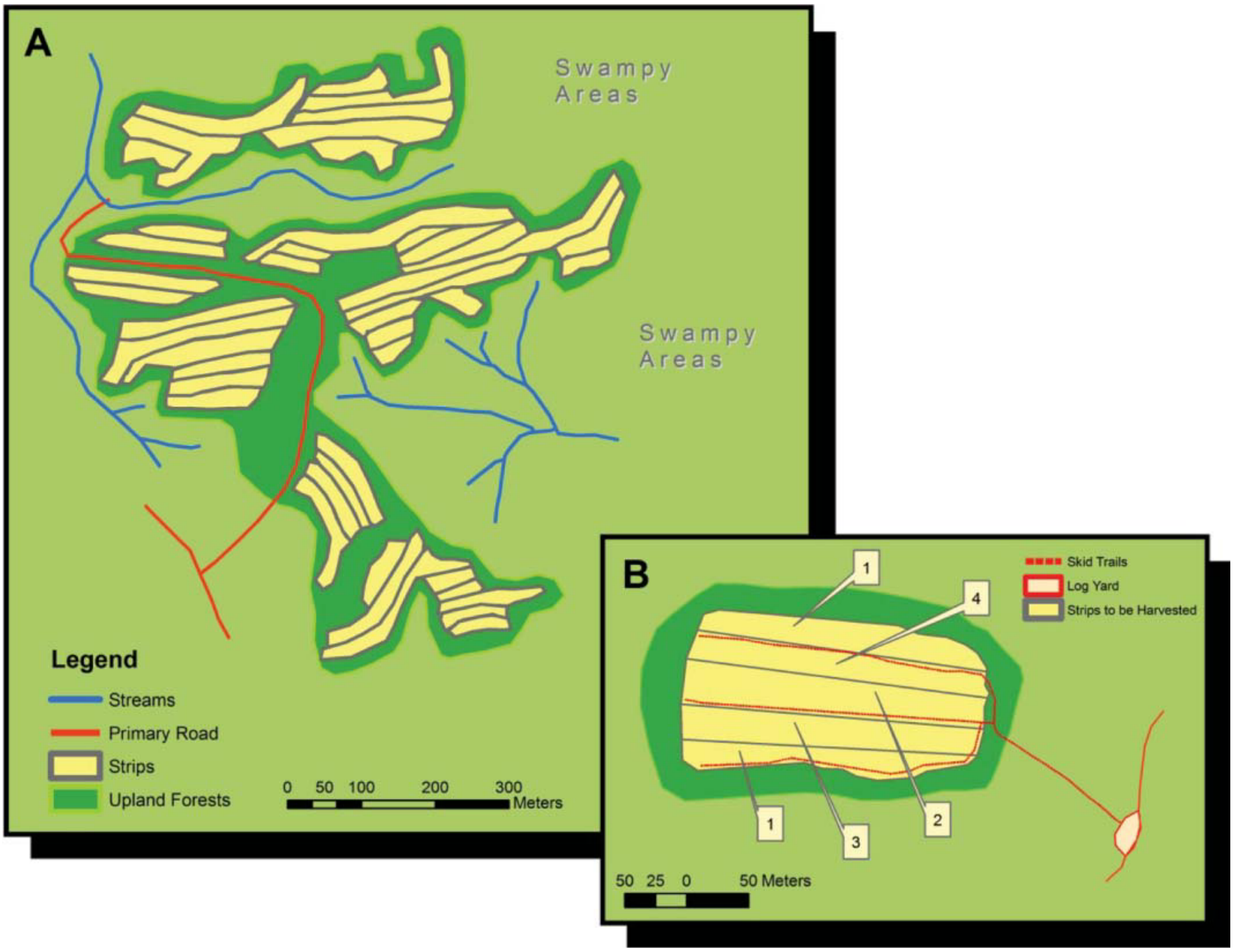
THE PALCAZU FOREST MANAGEMENT MODEL

The Palcazu Forest Management Model (PFMM) incorporated social, ecological and economic considerations for the sustainable development of the Palcazu Valley (Hartshorn and Pariona 1993, Stocks and Hartshorn 1992). The social benefit was the creation of the Yanesha Forestry Cooperative to harvest and process timber in the valley (Hartshorn 1989b, Stocks and Hartshorn 1992). The ecological benefit was the use of strip clear-cutting to promote rapid regeneration of timber species (Hartshorn 1989a, Tosi 1982). The economic benefit was the complete utilization of all timber obtained from the clear-cut strips (Hartshorn 1989a, Tosi 1981).

Strip clear-cutting

In this system, heterogeneous tropical forests are managed by clear-cutting long, narrow strips (Figure 2A) that mimic natural tree-fall gaps and allow for the regeneration of timber species (Hartshorn 1989a, Tosi 1982). Upland forest is clear-cut into 30–40 meters wide strips with a rotation cycle of 30 to 40 years. The narrow width of the strip simulates the diameter of a canopy opening by a tree-fall, making the strip clear-cut an elongated gap (Hartshorn and Pariona 1993). The length of the strip (usually 100–300 meters) varies and depends on topography and logistics on log extraction (Hartshorn 1989a). Strip clear-cutting targeted the areas of primary forest on the low and moderately steep hills of the Palcazu Valley, excluding steep slopes, swampy terrain, inaccessible forest patches and buffer zones along streams (Hartshorn 1989a). A typical production unit consists of 100–500 hectares, in which 48 percent is designated for strip clear-cutting (Hartshorn 1989a).

FIGURE 2 *Strip clear-cutting is the silvicultural system used in the Palcazu Forest Management Model (A), where the strips are not harvested in a sequential manner, for instance, in a four-harvesting cycle (B), two strips are harvested in the first cycle (1); in the second cycle a strip (2) is harvested between the two strips from first cycle; and in the third (3) and fourth (4) cycle a strip is harvested between the strips of the first and second cycle. This figure is a modified version of Staver et al. (1994)'s*



The strips that will be harvested in a production unit are marked and located to maintain a high forest matrix; thus, adjacent strips are not harvested in a sequential manner (Hartshorn and Pariona 1993) (Figure 2B). In the first harvest, blocks of primary forest (>100 meters) separate the strips and serve as seed source for natural regeneration, but as the harvest cycle continues these forest blocks will be harvested (Hartshorn 1989a). The second cycle starts by harvesting one strip intermediate between the two strips harvested in the first cycle. Similarly, a third cycle starts by harvesting one strip between the first and second cycle. Figure 2B shows a four-cycle sequence (Figure 2B) (Hartshorn and Pariona 1993). In a 30–40 year rotation, there could be up to 4–6 harvesting cycles in a production unit, where all strips marked to be clear-cut will be harvested once (Hartshorn and Pariona 1993).

The total area of forest production capability in the Palcazu Valley was ~ 44 000 hectares and it was estimated that ~ 20 000 hectares would be exploited over a 35-year period or 570 hectares per year (Hartshorn 1989b). In this harvesting system all timber trees (≥ 5 cm diameter at breast height [dbh]), regardless of species, are harvested from the strips (Hartshorn 1989a). Effort is made to use directional felling to avoid damaging the canopy of the bordering forest or the unharvested trees that survive the clearing. To avoid soil compaction and ruts, no machinery is allowed on the strip. Animal traction is used for log extraction and to reduce soil compaction (Hartshorn 1989a). Small branches and leaves are left in the strip to provide nutrients for the regenerating forest (Hartshorn 1989b).

Natural regeneration of seeds and stump sprouts is allowed in the strips (Hartshorn 1989a). Silvicultural treatments start in the second year to control for vines and climbers and to reduce the number of stump sprouts (Hartshorn and Pariona 1993). The first thinning treatment starts in the fourth year and other thinning treatments are prescribed based on growth increments of desired tree species (Hartshorn and Pariona 1993). Thinning can be carried out (e.g. up to four times in a strip [Elgegren 1993]), not only to enhance the growth of desired species (mostly destined for sawnwood) and influence the composition in the clear-cut strips (Hartshorn 1989a), but also to obtain additional timber for fences and electric posts during the 40-year cutting cycle (Elgegren 1993).

Social benefits

The Yanesha Forestry Cooperative Limited (COFYAL) was created in 1986 with the collaboration of USAID and specialists from TSC and PEPP (Stocks and Hartshorn 1992). At that time there were several conflicting land claims in the Palcazu Valley; thus, USAID required the Peruvian government to give land titles to the native communities as a precondition for disbursing funds (Stocks and Hartshorn 1992). This effort led to the recognition and legal title of 11 Yanesha native communities (Hartshorn and Pariona 1993). The Yanesha as a community held about 80 percent of the southern half of the lower Palcazu Valley and most of the land was in primary forest (Hartshorn and Pariona 1993). COFYAL was founded by 70 Yanesha individuals and five native communities, with the purpose of providing employment for community members, managing their forests for sustained timber yields, and protecting the cultural integrity of the Yanesha (Hartshorn 1995). To belong to the cooperative, the Yanesha communities had to set aside ≥ 100 hectares of production forest for communal management (Staver *et al.* 1994).

COFYAL was in charge of the communal forest management and the processing of timber products. Local processing of timber products added value to the wood products. The Shiringamazu community granted land to COFYAL for the construction of a processing plant (Stocks and Hartshorn 1992), consisting of a sawmill ($653 000) and a wood treating plant ($295 000) (Tosi 1982) donated by the Peruvian government through a USAID loan (Staver *et al.* 1994). The main timber products produced at the plant were sawnwood, preserved roundwood, and charcoal from scrap wood (Hartshorn 1989a). The sawmill had basic machinery for rough sawing of lumber (a semi-portable circular saw with a Mighty-Mite mill), a 32” circular saw for re-sawing operations and a band saw for re-sawing wood into precise dimensions (Stocks and Hartshorn 1992). The wood treating plant had a bank for preserving small-dimension roundwood for utility and fence posts (Hartshorn and Pariona 1993). In addition, there was a carpentry shop for making rural furniture and a portable kiln for charcoal production (Hartshorn and Pariona 1993).

Technical assistance and economic support was provided for COFYAL management training (Stocks and Hartshorn 1992). The processing plant had a salaried staff, who belonged to various Yanesha communities and performed administration, marketing and accounting activities. COFYAL also provided technical resources to establish forest management plans and harvest timber through organized work groups, which were to sell timber to the COFYAL processing plant (Stocks and Hartshorn 1992). Profits to the COFYAL, from processing and sale of products, were to be distributed back to the Yanesha communities, providing a positive feedback for conserving and managing the forest (Stocks and Hartshorn 1992).

Ecological Benefits

Strip clear-cutting was introduced by Tosi (1982) and Hartshorn (1989a) to mimic natural gaps, important sites for the regeneration of timber species, and simulate their dynamics. Due to the implementation requirements, TSC investigators did not have time to study forest dynamics in the Palcazu Valley (Southgate 1997). Thus, a forest management plan was designed based on research conducted in Costa Rica (Tosi 1982), where 50 percent of the native tree species, and 63 percent of canopy tree species, require gaps for their regeneration (Hartshorn 1980). Furthermore, in Costa Rica, gap-dependent, light-demanding tree species have rapid height and diameter growth and can reach the canopy (30–40 meters) in 10–20 years (Lieberman *et al.* 1985). The median life-span of trees > 10 centimeters dbh in Costa Rica is 34 years (Lieberman *et al.* 1985). Gap-dependent, canopy tree species of commercial value are called light hardwoods and require massive canopy disturbance (e.g. high volume timber extraction) for their regeneration (Swaine and Whitmore 1988).

Strip clear-cutting concentrates high intensity harvesting in small areas (Hartshorn 1989a). The narrow size of the strips and the presence of a forest matrix for seed source was expected to ensure the regeneration of many tree species, instead of favouring the colonization of pioneer trees of non-commercial value, typically found in large clearings (Hartshorn 1989a). Since the logging slash would not be burned as for the preparation for agriculture, the cut stumps would sprout, complementing the regeneration from seed source (Hartshorn and Pariona 1993). Richness and abundance of tree regeneration in the strips would allow the application of silvicultural treatments to influence the composition and structure of the strips for the next harvest (Hartshorn and Pariona 1993), making the strips even more profitable in successive cuts (Hartshorn 1989a).

In the case of the Palcazu Valley, timber extraction by strip clear-cutting would bring environmental impacts, but not as severe as the impacts from selective logging, agriculture or pasture (Hartshorn 1981). In selective logging a limited number of timber species are selectively cut in extensive areas, depleting the stocks of premium timber species and opening up the forest, through logging roads, providing access for other people (e.g. farmers, colonists). The advantage of strip clear-cutting over other land-uses is the maintenance of a forest structure that would support biodiversity and provide ecosystem services such as reduction of soil erosion, watershed protection, and stability of local climate (Hartshorn 1981, 1995). Some of the impacts of strip clear-cutting would be the regeneration of shade intolerant tree species while reducing the population of shade tolerant species (Hartshorn 1981). Furthermore, tree species that do not reach sexual maturity within the rotation cycle (30–40 years) may be lost in future harvests (Hartshorn 1989a).

Economic Benefits

The PFMM offered a more complete use of the timber resource than selective logging, which implied higher earnings (Hartshorn 1989a). This more intensive silvicultural system was based on the anticipated acceptance of lesser known timber species that were commercially unacceptable in the past by national markets (Hartshorn 1989a, Tosi 1982). Hartshorn (1989a) argued that strip clear-cutting, harvesting about 250 cubic meters per hectare, offered a more cost efficient use of the timber resource than selective logging, harvesting 3–5 cubic meters per ha.

A survey of wood industries and timber markets was conducted to provide an operational basis for the PFMM (Tosi 1988). The timber processing facility in the Palcazu Valley was expected to increase the value of timber products (Hartshorn 1989a). In the PFMM, trees ≥ 30 centimeters dbh are cut for saw timber, while smaller trees are used for telephone poles and construction posts (Hartshorn and Pariona 1993). The main feature in the processing facility for using lesser known timber species was the PresCap® method, a sap displacement method used to impregnate logs with heavy metal salts to make preserved posts and poles (> 5 centimeters in diameter) of any lengths (Stocks and Hartshorn 1992). It was calculated that 60 percent of timber would be processed for sawnwood and about 35 percent would become preserved posts and poles (Stocks and Hartshorn 1992). The remaining timber would be converted to charcoal (Hartshorn 1989a).

Initial economic estimates were promising. The net returns were estimated to be $3 600 per hectare (Table 1). At its early phase, the basic machinery at the COFYAL facility could process 12 hectares of timber per year, but there were plans to diversify and expand the processing capacity by adding more equipment (Hartshorn 1989b, Simeone *et al.* 1986, Tosi 1982). There were plans of managing more than 800 hectares per year (>10 forest units per year, each with 80 hectares) and harvesting more than 20 hectares of old growth forest per year (Tosi 1982). The processing plant diversification and expansion was thought to increase the net returns to $27 555 per hectare over a 30–40 year cycle, with potential yearly returns between $736 to 786 per hectare (Hartshorn 1989b, Stocks and Hartshorn 1992). Thus, timber production could bring more yearly returns than pasture ($12 per hectare), but lower returns than coffee ($1 176 per hectare), discouraging the expansion of pasture in the valley, but not that of coffee farms, which were more profitable (Stocks and Hartshorn 1992).

RESULTS FROM THE APPLICATION OF THE PALCAZU FOREST MANAGEMENT MODEL

The PFMM was carried out in the Palcazu Valley during the 1980s and ended in the early 1990s. During this project, there were several political and social problems that made its application difficult; as a result, only five strips were harvested with an average area of ~1 ha (Elgegren 1993) (Table 1). Studies on strip clear-cutting have been conducted in Jenaro Herrera, Loreto (Rondon *et al*. 2009, 2010); although they took place in a different forest, their results show the potential ecological and economic constraints when applying the PFMM in the tropics.

TABLE 1 *Projections of timber production, value, costs and earnings from strip clear-cutting (Tosi 1982), and actual estimates from five strips clear-cut in 1991 by the Yanesha cooperative (COFYAL) (Elgegren 1993) in the Palcazu Valley, Pasco, Peru*

Palcazu strips	1989 Projections	COFYAL Production in 1991			
		S1	S2	S3	S4+S5
Width × length (m)		28 × 470	30 × 350	42 × 120	no data
Area (ha)	1,0	1,3	1,1	0,5	~ 1 ha each
Timber products					
Sawnwood (m^3/ha)	52,1[1]	25,8	18,2	0	7,8
Electric posts (units/ha)	20,0	63,8	45,5	52,0	22,0
Fence posts (units/ha)	89,0	67,7	269,1	316,0	250,5
Charcoal (tons/ha)	2,9				
Firewood (m^3/ha)	7,0				
Value ($/ha)	3 902,9	5 491,8[2]			
Total Costs ($/ha)	984,7[3]	5 714,9[2]			
Earnings ($/ha)	3 606,2[4]	–123,1[2]			

[1] The total production of saw logs was 100 m^3/ha (Tosi 1982), and it was divided by 1.92 (INRENA 2008) to estimate sawn wood production.
[2] No data for individual strips.
[3] Total cost consisted of a non-recoverable ($296.7/ha) and a recoverable cost ($688/ha) (Tosi 1982).
[4] The non-recoverable cost was substracted from the total value; the recoverable cost was a family income for labour (Tosi 1982)

Political and social performance

The pre-existing PEPP project designed for the Palcazu Valley was difficult to overcome (Stocks and Hartshorn 1992, Tosi 1988). From the beginning, the original PEPP program met strong opposition from indigenous and environmental NGOs (Simeone *et al.* 1993, Smith 1982). This led to changing the program to a resource management project with the Yanesha (Simeone *et al.* 1993). USAID committed $22 million to the project, $4 million was technical assistance grant and the rest was a low interest loan to the Peruvian government (Stocks and Hartshorn 1992). Nevertheless, even before USAID disbursed the funds, the Peruvian government, which committed $8 million in counterpart funds to the project, had already begun the colonization of the valley, using its own land-use classification system where agriculture was disproportionally represented (Stocks and Hartshorn 1992, Tosi 1988). Despite TSC and USAID efforts to convince PEPP to develop a forestry project in the Palcazu Valley instead of commercial agriculture, due to poor soils, PEPP insisted on using the funds for an agricultural project (Tosi 1988).

The PFMM lacked a social component to integrate the Yanesha into the project and to develop the idea of a cooperative (Morrow and Hull 1996, Stocks and Hartshorn 1992). PEPP had little interest in the Yanesha participation in the project, and therefore did not initially consult them (Stocks and Hartshorn 1992). During the operational phase, the Yanesha showed discontent with the PFMM because it was not compatible with their traditional subsistence activities (Smith 2002). The Yanesha lacked skills in timber harvesting, timber processing, administration and management. Decisions made in COFYAL were in favour of individual families at the expense of the cooperative (Gram 1997, Smith 2002). Thus, COFYAL was beneficial only to those Yanesha employed by the project, creating conflicts with other Yanesha who provided forest land, but did not receive any income (Gram 1997).

While there was funding, 1986–1993, COFYAL worked effectively (Benavides and Pariona 1995). In 1989 foreign technicians and scientists withdrew from the Palcazu Valley largely due to guerrilla activity (Hamlin and Salick 2003, Stocks and Hartshorn 1992). During the next four years, WWF provided limited support to COFYAL through FPCN (*Fundación Peruana para la Conservación de la Naturaleza*), an environmental non-governmental organization (NGO) in Lima (Benavides and Pariona 1995). However, problems arose among the cooperative, the participating Yanesha communities, and the NGO, leading to the closure of the cooperative and the suspension of operations (Benavides and Pariona 1995). In 1999, a group of Yanesha reactivated COFYAL, but as a private agricultural enterprise under a new name *Empresa Comunal de Servicios Agricolas Yanesha* (ECOSAYA) (Benavides and Pariona 1995).

Ecological Performance

The early regeneration of the clear-cuts strips in the Palcazu Valley indicated that the system had a high regeneration capacity (Hartshorn 1989a). Out of the five strips harvested in the Palcazu Valley, only two strips were monitored for tree regeneration (Hartshorn 1989a). Two and a half years after clear-cutting, there were 209 tree species (n=1 983 stems) > 50 centimeters tall in one strip (0,15 hectares) and 285 (n= 6 624) in a second strip (0,50 hectares) (Hartshorn 1989a). Six years after clear-cutting, the first strip had 182 (n= 1 172) tree species and the second strip had 259 species (n= 3 218) (Hartshorn and Pariona 1993). Strip clear-cutting also promoted sprouting from the cut stumps of several hardwoods in the strips (Hartshorn 1989a). After two and a half years, 17–18 percent of the total number of trees were attributed to resprouting stumps, representing 47–71 percent of the tree species in strips 1 and 2 (Hartshorn 1989a). In the strip clear-cuts from Jenaro Herrera, frecuency of sprouting was the highest among trees in the Vochysiaceae, Lecythidaceae, Fabacae, and Lauraceae plant families; and smaller trees (7.5–15 cm dbh) were more than twice as likely to sprout as larger trees (> 30 cm dbh) (Gorchov *et al.* 1993).

Studies conducted in two strips (0,45 hectares) clear-cut in 1989, in high terrace lowland, tropical rainforest of Jenaro Herrera, Loreto (Gorchov *et al.* 1993) have questioned the regeneration capacity of timber species in this system. During the first year after clear-cutting, nearly all seeds dispersed into the strips were of small-seeded species dispersed by birds, bats, or wind (Gorchov *et al.* 1993); very few seeds of large-seeded species, characteristic of commercial timber species (Hammond *et al.* 1996), were dispersed into the strips. Moreover, among the seedlings in the strips, pioneer tree species of little commercial value were dominant (Gorchov *et al.* 1993). Ten to 30 months after the clearing, seeds of *Hymenaea courbaril*, a valuable timber species, were rarely dispersed by rodents into the centre of a strip; seeds were only dispersed up to the edges (Gorchov *et al.* 2004). Three years after the clearing, predation of large seeds (*Pouteria* sp., a commercial species) was greater in the strips than in the surrounding forest (Notman *et al.* 1996). Fifteen years after the clearing the strips had recovered most of their original tree basal area (58–73 percent), species richness (45–68 percent) and composition, but had recovered only 24–43 percent of the relative abundance of commercial tree species (Rondon *et al.* 2009a).

Growth rates of timber trees regenerating in the clear-cut strips of Jenaro Herrera were low and growth projections suggested only a few timber trees would reach commercial size 40 years after felling, the time of a second harvest (Rondon *et al.* 2009b). Despite a thinning treatment, seven to ten years after the clearing, the annual diameter growth increment of timber trees averaged < 0,3 centimeters (Dolanc *et al.* 2003). Diameter growth and mortality data of six focal timber species were used to simulate tree growth under three scenarios (Rondon *et al.* 2009b): average growing conditions, high light conditions, and fast growing conditions. In all three scenarios, two emergent tree species, out of the six projected, reached commercial size (30 centimeters dbh) after 40 years. When the timber trees ≥ 6.5 centimeters dbh were projected (115–204 trees per hectare) using the average growing and high light scenario, only 2–6 trees per hectare reached commercial size. Under the fast growing scenario, 23–26 trees per hectare reached commercial size, but this was the least realistic scenario because it assumes all timber trees grow continuously with high growth rates until the second harvest (Rondon *et al.* 2009b).

Economic performance

In the PFMM operational phase, there was an unexpected lower production of sawnwood, but a greater production of utility and fence posts. In the Palcazu Valley, the production of sawnwood obtained from the first harvest was 0–25 cubic meters per hectare (Table 1), instead of the initial estimates of 52 cubic meters per ha (Table 1). The production of utility posts was 22–64 units per hectare, higher than the initial estimates of 20 units per ha (Table 1). The production of fence posts was 68–316 units per hectare, also higher than the initial estimates of 89 units per ha (Table 1). In Jenaro Herrera, several forest products were also obtained from the first harvest of the strips, but the utilization of the felled trees was incomplete (Table 2) (Cornejo and Gorchov 1993). The estimated average production of sawnwood from the first harvest was 105 cubic meters per hectare (Cornejo and Gorchov 1993), but growth simulations predicted a much lower production for a second harvest, 1.9–22.4 cubic meters per hectare (Table 2). The production of roundwood pieces for housing construction in a potential second harvest was projected to be 3–92 units per hectare (Table 2). To obtain maximum utility from the strips, charcoal production was included in the calculations for Jenaro Herrera; a projected 11–20 tons per hectare of charcoal could be obtained in a second harvest if charcoal is made from all wood not used for higher-value uses, instead of only from coarse woody debris as in the first harvest (Table 2).

COFYAL timber production resulted in net losses. The net loss from the first harvest of the Palcazu strips in 1991 was $123 per hectare (Table 1). The revenue calculations included sawnwood sold to the Ecological Trading Co. Ltd. United Kingdom, to the Huancayo and Lima markets, and locally to the Palcazu and Yanesha community (Elgegren 1993). Utility and fence posts were sold to the national market. In Jenaro Herrera, a net loss of $118 per hectare was found in one of the strips, but the second strip had a net profit of $1 229 per hectare (Table 2). The net present values (NPVs) of a potential second harvest for the clear-cut strips of Jenaro Herrera with a 15 percent discount rate were projected to range from −$73 to +$78 and from −$57 to +$76 per hectare; these estimates included certified sawnwood and charcoal production from the strips (Table 2).

TABLE 2 *Timber production, value, costs and earnings from two strips clear-cut in 1989 (Cornejo and Gorchov 1993) and projections for a second harvest, 40 years later (Rondon et al. 2010), in Jenaro Herrera (JH), Loreto, Peru*

JH strips	**First Harvest**[1]		**Second Harvest**[2]	
	S1	**S2**	**S1**	**S2**
Width × length (m)	30 × 150	30 × 150	30 × 150	30 × 150
Area (ha)	0,45	0,45	0,45	0,45
Timber products				
Sawnwood (m^3/ha)	7,8	27,3	1,9 - 18,9	3,9 - 22,4
Roundwood pieces for housing construction (units/ha)	na[3]	344,0	10,6 - 80,6	3,1 - 92,4
Fence posts (units/ha)	222	1 111	0	0
Charcoal (tons/ha)	3,1	na	11,0 - 19,5	11,1 - 17,5
Palm leaves (no leaves/ha) (*Geonoma* sp., *Lepidocaryum* sp., *Orbignya* sp.)	1 778	na	na	na
Value ($/ha)	1 804	6 469	2 945 - 9 766	3 517 - 10 511
Costs ($/ha)	1 922	5 240	3 020 - 5 948	3 301 - 6 167
Earnings ($/ha)	-118	+1 229	-75 - +3 818	+216 - + 4 344
NPV ($/ha)[4]	na	na	-73 - +78	-57 - +76

[1] Estimates based on an incomplete utilization of felled trees: 17% and 45% of felled trees were used for processing sawn wood in strips 1 and 2; 13 m^3/ha were used for processing round wood pieces of housing construction in strip 2; and coarse woody debri left from harvesting strip 1 was used for charcoal production.

[2] Projections based on a complete utilization of felled trees. Charcoal production was calculated using hard woods of no commercial value and some of commercial value (> 15 cm but < 30 cm dbh).

[3] na = not applicable or not calculated.

[4] Net present value at a 15% discount rate with certified sawn wood.

Net losses from timber harvest were attributed to high costs in the operational phase of the PFMM. The initial estimates for harvesting timber from the strips in the Palcazu Valley was \$985 per hectare; this included non-recoverable costs for machinery, tools and administration fees (\$298 per hectare); and a recoverable cost (\$688 per hectare) received as family income for labour in timber harvesting, equivalent to 142 one-day labour (*jornales*) per hectare (Tosi 1982). COFYAL, however, spent in harvesting labour alone \$1500 per hectare equivalent to 400 one-day labour (*jornales*) per hectare; and the total extraction and transport cost was about \$3 000 per hectare (Elgegren 1993). In Jenaro Herrera, the average cost of timber extraction and transport were similar to the Palcazu, \$2 880 per hectare (Cornejo and Gorchov 1993). Overall, these costs were higher than those for a small private selective logging enterprise in Pucallpa (\$473 per hectare) (Elgegren 1993). Processing sawnwood in COFYAL also became costly (\$60 per cubic meter) (Elgegren 1993). Payments for electricity, from diesel-powered generators, amounted to as much as a fifth of wood processing costs (Southgate and Elgegren 1995). Processing sawnwood in Villa Rica sawmill cost \$30 per cubic meter and in Jenaro Herrera \$23 per cubic meter (Cornejo and Gorchov 1993, Elgegren 1993). In addition, outside technical assistance would be needed for many years to make this forest management model successful (Simeone 1990), increasing overall costs (initial budget is found in (Tosi 1982).

THE SUSTAINABILITY OF THE PALCAZU FOREST MANAGEMENT MODEL

The PFMM performance was affected by the interplay of unfavourable extrinsic and intrinsic conditions for the sustainable use of timber. The extrinsic conditions were a lack of forestry policies and economic incentives for timber production, high inflation rates and poor timber markets. The intrinsic conditions were a forest management approach without social inclusion, limited knowledge of strip clear-cutting biology, high costs from timber harvesting, and low income from timber products.

The Peruvian administration lacked government policies promoting the sustainable use of timber. In the 1980s, both the Belaúnde (1980–1985) and García (1985–1990) administrations enforced the rural development of the Amazon through colonisations and agricultural programs (Instituto de Investigaciones de la Amazonía Peruana 2009). The Peruvian law at that time only recognized agricultural cooperatives; as a result, it took about two years for the Yanesha cooperative to obtain official status (Hartshorn 1995). Moreover, the 1975 forestry law was active and established a dual system for timber extractors (Smith *et al.* 2006). Individual small-scale extractors (non-indigenous people) could acquire only one contract of 1 000 hectares maximum and harvest ≥ 6 species, for 2–10 years, while logging companies could obtain contracts of up to 100 000 hectares for 10 years, renewable, and harvest ≥ 20 species. Contracts were of short duration because forests were likely to be converted to agricultural land or cattle ranching (Barrantes and Trivelli 1996). This old forest policy encouraged the use of poor logging practices.

There were no economic incentives to increase the retail value of timber products from forest management programs. In the domestic markets of Lima and Iquitos, sawnwood of low value hardwoods (e.g. *Cedrelinga* sp., *Virola* sp.) sold for < \$140 per cubic meter (Cornejo and Gorchov 1993, Southgate and Elgegren 1995). Nevertheless, the Luthier's Mercantile, USA and Ecological Trading Co. Ltd., UK bought sawnwood timber from sustainable forest management programs for \$400 to > \$500 per cubic meter (FOB border value) (Cornejo and Gorchov 1993, Elgegren 1993). The retail price of sawnwood in Peru has not changed much since the late 1980s. In 2007 sawnwood of *Virola* spp. sold in Iquitos for ≤ \$122 per cubic meter and that of *Simarouba* spp. for ≤ \$138 per cubic meter (International Tropical Timber Organization Market Information Service 2007). Although the retail value of construction roundwood has increased (Cornejo and Gorchov 1993, Rondon *et al.* 2010), this timber product does not generate much income, due to high transportation costs relative to the retail price (Rondon 2008, Rondon *et al.* 2010). Due to lack of experience, COFYAL produced timber products of uneven quality (Benavides and Pariona 1995), which also affected profits (Southgate 1997).

Profits from the PFMM were also affected by weak timber markets, high transportation costs and high inflation rates. Initial studies indicated that international, national and local markets existed for a wide variety of timber species and products (Southgate 1997), but many of the timber products produced by COFYAL lacked acceptance by local consumers because they were unknown (Benavides and Pariona 1995). While there was a national market for sawnwood, construction roundwood and charcoal, the market for preserved timber posts and poles was very weak (Benavides and Pariona 1995, Stocks and Hartshorn 1992). Transportations costs were also high despite the road connection to the Marginal Highway system (Southgate 1997). Furthermore, during this time, Peru had one of the highest inflation rates in Latin America. Government policy required exporters to deposit their foreign currency earnings with the central bank to be paid out several weeks later in the local currency at the initial exchange rate, reducing earnings by 30–35 percent (Southgate 1997).

A traditional top-down approach to natural resource management without social inclusion was used in the developmental and operational phase of the PFMM. As in many other community forestry projects (Hoch *et al.* 2012, Pokorny and Johnson 2008, Pokorny *et al.* 2012), the institutional rules for PFMM were developed like a technical package, incompatible with the local context and interests of the Yanesha, resulting in lack of project ownership and strong dependency on donor support (Morrow and Hull 1996). The PFMM could have benefited from an integrated knowledge system in resource management (Altieri and Hecht 1990, DeWalt 1999, Sears *et al.* 2007), but for this kind of integration, three levels of knowledge need to be recognized: technical or know-how (*techne*), scientific or know-why (*episteme*) and *phronesis* or local knowledge (Flyvbjerg 2001, 2004). *Phronesis* is the contextualized, place-dependent knowledge, derived from practical experience and cultural values (Flyvbjerg 2001, 2004). In PFMM, the scientific knowledge was provided by TSC, the technical knowledge by the PEPP staff, but *phronesis* from the Yanesha was lacking.

Moreover, strip clear-cutting is a relatively new silvicultural system in the tropics that needs further experimentation before its implementation. Transferring a silvicultural system into a new forest without previous tests involves potential dangers (Hutchinson 1988, Putz 1992). Strip clear-cutting has been used extensively in North America, Europe (Matthews 1989, Smith 1986) and other parts of the world. After years of experimentation in the US, strip clear-cutting trials for white cedar regeneration, for example, were declared successful based on the presence of seedlings rather than stand recruitment, which was later affected by deer browsing, logging slash and competing species, among other factors (Heitzman *et al*. 1999) (Heitzman *et al.* 1999) (Heitzman *et al.* 1999) (Beguin *et al*. 2009, Heitzman *et al*. 1999). Even when strip clear-cutting improved the stocking of timber stands, as in the case of black spruce in Canada, additional costs in this system can be avoided where the advance regeneration is abundant and has a height advantage over newly established seedlings (Pothier 2000). Strip clear-cutting trials were successful for mangrove regeneration in Indonesia when seed trees were left in the strips (Burbridge and Koesoebiono 1982).

Research in the tropics has shown several deficiencies in the gap-phase regeneration concept, the basis of strip clear-cutting (Hartshorn 1989a). When a canopy gap is formed (0,02 to > 0,06 hectares), the regeneration is often dominated by weedy tree species that germinate from the seed bank, resprouted trees damaged from tree falls, and vines (Brokaw 1985, Lawton and Putz 1988, Putz 1983, 1984, Putz and Brokaw 1989). One of the assumptions in strip clear-cutting was that most timber species are gap-dependent or shade intolerant; thus, they would establish in gaps and have high growth rates (Hartshorn 1989a), but not all timber species are gap dependent. Seedlings of timber species exhibit a broad range of shade tolerances and growth rates (Martini *et al.* 1994, Pinard *et al.* 1999) and belong to different functional groups (Rondon *et al.* 2009b). A series of strip clear-cutting trials, differing in size and spatial arrangement will be necessary in order to evaluate recovery rates and determine the thresholds that limit the regeneration of timber species.

Timber harvesting by strip clear-cutting could make the forest landscape vulnerable to fires. The average clear-cut strip will remove much larger amounts of biomass (250 cubic meters per hectare) than selective logging, 19–40 cubic meters per hectare (Nepstad *et al.* 1999), but even selective logging, depending on the harvest intensity, has been shown to alter forest biophysical properties, including increasing water and wind stress, changing microclimates (Pringle and Benstead 2001), and increasing forest susceptibility to fire (Holdsworth and Uhl 1997, Uhl and Kauffman 1990). Thus strip clear-cutting may increase the susceptibility of the landscape to forest fires due to potential elevated temperatures, reduced humidity and higher wind speeds, leading to the drying of soil debris. In addition, strip clear-cutting will leave a higher amount of logging slash than selective logging, creating a potentially larger fuel bed for fire, which is likely to damage surviving saplings, the seedbank and soil. In landscapes with slash-and-burn agriculture or pasture, forest fires can start from fires lit intentionally for these land uses.

The PFMM is not an attractive option for timber harvesting based on the profits from the first harvest in PFMM and projections of a potential second harvest in Jenaro Herrera. When the ex-ante financial analysis of the PFMM was re-evaluated, a 20 percent internal rate of return was found, but this was subject to changes in output prices and unit production costs (Elgegren 1993). Considering the unfavourable economic conditions during this period, COFYAL production resulted in net losses exceeding those of a private, selective logging enterprise ($35 per harvested hectare) in Pucallpa (Elgegren 1993). A community forestry enterprise in Loreto (Pinedo-Vasquez *et al.* 1992) that harvested all marketable timber trees > 25 centimeters dbh (67 cubic meters per hectare) generated higher profits ($481 per hectare) than the PFMM due to lower harvesting costs ($189 per hectare) than in the PFMM, where initial investments were covered by donors (e.g. infrastructure, training, machinery). More conservative estimates for yearly returns on strip clear-cutting in the Palcazu Valley (320 hectares production forest) without wood processing were $12–17 per hectare (Gram 1997).

Improving the Palcazu Forest Management Model

The factors that affected the PFMM are common to other community forestry (CF) projects (Hajjar *et al.* 2011, Humphries *et al.* 2012). In the past, CF projects have been successful when social arrangements have been worked out beforehand. This is the case of the Maya communities of Quintana Roo, Mexico (Bray 2001, Bray *et al.* 1993, Snook *et al.* 2003). In 1984, a state and federal government program with German technical assistance (*Plan Piloto Forestal*) developed organizational structures and management practices for commercial timber production by the communities in Quintana Roo (Bray 2001). Through a series of reforms, the government helped communities in conducting participatory forest inventories and establishing CF enterprises in the region (Bray 2001). The government also created organizations that were channels for technical assistance, donor support, and negotiations with government agencies (Bray *et al.* 2004). The Maya forestry enterprises of Quinta Roo harvest mahogany by selective logging and others have established common sawmills for timber processing (Gram 1997, Snook *et al.* 2003). These enterprises negotiate with timber buyers, administer the logging process, generate employment and distribute profits to the community (Bray *et al.* 2004, Snook *et al.* 2003).

The PFMM could have benefited from an adaptive management approach to resource management. While traditional resource management approaches are viewed as top-down or command-control practices to make complex systems more predictable, adaptive management approaches recognize that uncertainty arises from complex systems, requiring a more interdisciplinary intervention (Berkes *et al.* 1998, Holling and Meffe 1996). Adaptive management emphasizes learning by doing, eliminating the barrier between research and management (Berkes *et al.* 1998). It has the advantage of systematic experimentation and incorporation of scientific research into the management scheme (Berkes *et al.* 1998). An adaptive management approach also allows for the integration of local and scientific knowledge (Klooster 2002). In Mexico, there are hundreds of CF projects that have resource management approaches that come close to adaptive management. Moreover, these communities have adapted scientific forestry practices (e.g. forest management plans) into their traditional management practices, and the successful ones, e.g. Quintana Roo (Snook *et al.* 2003), have been able to avoid conflict between foresters' restrictions and forest users' traditions (Klooster 2002).

Aside from unfavourable forestry policies, one of the main challenges of CF projects is financial viability to avoid land use change. As a result of major economic and financial incentives, there is the potential threat that large areas of timber production may be converted into other land uses such as biomass and biofuel-producing plantations, export-oriented agricultural fields, or cattle pastures. Thus, one feasible counteraction is to improve forestry practices to increase their economic value.

The value of the PFMM could increase using silvicultural techniques that enhance the regeneration and growth of timber species. In general, the low density of timber species (Schulze *et al.* 2008) and their slow growth rates in the Amazon (Dauber *et al.* 2005, Keller *et al.* 2007) make timber harvesting in short cutting cycles unprofitable. Enrichment planting of fast-growing, valuable timber species can be implemented in the strips, as it has been done in other systems (Pena-Claros *et al.* 2008, Schulze 2008) to increase their value and to facilitate the development of a rapid canopy cover. In addition, periodic thinning treatments should be implemented in the strips to increase the growth rates of timber trees (Pena-Claros *et al.* 2008). Despite the potential benefits, there are high costs associated with silvicultural treatments (e.g. Schulze 2008).

Reducing the harvesting intensity in the PFMM to only harvest desired species of commercial size may reduce costs and increase the value of the strips. In Jenaro Herrera, an experimental deferment-cut treatment was applied in the south half of one of the strips. In this treatment trees < 30 centimeters dbh of commercially valuable species were left uncut (n=56) for the next harvest, but all trees ≥ 30 centimeters dbh and other non-commercial species > 5 centimeters dbh were felled (Cornejo and Gorchov 1993). Fifteen years after the harvest, this treatment had a greater abundance of timber species, and a lower abundance of pioneer tree species, than the clear-cut strips (Rondon *et al.* 2009b). Growth models projected the deferment cut would have a greater number of timber trees reaching commercial size (33–66 trees per hectare) in a second harvest than the clear-cut strips (2–6 trees per hectare) (Rondon *et al.* 2009b). Higher timber yields resulted in higher NPVs in a potential second harvest for the deferment-cut (+ $131 to $540 per hectare with certified sawnwood and +$40 to + $287 per hectare with sawnwood not certified) than for strip clear-cutting (Rondon *et al.* 2010).

Certification and payment for ecosystem services schemes could also increase the value of the PFMM. Forest management practices under the Forest Stewardship Certification are audited according to rigorous standards (Cauley *et al.* 2002, Gullison 2003). In this scheme, the creation of employment for local people is considered as social responsibility (Cauley *et al.* 2002, Gullison 2003). Chain-of-Custody certification and its label involve tracking the origin of forest products through the production chain. Good management practices are rewarded by having market access and premium prices for certified products (Washburn and Miller 2003). The PFMM could also be modified for the adoption of a REDD+ scheme (Reduction of Emissions from Deforestation and Degradation plus enhanced carbon stocks). Reducing the volumes of timber extraction and using reduced impact logging techniques can reduce carbon emissions, and post-logging silvicultural treatments can enhance carbon stocks (Nasi *et al.* 2011, Putz *et al.* 2008). Although these schemes bring economic benefits, their certification costs are high for small producers (Nasi and Frost 2009) and may bring other complexities to local people (Markopoulos 1998, Wunder 2006).

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