9 Permanent Smallholder Rubber Agroforestry Systems in Sumatra, Indonesia

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Although there is a long tradition in Southeast Asia of trading resins and latex collected from the natural forest or secondary forests that were part of shifting cultivation cycles, the introduction more than a century ago of Pára rubber (*Hevea brasilienses* [Willd. ex Adr. Juss.] Muell Arg.) from the Amazon to Southeast Asia formed the basis for the spontaneous and broad-based adoption of new agroforestry practices at a scale not matched elsewhere. "The history of agriculture probably has not seen any other case where the introduction of a single crop had such a dramatic effect on the economic condition of smallholders in vast areas, as the introduction of *Hevea brasiliensis* in Indonesia" (van Gelder 1950:428). The food crop–based shifting cultivation systems in which the fallow was of secondary importance were transformed into systems in which the food crop that could grow in between young rubber trees became a secondary aspect of a production system relying on rubber to generate income. Rubber agroforestry appears to have many of the attributes of a best-bet alternative to food crop–based slash-and-burn agriculture: They are profitable, produce easily marketed products, and generate environmental benefits. Therefore rubber agroforests of various management intensities have become one important focus of Alternatives to Slash and Burn's (ASB's) research program (Tomich et al. 1998, 2001; van Noordwijk et al. 1995, 1997). Yet the impact of this land use system—which helped attract migrants to the forest margins—on the rate of deforestation is still debated (van Noordwijk et al. 1995; Tomich et al. 2001).

Rubber is a major export commodity supporting the Indonesian economy. More than 1 million households now depend on rubber as their main source of income. Smallholder rubber constitutes 83 percent of the total Indonesian rubber area (3.5 million ha) and 68 percent of total rubber production. Smallholder rubber systems often are called jungle rubber (Gouyon et al. 1993; Williams et al. 2001), a complex agroforestry system based on production of an economically important commodity that maintains the structure, carbon stocks, and species richness of secondary forest vegetation (Foresta and Michon 1996). Typically, management by smallholders is extensive and uses very few external inputs. However, major opportunities may exist to increase the productivity of these systems by making use of improved rubber germplasm.

All rubber agroforestry systems in Indonesia start (or started) by clearing land: slashing, cutting, and felling the forest and burning it during the dry season. Rubber seedlings typically are planted into an upland rice crop (for 1 or 2 years) and left to grow along with those forest species that can regrow from stumps and the secondary forest species that come into the plot as seeds from neighboring areas. When the rubber trees have reached a girth of about 40 cm (after 5 to 10 years, depending on site conditions), tapping can begin and part of the vegetation is cleared to create a path for walking from tree to tree and to promote rubber seedling growth. When the first generation of trees becomes old and unproductive, two basic options exist for rejuvenation of the stand: cyclical and permanent agroforestry.

A cyclical rubber agroforestry system begins a new cycle with another round of land clearing: slashing, cutting, and felling the old jungle rubber and burning it during the dry season. Cleared land is replanted with seedlings or grafted clonal rubber trees, sometimes in combination with upland food crops (e.g., rice [*Oryza sativa* L.], maize [*Zea mays* L.], or mung bean [*Vigna radiata* L.]). Leguminous cover crops are used only in establishing a new rubber plantation on large estates. Technical, economic, and ecological aspects of these systems are well documented (Gouyon 1996; Penot and Wibawa 1997; Wibawa and Thomas 1997).

But the cyclical system can suffer from or pose financial, agronomic, and environmental problems. For example, replanting rubber after slash-and-burn land clearing in cyclical systems may reduce farmers' incomes from rubber during the immature period (5–7 years), and replanting with clonal varieties is expensive. Substantial risk of plant damage also exists throughout the establishment period from pests (wild pigs, monkeys), diseases (white root rot), and fire. Global environmental benefits of such agroforestry systems in terms of biodiversity conservation and carbon stocks (chapters 2 and 4, this volume) are limited by the recurrence of a burn after each cycle of 25 to 30 years.

An alternative method of rejuvenating old rubber agroforests in Sumatra is the sisipan system, which culminates in a permanent rubber agroforest that more closely resembles a natural forest in terms of the age and size distributions of trees. This permanent system is based on the management of small plots (about 1 ha in size) within which very small parcels (about 100 m^2 in size) are rejuvenated either by spontaneous regeneration from seeds or by rubber seedlings planted in forest gaps. This type of rejuvenation is common in Sumatra in damar (*Shorea javanica* Koord. & Valeton) and fruit tree agroforests and home gardens. With this type of management, a single field can contain rubber trees of all ages, with a subset always available for tapping. Decisions on gap replacement are made at the tree rather than field level, thereby providing more opportunities to introduce valuable nonrubber trees and to retain older, productive rubber trees. We hypothesize that the prospects for biodiversity conservation and time-averaged carbon stocks are higher in permanent rubber agroforestry systems than in cyclical systems and that the risks and investment associated with permanent systems are better suited to smallholders with little land, labor, and capital at their disposal.

As part of the ASB research activities in Indonesia, villages in and surrounding the benchmark areas in the lowland peneplain and piedmont zones (van Noordwijk et al. 1995) were surveyed to better understand farmers' interests in and constraints to adopting the sisipan permanent agroforestry system as an alternative to the cyclical system. Land use systems (LUSs) were characterized at the field, patch or gap, and tree levels. At the LUS level, the following issues were addressed: What farm and farmer characteristics (e.g., gender, age) are associated with sisipan system adoption; how does the economic performance of the sisipan system compare with the cyclical slash-and-burn alternative; and what are the scope for and obstacles to increasing the productivity of sisipan systems? This chapter presents the materials and methods, results and conclusions from this study.

MATERIALS AND METHODS

The survey was carried out in Jambi Province, Sumatra, in an area extending beyond the original ASB benchmark site (van Noordwijk et al. 1995, 1997; Murdiyarso et al. 2002). Jambi is one of the main rubber-producing provinces in Indonesia and represented approximately 17 percent of national smallholder rubber area (495,556 ha) in 1995 (DGE 1995). From this province, seven villages in the Bungo Tebo district were chosen to represent two main agroecological zones: the foothills (piedmont zone) and the lowland peneplain zone. Five of the villages are in the piedmont zone (Rantau Pandan site), and the other two are in the peneplain zone (Bungo Tebo site; see table 9.1). The survey was carried out between October 1998 and January 1999, so all financial information refers to the period after the monetary crisis that began in the second half of 1997.

In these villages, farmers who had implemented sisipan as part of their livelihood strategy were chosen for interviews. Thus the survey was of an exploratory nature and did not propose to identify the proportion of farmers who practiced sisipan or slash-and-burn–based systems. The objective was to improve our understanding of how sisipan systems were practiced and to explore why farmers chose sisipan for rejuvenating rubber agroforests. Insights for selecting larger, random samples for future studies can be gleaned from this research. Respondents selected were those available at the time of the interview and chosen from lists provided by village chiefs and farmer leaders. Seventy-six farmers were involved in the study.

The interview process had two stages. The first stage consisted of interviews with village chiefs and farm leaders. The aim was to collect secondary data on village char-

Table 9.1 Villages Surveyed and Numbers of Respondents, by Agroecological Zone

Agroecological Zone	Village	Number of Respondents
Piedmont zone	Sepungur	9
	Lubuk	7
	Muara Kuamang	11
	Pintas Tuo	8
	Embacang Gedang	10
Peneplain zone	Rantau Pandan	14
	Muara Buat	17
Total sample size		76

acteristics, the number of farmers who had implemented permanent systems, and general rubber-farming conditions. In the second stage, interviews were conducted at the household level to collect primary data on farmer, farm household, and farm characteristics and to obtain detailed information on the implementation of permanent systems. These structured interviews were supported by direct observation of the respondents' rubber agroforests.

To compare the necessary inputs and financial performance of sisipan and cyclical rubber agroforestry systems, five variations on these basic systems were identified and analyzed: cyclical systems using locally acquired seedlings, cyclical systems using high-productivity clonal rubber seedlings, sisipan systems using local seedlings and standard yields, sisipan systems using low-productivity seedlings (15 percent lower yields than those of local standard seedlings), and sisipan systems using local seedlings with standard yields but also benefiting from offtake from fruit trees.

The net present values (NPV), internal rates of return (IRR), and benefit:cost (BC) ratios were calculated for each of the five systems. In addition, for each system two cost scenarios were calculated, one (called fully costed) that used market prices to value all inputs used in production (land, family labor, hired labor, small farm equipment, and fertilizers) and a second (called partially costed) that used market prices to value inputs actually purchased in the market (i.e., land, family labor, and upland rice seeds were not included in this cost scenario because their true opportunity costs may have been below the market price).

RESULTS AND DISCUSSION

Characteristics of Farmers Interested in Permanent Rubber Agroforests and Their Farms

In the study area, sisipan practices appeared to be widespread. Between one- and two-thirds of the farmers had adopted sisipan on at least part of their operational holdings. The seventy-six respondents who were managing permanent rubber agroforests at the time of the survey had the following characteristics.

The head of the family managing a permanent rubber agroforest was typically male (95 percent), was a local rather than migrant farmer (75 percent), and had completed primary school (71 percent). Twenty-eight percent of farmers were partially employed in off-farm, nonagricultural activities (e.g., teachers, carpenters, or traders), and 17 percent had official village roles, such as village officer or Muslim scholar (*ulama*).

The average respondent was 41 years old (the median age was 36 years), had long experience of rubber farming (18 years), and had known about the sisipan technique for about 7 years. Older farmers tended to be more recent adopters of the sisipan system, whereas younger farmers tended to have known about it for as long as they had had rubber agroforests. This result suggests that land availability, distance to forest plots, and establishment costs may affect sisipan adoption. For example, young farmers tended to have land further from the village than the older farmers, making it more difficult to control pest damage in a new plantation. And, as an alternative to rejuvenating old rubber agroforests, forest land could be opened, cleared, and planted using the cyclical system. But forest clearing is done by young farmers, who still have strength to do the hard work it entails, or by the rich, who can afford to hire such services. Most new rubber agroforest land is prepared using slash-and-burn. Of the land opened by slash-and-burn in our survey, most was forest and fallow (bush) land (88 percent), and only 12 percent was old (cyclical system) rubber.

The average operational holding was 6.4 ha and included several land uses (table 9.2). Most farmers (61 percent) had other farm land or forest, bush, or fallow land, suggesting that they could expand the area under production. Size of operational holding did not seem to influence sisipan adoption, which was practiced by some farmers with very large and others with very small farms.

Eighty four percent of farmers indicated that knowledge of sisipan was passed from father to son. The role of extension officers in influencing sisipan adoption decisions was very limited; only 4 percent of the sample reported learning about sisipan from extension workers.

Average household size was 5.7 people. Of these, the average number of potential family laborers (males and females between ages 15 and 55) was about 3, and the amount of family labor used on the farm was about 2.2 people (roughly equivalent to 660 person-days per year). Perhaps most importantly, the majority of farmers (68 percent) reported facing labor shortages. Sisipan is well adapted to labor shortages

Table 9.2 Average Area Dedicated to Particular Land Uses and Total Operational Holding

Land Uses	Average Areas (ha)	Number of Respondents Reporting a Given Land Use
Rubber garden		
Mature rubber	2.2	71
Immature rubber	1.8	60
Rice fields and other farming operations	0.7	50
Housing	0.1	42
Other land (forest, bush, and fallow)	1.6	46
Total operational holding	6.4	

because little time must be devoted specifically to it. For example, farmers manage emerging components of sisipan systems (planting or maintaining the saplings) after tapping mature trees, while performing other tasks in the field, or during rainy days when the opportunity cost of their time is low.

Regarding overall labor use, 54 percent of farmers depended exclusively on family labor in rubber production, and the remainder reported using family and hired labor. Most respondents (97 percent) agreed that hired labor was available in the village at a daily wage rate of Rp7000 to Rp17,000 (approximately US$1–2 at the late 1998 exchange rate of US$1 = Rp7500). Wage rates varied by task, location of task, and gender of laborer and were linked to the price of rice; the daily wage rate was generally equivalent to the market value of 2.5 kg of rice.

The average, continuously tapped rubber area was 2.2 ha and contained approximately 525 trees/ha. This average area produced an 82.4-kg slab of rubber per week. The dry rubber content of this slab was about 45 percent, so the average productivity of a rubber garden was about 880 kg of dry rubber/ha/yr, or approximately 12 g of dry rubber per tree per tapping-day. The productivity of rubber in the study areas was 35 percent higher than the national average for smallholders (Ditjenbun 1997) but much lower than the productivity of clonal rubber in plantations (1500 kg of dry rubber/ha/yr) (Hendratno et al. 1997).

Sixty-nine percent of the farmers' income was derived from rubber, with the remainder coming from off-farm employment, rice production, and the collection of wood and nontimber forest products (table 9.3). Because of the importance of rubber in generating income, most farmers could not afford to slash and burn and replant entire areas that contain low-productivity trees because doing so could interrupt income flows for up to 7 years. The sisipan system provides a continuous, though sometimes reduced, flow of revenues from rubber tapping by introducing seedlings while retaining older but still productive rubber and other trees. Income flows from

Table 9.3 Average Annual Income and Expenditures by Source and Use

	Income and Expenditures (thousands of 1998 Rp)[a]	Percentage of Total Income or Expenditures
Income		
Rubber	4819	69
Other farm activities	1424	20
Off-farm activities	768	11
Subtotal	7011	100
Expenditures		
Consumption (mainly food)	4344	68
Education	46	1
Others (clothes, socials, etc.)	2028	31
Subtotal	6418	100

[a]US$1 = Rp7500 in late 1998.

agroforests were sustained during a sisipan phase by intensively tapping all remaining rubber trees (and accepting the consequent reduction in their lifespans) or by selling fruits and timber products. Farmers were aware that the growth of sisipan rubber seedlings was very slow, but by maintaining high plant density and planting low- or no-cost seedlings farmers could stabilize incomes at acceptable levels. As regards overall family budgets, most farmers (76 percent) reported an annual income surplus after basic necessities were met, whereas the remaining 24 percent of farm households faced recurring deficits; for most farmers, then, the sisipan rubber system seemed to provide an adequate living.

Damage to seedlings by pests (mainly monkeys and wild pigs) could be substantial. To reduce these risks farmers could plant seedlings in fenced, large-diameter stumps or in bushy areas to hide seedlings from pests. In areas where risk of pest damage was very high, farmers generally used low-cost (and low-productivity) local seedlings as planting material, thereby reducing the value of unavoidable losses. Farmers wanting to boost productivity in these high-risk areas could plant clonal rubber and protect the seedlings with fences or live temporarily on the plot to guard seedlings.

Nonrubber trees in permanent systems also provided benefits to farm households, and the abundance of these trees depended on the growth stage of the patch and management intensity. Farmers surveyed mentioned more than eighty valuable nonrubber tree species, forty of which could be exploited from permanent rubber agroforest systems, and others were of less value but still retained if they did not compete with valuable species. Three fruit species were identified by many farmers as sources of food or income: petai (also known as parkia; *Parkia speciosa* Hassk.), jengkol (also known as blackbead; *Pithecellobium jiringa* W. Jack]), and durian (*Durio zibethinus* Murray). The number and diversity of nonrubber plants in rubber agroforests were closely related to the management choices by the farmers who weeded intensively (two to three times per year) during the first 2 years while food crops were grown (*ladang* phase) and thereafter only minimally managed the agroforest (again, via weeding). During this period of less intensive weeding, forest regrowth from seedlings or resprouting from stumps emerged and valuable trees (timber, fruits, and, rattan) were selected for retention every 3 to 4 years as farmers slashed weeds and other less valuable vegetation. This management process continued selectively cutting trees to allow light to promote rubber seedling growth.

Farmer Concerns, Economic Performance of Alternative Systems, and Strategies for Improving Rubber Agroforest Productivity

The survey identified five main factors that jointly affected farmers' decisions to adopt permanent rubber agroforestry systems (table 9.4). Note that continuity of income flows and risk reduction were key farmer objectives met by the sisipan system.

Table 9.4 Factors Influencing Farmers' Decisions to Practice Sisipan, in Descending Order of Positive Response Rates

Factor	Percentage of Respondents Indicating a Positive Effect on Sisipan Adoption Decision
Sisipan increases land productivity and maintains income flows from existing rubber and other trees.	99
Sisipan reduces the risk of pest damage.	74
Sisipan can be practiced using family labor alone.	58
Sisipan is a simple, known management practice.	56
Sisipan can be practiced with little or no capital or cash.	51

As indicated earlier, economic performance indicators were calculated for two versions of the cyclical system (the first using local seedlings and the second using more productive clonal planting material) and three versions of the permanent system (the first using local seedlings, the second using seedlings yielding 15 percent less than local seedlings, and the third using local seedlings and deriving income from nonrubber trees). The results of this analysis appear in table 9.5. All calculations were done on the basis of 1-ha parcels managed over a 30-year period and assumed a farmgate price of dry rubber of Rp3570 per kg and daily wage rates for men and women of Rp7000 and Rp5000, respectively. Prices were derived from survey data and were assumed to remain constant over the entire 30-year evaluation period. Three measures of eco-

Table 9.5 Financial Performance Indicators for Cyclical and Permanent Agroforestry Systems, by Productivity and System Scenario and by Cost Accounting Method

Systems and Scenarios	Measures of Financial Performance		
	Net Present Value (20% discount rate; thousands of late-1998 Rp)	Internal Rate of Return (%)	Benefit:Cost Ratio
Fully costed			
Cyclical			
Local seedlings	80	22	1.02
Improved seedlings	250	21	1.03
Permanent			
Local seedlings	1,300	33	1.09
Low-productivity seedlings	400	32	1.03
Local seedlings and fruit	3,900	>50	1.27
Partially costed			
Cyclical			
Local seedlings	1,800	35	2.80
Improved seedlings	1,500	24	1.29
Permanent			
Local seedlings	13,800	>50	8.72
Low-productivity seedlings	11,400	>50	7.41
Local seedlings and fruit	13,800	>50	8.72

nomic performance were calculated (NPV, IRR, and BC ratio) all of which presented consistent patterns; in what follows we focus on important NPV results.

First, all rubber agroforestry systems evaluated generated positive economic returns; that is, the discounted streams of benefits minus costs were positive for all systems. Simply put, it paid to invest in rubber agroforests of any kind.

Second, the permanent systems clearly dominate the cyclical systems in terms of NPV. The cyclical system using improved seedlings (NPV = Rp250,000) could not compete with even the permanent system using low-productivity seedlings (NPV = Rp400,000). This result is more significant when one considers the continuity of income emerging from the permanent systems but absent from the cyclical systems (important to the results presented in table 9.5 but not specifically addressed there).

Third, including income derived from timber, bark, and fruit trees such as jengkol, petai, and durian dramatically increased the economic performance of permanent systems (NPV increased from Rp1,300,000 to Rp3,900,000).

Fourth, not surprisingly, all measures of economic performance improved if farm land and family labor were not considered in calculating production costs. Differences were largest for the permanent systems that used family labor more intensively.

Finally, rubber yields may vary spatially and over time. Sensitivity analysis (not presented in table 9.5) suggested a BC ratio of 1 if rubber yields fell to 656 kg/ha/yr.

The productivity of both cyclical and permanent systems was low when local seedlings were the source of planting materials. To increase productivity, new planting material must be introduced. Smallholder rubber yields per tree could be more than doubled if improved clonal material were to replace local seedlings. The Indonesian Rubber Research Institute has recommended the planting of several rubber clones that increase rubber productivity and also provide useful timber products (Lasminingsih 1995). Economic analysis suggests that farmers would benefit from switching to improved seedlings, but obstacles to adoption exist (Williams et al. 2001; Joshi et al. 2002). For example, the economic returns to investing in improved seedlings depended on farmers' abilities to protect them from pest damage by fencing, round-the-clock vigilance, or village-level hunting. Although pest risks under cyclical and permanent systems cannot be compared yet, fencing individual trees in permanent systems with bamboo shafts appears to be effective (unpublished ICRAF report). In addition, improved seedlings (which are usually grafted) grow more slowly in heavily shaded permanent systems than in cyclical systems, but growth can be sped up if improved material is grafted directly onto well-established local seedlings.

Although initial farmer responses to seedling grafting have been quite positive, impediments to adoption exist. Currently, there are few reliable sources of improved planting material (district-level markets in Muara Bungo or Rimbo Bujang dominate the market for these seedlings), and grafting skills are not widespread. Expansion of the area dedicated to improved planting material (via grafting) could promote the development of local businesses such as rubber and other tree crop nurseries and increase job opportunities for those skilled in grafting.

CONCLUSION

Permanent rubber agroforestry systems occupy significant proportions of agricultural systems in the lowland peneplain and lower piedmont zones of Sumatra, Indonesia, where they also make substantial contributions to smallholder income. Although these systems are becoming more broadly adopted, little is known about their economic performance or the environmental services they generate. One traditional method of establishing and maintaining permanent rubber agroforests is the sisipan system, which does not use slash-and-burn practices but rather selectively removes old and less valuable trees and replaces them with rubber seedlings. The economic performance of permanent systems was found to be superior to the alternative cyclical systems that do use slash-and-burn techniques. Sisipan was also found to be compatible with smallholder characteristics in the region, especially labor shortages and lack of capital for agricultural investments. As the extensive margin is reduced in Sumatra and forest resources become scarcer, the sisipan system will become even more widespread.

But the productivity of sisipan systems based on local planting material remains low, with consequences for smallholder welfare. Productivity can be improved by introducing clonal rubber germplasm or by expanding the number of products extracted from rubber agroforests. More and more focused research is needed. Policy action to develop more productive germplasm and facilitate its adoption by smallholders is also needed.

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