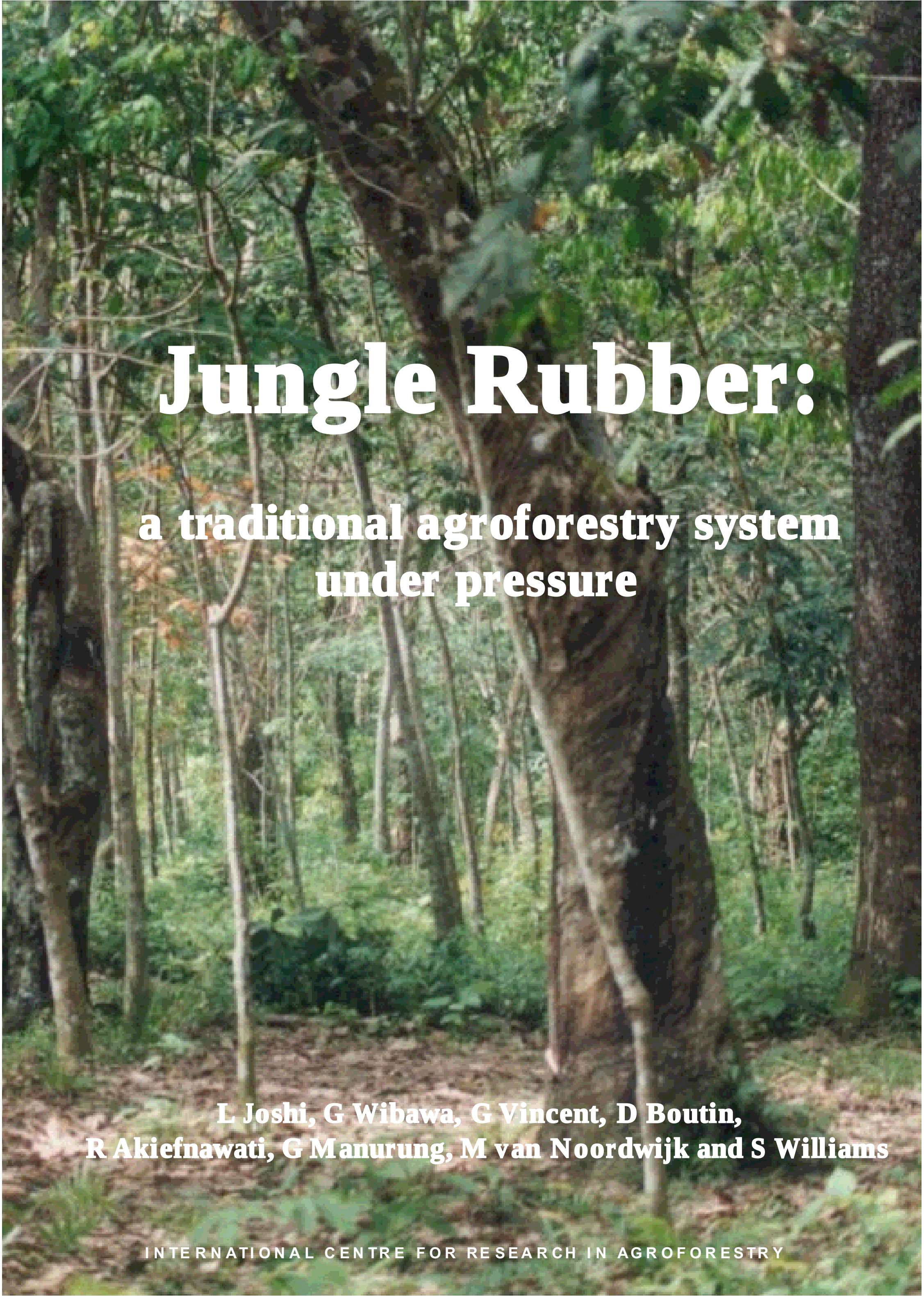

Jungle Rubber:

a traditional agroforestry system under pressure

L Joshi, G Wibawa, G Vincent, D Boutin,
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INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY

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ICRAF – **World Agroforestry Centre**
Transforming Lives and Landscapes

1. ICRAF SEA
2. University of Wales, Bangor (UK)
3. Indonesian Rubber Research Institute
4. IRD (France)
5. CIRAD (France)
6. Freelance Consultant

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International Centre for Research in Agroforestry
Southeast Asia Regional Research Programme
Jl. CIFOR, Situ Gede, Sindang Barang, Bogor 16680
PO Box 161, Bogor 16001, Indonesia
Tel: +62 251 625415; fax: +62 251 625416; email: icraf-indonesia@cgiar.org
Http://www.icraf.cgiar.org/sea

Cover Photos:

Cover page: In a sisipan system young rubber seedlings are planted inside rubber agroforest to gradually replace unproductive trees (*Gede Wibawa*).

Back page:

top: Pak Lahsono of Lubuk village in Jambi is still tapping this rubber tree believed to be over 80 years (*Laxman Joshi*).

bottom: Pak Zainol of Sepunggur village has started tapping rubber trees in an experimental plot (*Ratna Akiefnawati*).

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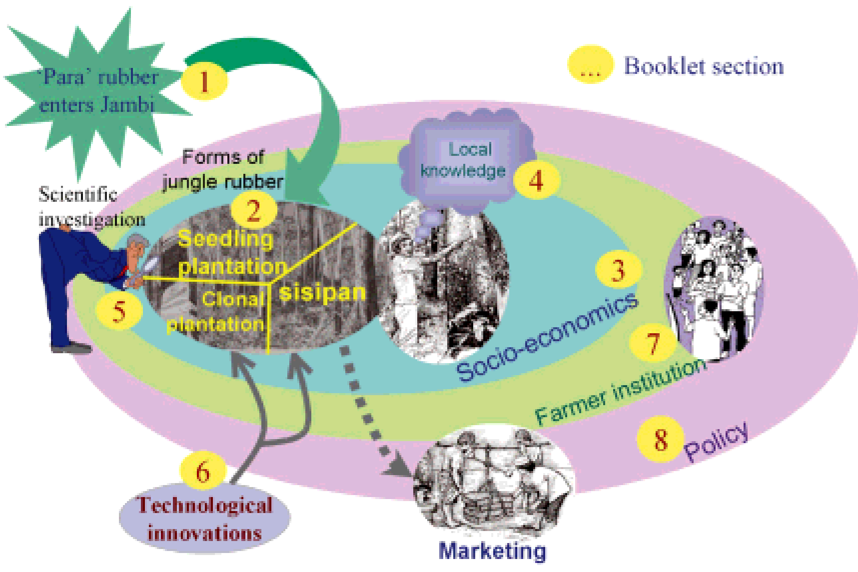
Preface

The International Centre for Research in Agroforestry (ICRAF) began research into rubber based agroforestry systems (*Hevea brasiliensis*) in the Jambi Province of Sumatra (Indonesia) some seven years ago. Various research activities, including surveys and experiments, have been undertaken since then. This booklet contains some of the research findings which were the result of these activities. These findings concern various issues associated with jungle rubber agroforestry, which are specifically relevant to the context of Jambi Province. The booklet has eight sections, each covering different aspects of the system. These are summarised in the following diagram.



Section 1 of this booklet contains information about the beginning of 'Para' rubber (*Hevea brasiliensis)* cultivation in Jambi Province, a process which quickly transformed the landscape of the region. This brief history is followed, in Section 2, by an account of the various forms of jungle rubber which now exist. The socio-economic issues influencing farmers' decisions when they choose between slash and burn and a more permanent system of agroforestry are discussed in Section 3. The local ecological knowledge of farmers is considered in Section 4. Section 5 summarises current scientific understanding of the growth and productivity of jungle rubber agroforests. Section 6 includes brief summaries of relevant experiments carried out in order to develop improvement pathways for jungle rubber. The testing of farmer institutions as a means to garner support and required resources to improve the system in a collective manner is described in Section 7. Finally, Section 8 considers some policy issues that impinge on the production of, and even threaten the existence of jungle rubber agroforestry as a viable option for smallholder farmers in Jambi Province. Examples of real life cases are provided in boxed texts to highlight a number of important aspects of jungle rubber.

The information in this booklet has been compiled from numerous research activities and surveys carried out in Jambi. However, this is not a comprehensive report on such research, nor does this booklet report the findings of all research undertaken by the many institutions active in the Province. The support, both financial and otherwise, provided by Department for International Development (DFID, UK), the University of Wales, Bangor (UK), Institut de Recherche pour le Développement (IRD, France), Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD, France) and the Indonesian Rubber Research Institute (IRRI), Sembawa Research Station (Palembang, Indonesia), for various projects and activities, has been instrumental to our research in jungle rubber. However, these institutions, including donor organisations, are not responsible for the information contained in this booklet.

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1. 'Para' rubber in Jambi province

Until the start of the 20th century, Jambi Province in Sumatra (Indonesia) was largely covered by natural forests. It had experienced little economic development, and had a poorly developed infrastructure. Rivers were the main medium of transportation. Most people practiced shifting cultivation and the gathering of forest products, including timber and some latex. However, latex, or 'getah', gained importance towards the turn of the century, when demand from industrialized countries for natural rubber increased and created a 'rubber boom'. The high price of rubber attracted the attention of farmers and colonial (Dutch) officials, and they began to cultivate latex-producing trees.

The first plantations were established in the 1890s, using the local species *Ficus elastica*. Although 'para' rubber (*Hevea brasiliensis,* from Brazilian Amazon) was by that time already known in Indonesia, *F. elastica* was the preferred species for latex production because it gave higher yields in field trials. However, preference shifted to *Hevea* after the introduction of improved tapping techniques increased its productivity beyond that of *F. elastica*.

In the early twentieth century, 'para' rubber was introduced to Sumatra from Peninsular Malaysia by migrant plantation workers, tradesmen and passing pilgrims. Many local farmers from Central Sumatra went to work in new rubber plantations in Malaysia, both to avoid the taxes and forced labour schemes introduced by the recently-established Dutch government in Central Sumatra, and because they were attracted by the high wages offered by the Malaysian plantations. These individuals returned with seeds and seedlings, as well as with the knowledge and skills necessary to grow and tap rubber trees.

Smallholder rubber was first planted in Jambi in 1904. This event was reported in 1918 by an agricultural extension officer, who observed rubber trees that had been planted in slashed and burned fields, but that were managed (or unmanaged) as though 'wild', along with other natural vegetation. This was the first recorded incidence of jungle rubber agroforestry in Jambi. Although 'para' rubber was a species used primarily by estate plantations in the early years, it was quickly adopted by smallholder farmers who realised that it fitted into their existing practice of shifting cultivation in crop-fallow systems very well. Rice and other

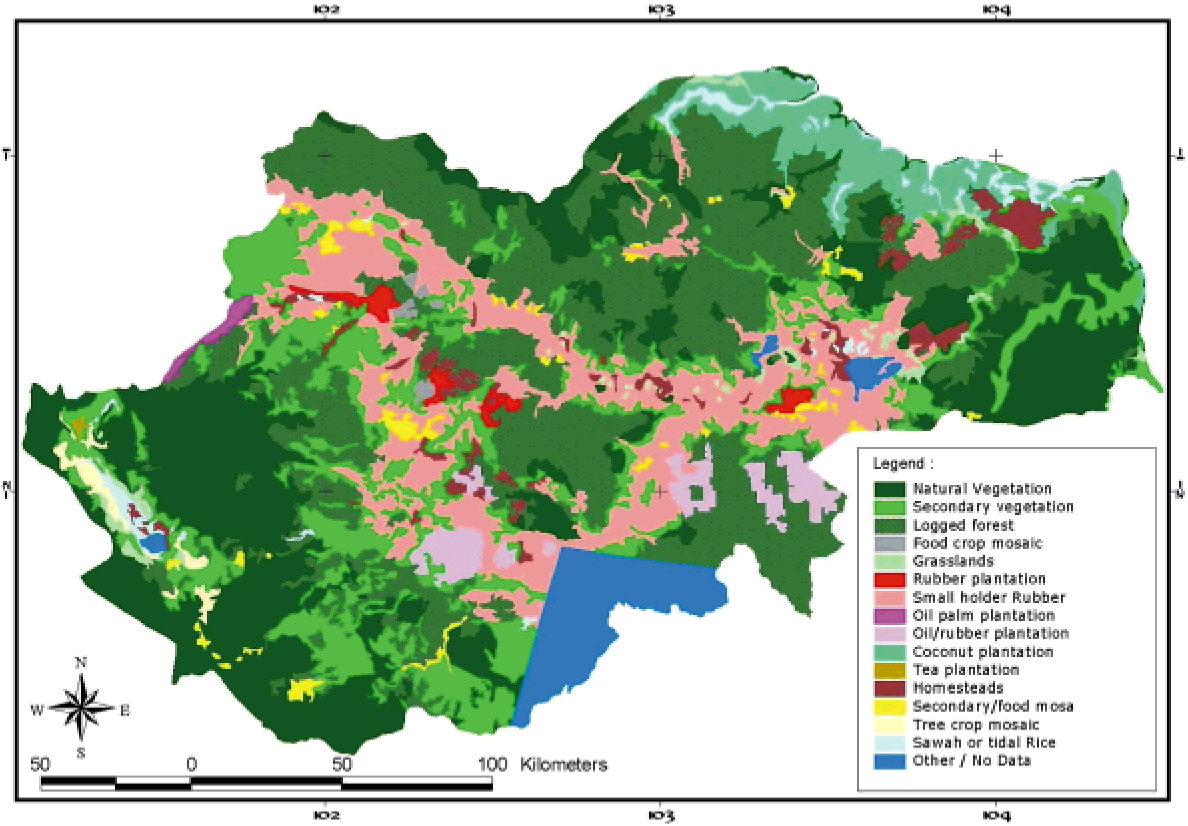


Figure 1. Landuse in Jambi province in 1992 (*Source: Danan Hadi, ICRAF*).

annual crops could still be grown in the first few years of the cycle. Moreover, the existing system of river transport to Jambi town, and its mainly Chinese tradesmen, provided an efficient way to market latex (rubber) from the area. The rapid expansion of *Hevea* in many parts of Indonesia, including Jambi, changed the landscape quickly and forever. Little natural forest now remains in Jambi, as it has been largely replaced by rubber gardens and plantations (Figure 1). The area under rubber in Jambi Province doubled from 1965 to 1985 and continued to increase until around 1993. Since then, the trend has levelled off (Figure 2).

Rubber is a major export from Indonesia. In Sumatra and Kalimantan, the two major rubber producing islands of Indonesia, an estimated seven million people currently make their living from more than 2.5 million hectares of rubber-based agroforests. Smallholder rubber gardens constitute 84% of the total Indonesian rubber production area, producing 68% of its production volume (DITJENBUN, 1999). Jambi Province now ranks third, after South Sumatra and North Sumatra, in terms of latex production, with 97% coming from smallholder farmers with less than 5 ha of rubber gardens. Between 1992 and 1998, the total area under rubber in Jambi increased at a rate of 5,520 ha/year. The productivity of jungle rubber, however remains far lower, at only one third to half (500-650 kg/ha/yr at 100% dry rubber content (DRC)) of the productivity of clonal plantations (1000-1800 kg/ha/year at 100% DRC).

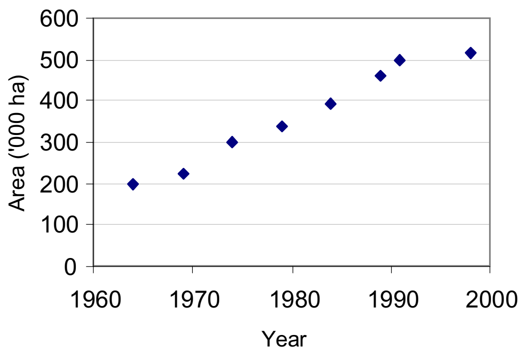


Figure 2. Area of rubber production in Jambi province, Indonesia.

2. Forms of jungle rubber

Because the term forest is associated with conflicts with the State, farmers prefer to use the term *kebun karet* ('rubber garden') to refer to their agroforests. Many farmers rejuvenate their rubber gardens only after production from the old rubber becomes very low. They do so by slashing and burning to start a new jungle rubber cycle, hence called a cyclical rubber agroforestry system or CRAS, Figures 3, 4 and 5, (Gouyon *et al.,* 1993; Joshi *et al.,* in press [b]). In this process, farmers use either locally-obtained rubber seedlings (the traditional practice) or improved clonal planting material. In the

Figure 3. A monoculture rubber plantation that replaced an old jungle rubber agroforest following slash and burn activities (*Photo: Laxman Joshi*).

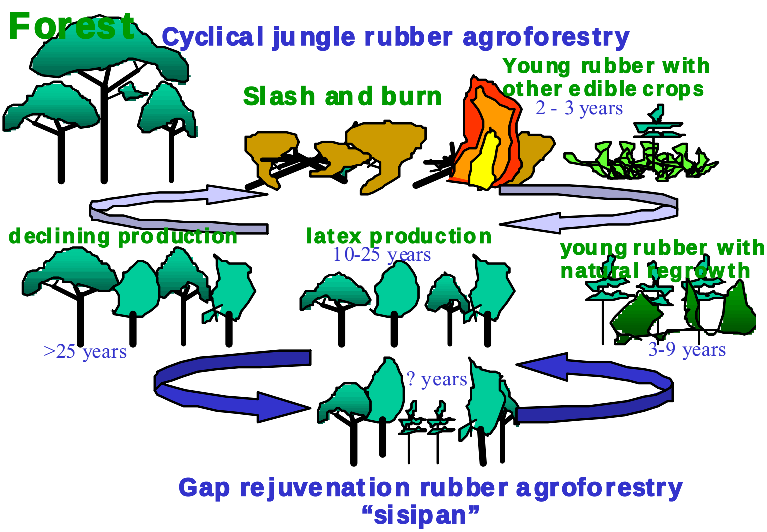


Figure 4. Schematic representation of the *sisipan* and the slash-and-burn system in rubber agroforestry.

first few years, smallholder farmers often plant upland food crops such as rice, maize, soybean, mungbean, pineapple or banana. Estates plant leguminous cover crops while the young plants become established.

Many smallholder rubber farmers lack sufficient capital to invest in the slashing, burning and replanting of rubber trees in their old rubber gardens. This lack of capital is not the only obstacle these farmers face: it is compounded by the fact that most of these plots are the major income source for these households, and by a decline in the availability of land for new planting in the area, as well as by the risk of failure due to vertebrate (wild pig and monkey) pest damage. To address these problems, farmers in Jambi have adopted a different technique of rejuvenation, one that does not require slashing and burning. In the *sisipan* system, new rubber seedlings are planted inside mature rubber gardens, in forest gaps, to replace dead, dying, unproductive or unwanted trees (Figure 6). This technique has the potential to significantly prolong the productive stage of rubber gardens.

Although some farmers perceive the gap replanting strategy as 'old-fashioned' and less efficient in terms of production and management, nearly half of rubber farmers actively carry out gap replanting in their rubber gardens. Some farmers in Jambi have practised this management style successfully for decades, although most seem to have started only

Figure 5. Existing vegetation in either jungle rubber agroforests and natural forests are cleared and burned to start a fresh cycle of jungle rubber agroforest (*Photo: Laxman Joshi*).

Figure 6. Natural or manually created gaps are used by farmers to plant new rubber seedlings in a sisipan system (*Photo: Gede Wibawa*).

within the last ten years or so. As many farmers own more than one plot of rubber agroforest, they are practising both *sisipan* and slash and burn simultaneously in different plots. As socio-economic and biophysical factors vary between villages, the proportions of farmers practicing *sisipan* can be expected to change accordingly.

3. Socio-economic factors and farmer decisions

Research carried out in Jambi, in the Muara Bungo District (in the villages of Rantau Pandan, Sepunggur, Danau and Muara Kuamang) and the Batanghari District (in the villages of Sungai Landai, Suka Damai, Malapari, Napal Sisik, Pelayangan, Rantau Kapas Mudo and Tuo), indicated that about 47% farmers undertake gap replanting in at least one of their rubber gardens (Wibawa *et al.*, 2000b).

Farmers gave five different reasons, in the same survey, for carrying out gap replanting in their old jungle rubber gardens:

1. to maintain continuity of income from their existing gardens (89%);
2. because they lacked capital to slash, burn and replant the plot (70%);
3. because they were unwilling to take the high risk of vertebrate pest damage, especially by wild pigs (65%);
4. they had confidence in gap replanting as a feasible approach to rejuvenate an old rubber garden (59%);
5. gap replanting is less labour-intensive, and may be carried out at times when tapping is not practised (36%).

Farmers following a slash-and-burn approach prior to rubber replanting, perceived that ash from the burned vegetation was necessary for rubber seedling growth (67%), and necessary for the successful growth of other agricultural crops (42%). Of these farmers, 30% said that most rubber trees in their rubber gardens were beyond the productive stage, and stated that these had to be replaced; gap replanting was not seen as a viable strategy under these circumstances. Some farmers were interested in planting clonal rubber or were participants in projects promoting clonal rubber (19%) and, again, did not perceive gap replanting as feasible method of rejuvenating their agroforest. Other reasons given for using the slash-and-burn technique included easier preparation of land for crops and rubber plants, as well as the convenience of guarding against vertebrate pests in open fields.

Rubber contributed, on average, 70% of the total household income in the surveyed villages (see Table 1 for details of average household income and expenses). The high dependency of such farmers on revenues from rubber means that those with no alternative source of income are unlikely to use slash-and-burn systems, as income from the replanted plot would stop until the new trees reached the productive stage.

Table 1. Average yearly income and expenses of farmers' households.

Details	**Total in rupiah '000**	**% of total**
Sources of income		
Rubber	4819	69
Non rubber farming	1424	20
Off farms	768	11
Total	*7011*	*100*
Expenses		
Consumption (mostly food)	4344	68
Education	46	1
Other	2028	31
Total	*6418*	*100*

1 US dollar = Rp 7500 (year 2000)

The choice of rejuvenation method (slash and burn or gap replanting) was largely determined by a household's financial strength (their ability to invest in slashing, burning and replanting). Such financial considerations included family labour availability and the household's dependency on rubber for a household income. The risks associated with crop failure, damage by vertebrate pests and fluctuation in the market price of rubber, as well as the farmers' own knowledge and confidence in the gap replanting technique and the availability of land for further clearing, were other driving factors behind the decision to use slash and burn or gap replanting. External factors, such as the availability of government projects and other means of support (capital/credit, land, transport and production inputs) also significantly influenced farmers' decisions and their perception of available options.

Financial calculations have been made, comparing various rubber-based agroforestry systems: the slash-and-burn type (using clonal or seedling plants) and the gap-replanting type. The assumptions made were based on farmers planting agricultural crops in the first two years after slash and burn; farmers can therefore also harvest non-rubber products from jungle rubber gardens in addition to latex. Labour for such projects comes primarily from family members. When additional labour is needed, it is hired at Indonesian Rp 7000 and Rp 5000 for a man or woman respectively. Our financial analysis considered two scenarios. In the first scenario, all production factors were purchased and all products were sold. In the second scenario, only some of the production factors were purchased, while most non-rubber products were consumed within the household.

The financial analysis indicated that, in the first scenario and using clonal rubber, return to labour was Rp 15000 while with seedling rubber, this was about Rp 6600. Under the gap replanting scenario, return to labour ranged from Rp 7800 to Rp 9500. All systems indicated their feasibility (Table 2); however, the gap replanting strategy produced a higher net present value (NPV) largely because of its very low input and labour requirements, compared with other systems.

Table 2. Feasibility indicators of various rubber based agroforestry systems, in which a proportion of the production inputs were not purchased and some of the non-rubber products were marketed.

Scenarios	NPV (20%) (million Rp)	Return to Labour (Rp/day)
Slash and burn systems		
Clonal rubber (moderate yield)	2.85	14664
Seedling (yield :0.5 x clonal rubber)	1.83	6176
Sisipan		
Seedling (constant yield: 728 kg/ha/y)	11.16	7676
Seedling (yield:0.5 x clonal rubber)	11.14	8221

In the current context of the increasing labour wage rate in plantations (Rp 10000) and the increasing price of input material (due to inflation), the low and fluctuating price of latex in the market (Figure 7) makes rubber tapping less profitable in comparison with working as a paid labourer in plantations. This is a choice many rubber farmers in Jambi are currently facing.

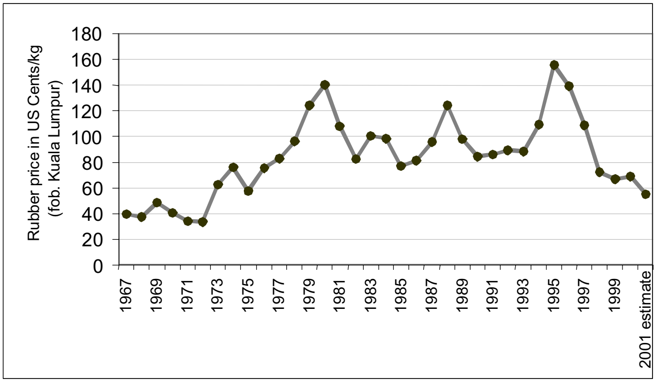


Figure 7. Fluctuation in international price of rubber in Kuala Lumpur market (fob).

4. Local ecological knowledge

Scientific understanding of the ecological factors and processes involved in gap replanting or *sisipan* inside jungle rubber agroforests is still sparse. Nevertheless, farmers who have practised *sisipan* for many years have learnt the skills needed to achieve success, and have obviously have garnered knowledge on how best to manage gap replanting (Figure 8). A study of farmers' understanding and knowledge of the jungle rubber system, and of the gap rejuvenation technique in particular, was carried out in Jambi.

Figure 8. Farmers are able to explain their knowledge about the ecological processes that occur in their fields (*Photo: Laxman Joshi*).

The large effect that the gap has, both at the canopy level (for sunlight) and at ground level (with regard to nutrients and moisture), on rubber seedling growth, was cogently expressed by farmers. The minimum gap required for successful gap replanting is a space of six to eight metres between two live trees. Although natural gaps can form inside a rubber garden, farmers may deliberately create gaps through selective culling (normally through ring barking) of unwanted and unproductive trees. At ground level, they carried out light weeding to reduce competition from weeds. These gaps need to

Box A.
A jungle rubber agroforest under share tapping

The rubber agroforest in Simpang Babeko, close to the Muara Bungo-Jambi City road, is a typical jungle rubber agroforest plot. The owner is Pak Japar (36 years old) but the agroforest is tapped by Pak Tukiono, under a share tapping arrangement. Rubber trees were planted, (presumably following slash and burn) some 40 years ago. Pak Japar inherited the field several years ago from his father, who had bought the land (with seedlings) in 1975. It is a relatively small plot (around 1 ha), and is less than half the size of the average jungle rubber plot (usually between 2 and 3 ha). Pak Tukiono, the share tapper, receives three fourths of the harvest. The most common sharing arrangement, however, is called *bagi tiga*, (translated as 'one third sharing') in which the tapper keeps two thirds of the harvest and the owner gets one third (Wibawa *et al.*, 2001). Generally, the proportion of rubber kept by the tapper increases as the productivity of the rubber trees decreases.

Current yield of latex (cup lumps) is about 40 kg per week from about 300 rubber trees. Presumably, however, not all rubber trees are tapped all the time. The field has timber species like Medang (*Alseodaphne* spp.), Meranti (*Shorea* spp.), Kemenyan (*Styrax benzoin*), Terentang, Terap (*Artocarpus elasticus*) and Asam Kandis (*Garcinia parvifolia*), as well as bamboo and fruit trees like Petai (*Parkia speciosa)*, Kabau and Rambe (*Baccaurea* spp.) and other minor species. A couple of years ago, Pak Japar sold some timber (Meranti and Medang) from the plot. However, he has not been able to harvest fruits, such as Petai, because it is accepted in the villages that anybody may pick fruits (for consumption only) without permission from the garden owner.

Pak Japar has five more hectares of rubber agroforests in another location. When the opportunity arises, he goes logging (*balok*) with other villagers.

be managed carefully to ensure that the rubber seedlings planted receive sufficient light and space as well as to stop weed proliferation (Figure 9).

Pig damage to young rubber plants is a major cause of seedling mortality in rubber agroforests in Jambi: up to 50% of planted rubber seedlings are damaged within the first year. Farmers see a clear relationship between weeding and the risk of damage posed by pigs to new seedlings in the field. Seedlings in cleanly-weeded plots are highly prone to pig damage, due to increased visibility and access. Even in the slash-and-burn system, where farmers stand guard to

Figure 9. In a *sisipan* system, young rubber seedlings are planted and protected close to old and unproductive rubber trees (*Photo: Laxman Joshi*).

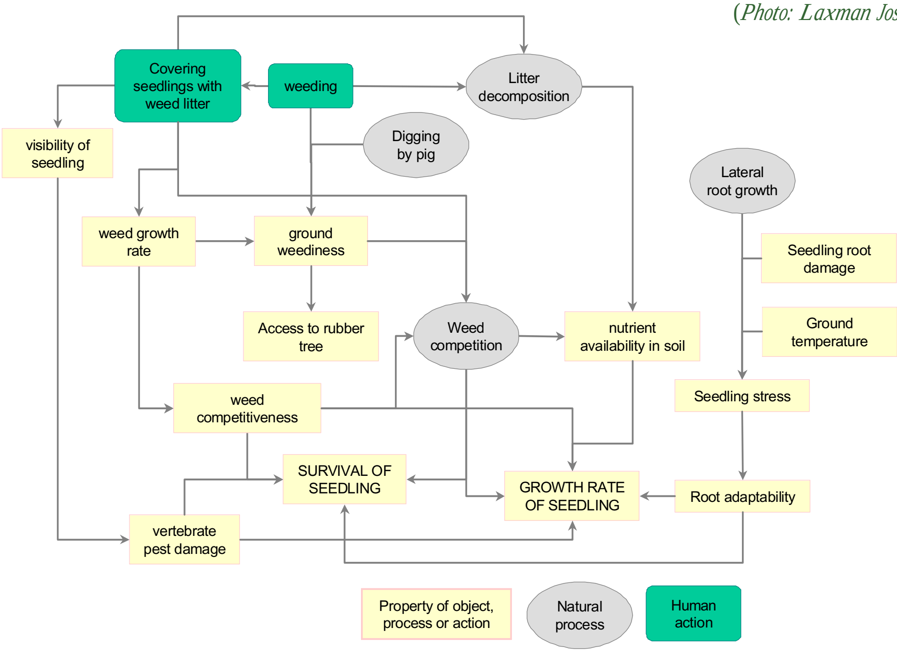


Figure 10. Farmers' knowledge about interactions among weeds, weeding and seedling performance in a *sisipan* system.

drive away the animals, weeds can provide a hiding place for the pigs. In the *sisipan* system, farmers weed around seedlings but leave the weed litter in order to physically hide rubber seedlings. Farmers are also aware that weed litter is a source of nutrients and moisture for seedlings (Figure 10).

5. Understanding Jungle Rubber Agroforests

5.1 Slash and burn

Figure 11. Thick smoke like this, arising mainly from burning fields, affected many parts of South East Asia in 1997 (*Photo: Quirine Ketterings*).

Slash-and-burn land clearance causes smoke that affects people's health and damages the environment - which is the main reason the government put restrictions on the use of fire (Figure 11). However, all farmers and plantation companies recognise that fire is the cheapest and easiest way of clearing vegetation and of making space for new crops and trees (Ketterings *et al.*, 1999). Moreover, the ash layer is a source of soil fertility. However, obvious questions remain. For example, does this mean that the more biomass that burns, the higher the soil fertility will be for the next crop? Or, are fires that become too hot harmful to the soil? Is it better to remove large pieces of wood from the field (to make planks, for firewood at home, for making bricks or for sale) or to burn them on site? Can fires be managed in such a way that they produce very little smoke? How can one manage without the use of fire - will extra fertiliser and lime be needed to compensate for the lack of ash? These are some of the questions to which ICRAF and its partners have tried to seek answers in Jambi.

5.1.1 Why do farmers burn -- what do they expect would be the result of not burning?

Most farmers who want to grow rice or food crops say "No fire, no farms", because fire benefits them through:

- The provision of free fertilizer via ash.
- The improvement of the soil's structure.
- The elimination of field debris (making it possible to walk around in the plot).
- A reduction in the regrowth of weeds (most understorey plants are killed by the burn and the ground is left completely clean, free of weeds and ready for planting the first crop).
- A reduction in pest and disease problems.

For farmers who want to grow tree crops, however, the options provided by a slash-and-mulch approach are better.

The impact of fire on the soil has both positive and negative aspects, depending on the temperature. In summary, for fires that don't increase the surface temperature above 150^{o}C, positive effects predominate, while fires that are hotter than 400^{o}C have negative effects throughout (Ketterings and Bigham, 2000).

5.1.2 Gas emissions during slash and burn

Fires used for land clearing after forest conversion lead to emissions of methane and nitrous oxides, as well as of the fine particulate organic material that is the main cause of 'haze'. The fraction of total biomass that is emitted in these forms depends on the type of fire, and especially on the ratio between the 'flaming' and 'smouldering' phases of the fire (Figure 12). If the fuel is wet, a larger part of it might be left behind as unburnt or partially burnt residue (and charcoal), while a larger fraction of the substance that was burned is emitted as gases or as small particulate matter. As everyone who has used wood in a fireplace or for cooking knows, hot fires using dry fuels tend to be cleaner, as more complete oxidation takes place. Overall, the total emission factor has to be integrated over the phases of a fire, as a wet/damp fuel load can be dried by the heat pulse ahead of the flames, before it actually catches fire itself.

Figure 12. Burning of vegetation and felled trees improves soil fertility. Remaining vegetation is piled up and allowed to dry a little before it is set on fire (*Photo: Quirine Ketterings*).

The negative impacts of fire on the soil can be reduced by not letting fires get too hot -- so one cannot wait until the fuel load is completely dry before burning. However, smoke emissions are lowest when the fire is hot, and this causes a dilemma. One answer is to avoid the use of fire completely, an answer which requires the use of a 'slash-and-mulch' technique which can be used for planting rubber or oil palm, but not for growing food crops.

5.2 Damage by vertebrate pests

The extensive conversion of natural forests that has occurred over the last ten years or so in Jambi Province, has coincided with a reported increase in pig damage in rubber agroforests. Destruction of their natural habitat has probably pushed wild pigs (*Sus scrofa*) into rubber agroforests. Moreover, the absence of tigers, their main natural predator, has led to a rapid increase in pig population (a female can give birth to 2 to 10 piglets per year). *Sus scrofa* seems to adapt well to rubber agroforests, showing preference for terrain with rough topography covered by bushy vegetation.

A recent survey carried out on wild pig ecology in the Muara Bungo area of Jambi Province (Sibuea and Tular, 2000) has shown that, on average, pigs spend two thirds of their active time foraging for food, a pastime carried out mostly during the night. The food sources in the agricultural land of the area include rubber plants (seeds, roots, and young stems), egg plants, chilli, maize, cassava, rice, guava (*Psidium guajava*), earthworms, insects and fish. Usually pigs are gregarious, forming groups of up to 21 individuals. In most cases, smaller groups will include parents and offspring. Population density is difficult to assess, as the animals are very mobile. The pig ecology study estimated 49 wild pigs inside the 85 ha area surveyed in one village.

Figure 13. Wild pigs are a major problem in rubber-based systems in Jambi (*Photo: Tulus Sibuea*).

According to farmers, pigs are the most important pest with which they have to cope at present. Monkeys, deer and termites were cited as pests of secondary importance in rubber plantations. When young plants are not simply uprooted by pigs, they are often broken, an occurrence which severely retards their growth (Figure 13). In ICRAF trials in a few villages around Muara Bungo, up to 70% of young plants were found to be broken, both by pigs and monkeys, even though those plots were fenced (Williams *et al.* 2001).

Interviews with 40 farmers, carried out in five villages in the Bungo District, showed that, on average, the survival rate of rubber plants was less than 50% one year after interplanting in existing rubber agroforests. The primary cause of seedling mortality was overwhelmingly attributed to wild pigs, even though in most cases one or more precautions had been taken to reduce pig damage. Indeed, farmers interplanting rubber seedlings in existing rubber agroforests have developed a range of strategies to minimize pig damage. These include individual plant fencing, using large seedlings (diameter >3 cm; Figure 14), hiding young plants with weeds and dead bushes, and hunting and trapping. None of those methods are foolproof, and most of them require a considerable amount of effort and cost.

Figure 14. Often large "seedlings" are planted by farmers to reduce damage by wild pigs and monkeys (*Photo: Laxman Joshi*).

Specific trials have been conducted to assess the efficiency of two protection strategies. Cinnamon (*Cassia vera*) plants (supposed to possess pig-repelling properties while not competing with rubber) were interplanted with rubber plants in an existing agroforest. However, they did not prove successful in reducing pig damage, possibly because of the poor development of cinnamon plants used in the experiment. Conversely, individual fencing, using bamboo shafts and salak palm (*Salacca edulis*) spines, did reduce pig damage by 50%. Though effective, the latter method entails significant investment.

A combination of individual fencing, the concealment of rubber plants behind bushes, and traps would probably yield a high level of protection

Box B.
Slash and burn to replant rubber

Pak H. Parori, from Muara Bungo, (who works in a government office in Jambi) owns the recently slashed and burnt field near Simpang Babeko, along the Muara Bungo-Jambi highway. This five hectare plot was previously an old jungle rubber agroforest (JRA) of around 50 years of age, and is now being planted with clonal rubber (clone PB 260) as a monoculture plantation.

The old JRA was cleared in June this year. Two labourers were hired with a chainsaw for a week, in order to fell the trees. About sixty truck-loads of timber were sold to a business which needed firewood for firing the bricks and roof-tiles that it produced. The price paid was low, only Rp 25,000 per truckload, as it was the business who brought the trucks to the field, and provided the labourers who loaded the wood onto them (the price for a truck-load of firewood delivered to the customer's door is Rp 160 000). The remaining dry vegetation in the field was burned in July, after a fire break three metres wide was constructed around the field. Six labourers were hired for the burning of the field, which took about six hours. Plenty of firewood remained after burning, and this was extracted from the field.

The total cost of clearing and replanting the 5 ha field with clonal rubber was Rp 20 million (about Rp 4 million/ha). This amount included the purchase of clonal planting material, which cost just over 6 million Rupiah. The remaining costs were primarily for labour (used for slashing the vegetation, felling the trees, burning, fencing, pitting and planting the field) and also for hiring a chainsaw and for buying additional poles for fencing.

The capital investment required for the rejuvenation of a jungle rubber agroforest through slash and burn and for replanting (particularly with clonal material) is obviously beyond the resources of the majority of resource-poor farmers.

under a gap replanting approach. Similarly, young rubber plantations would require complete plot fencing and permanent guarding – through temporary dwelling – during the first two years in many areas, to ensure that pig damage was kept at a tolerable level.

Given that there exists only a low population of natural predators, and unless epidemic diseases reduce population growth, it is likely that the pig population will continue to increase in the near future, and that the damage caused by pigs to agriculture will increase as a result. Given that this animal is highly mobile and adaptable, a purely local response to pig damage is unlikely to control the problem in the long term. Limited evidence suggests that lower pig damage incidence is associated with proximity to a busy road, as well as with high level of human activity inside the fields. A landscape approach, which would aim at controlling the overall pig population and confining it to non-productive land (riparian forests and non-productive fallows), would probably be more effective in the long term.

5.3 Plant diversity

Rubber agroforests are characterised by their uneven-age structure, and by the numerous companion species growing alongside the rubber trees (Beukema, 2001) (Figure 15). At a plot level, species richness of plants has been found to be about half that of natural forests. Similarly high values of species richness have been reported for birds and mammals (Figure 16). The uneven-age structure is due, in part, to natural regeneration, but also to active interplanting of rubber seedlings.

Figure 15. Jungle rubber agroforests like this in Jambi are becoming increasingly important as the remaining habitat for the declining biodiversity in the region (*Photo: Gede Wibawa*).

For example, a 35-year old rubber agroforest still in production in Muara Kuamang village in Jambi Province, contained 116 tree species in a one-hectare plot (total number of trees above 5 cm dbh = 898 individuals; including 300 rubber trees (Figure 17).

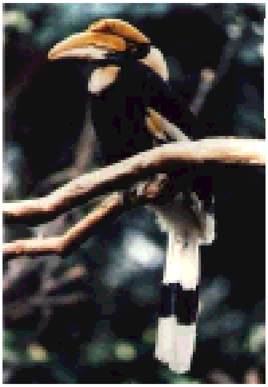
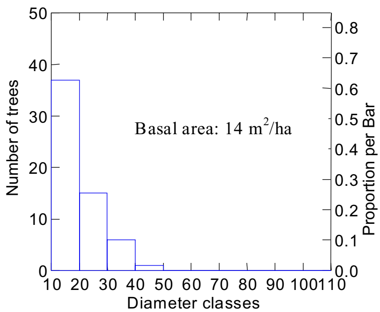
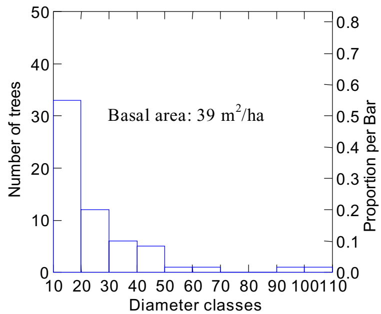


Figure 16. Species of wildlife, such as this Great Hornbill (*Buceros bicornis*, Coraciiformes), are now seen sheltering in jungle rubber agroforests as natural forests continue to disappear in the region.

In comparison with a mature forest, the basal area was low, due to the absence of big trees (Figure 17). The canopy was also more open than that of a dense natural forest, a fact which directly affects the regeneration dynamics (abundance and composition of the understorey). Species accumulation curves of saplings, inventoried in a forest understorey and in the agroforest, show a much lower, but still considerable, diversity in the agroforest (Figure 18).



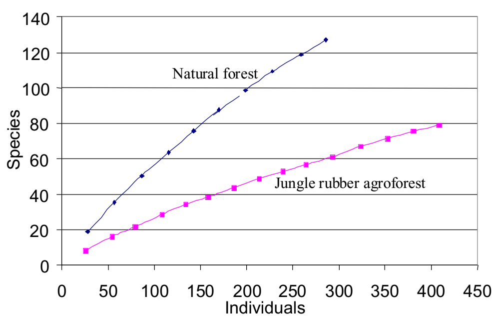
35 year old jungle rubber



Natural forest in Jambi

Figure 17. Diameter distribution of 60 trees sampled along a transect in primary forest and rubber agroforest.

Figure 18. Species accumulation curves for saplings sampled in primary forest and in rubber agroforest.



The data shown here are part of a landscape-level survey, recently initiated by ICRAF, which combined remote sensing with intensive field sampling of all the forest-like vegetation. The main objective of the study was to quantify the relative importance of the major factors which affect the potential conservation of forest biodiversity within rubber agroforests (for example, landscape characteristics, management practices and age/ structures of [agro-]forest).

5.4 Rubber growth and production in agroforests

Permanent sample plots have been set up in rubber agroforests to gather baseline data on growth of rubber, and other tree species in such environments. The analysis of the first year of growth for one such plot allows us to confirm and quantify the importance of a number of factors on diameter increment (Ruhiyana, 2000; Azhima, 2001; Martini, 2001; Sanjaya, 2001). Tapping frequency was shown to affect diameter increment negatively. Dawkin's crown form index, a simple measure of the crown development and balance, was linearly correlated with growth rate. Dawkin's crown position index, which reflects crown access to light, also proved to be positively related to diameter increment (Figure 19).

ICRAF, in collaboration with the Indonesian Rubber Research Institute (IRRI), also examined how management and planting material affected variability in latex production and tree growth. Latex yield and diameter increment of individual rubber trees of uncertain genetic origin were

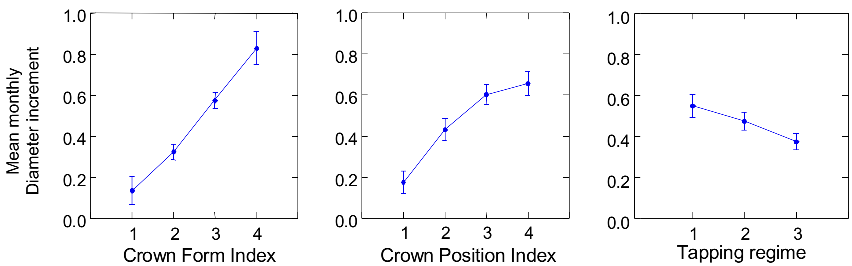


Figure 19. Adjusted least square mean of rubber tree growth per crown form category (1: least satisfactory, to 4: the most satisfactory crown form), crown position (from 1: no direct light, to 4: full overhead light) and tapping regime (1: not tapped, 2: irregularly tapped, 3: continuously tapped).

compared with trees growing in a seedling plantation (GT 1-illegit. 'clonal seedlings') and a clonal plantation (GT 1 grafted clones). After correcting latex yield data for length of tapping cut, the clonal plantation had the lowest variability in terms of yield, whereas variability in the seedling plantation and in the jungle agroforest were similar. Conversely, variability in growth rate was similar in both plantations and much lower than in the agroforest. Growth response is believed to be more sensitive to management and to the environment than is latex production. This suggests that latex production is given priority over growth under sub-optimal conditions.

These results, on determinants of growth and latex yield, serve to calibrate a spatially explicit dynamic growth simulator. This model can then be used to explore long-term productivity of a range of management scenarios and growing conditions.

5.5 Is enrichment planting with clonal material in rubber agroforest an option?

ICRAF has also investigated the growth of clonal rubber plants under different levels of canopy openness. The clones tested were PB 260, RRIC 100, RRIM 600 and BPM 24. GT 1 seedlings and wildlings served as controls. Growth parameters (diameter, height, number of whorls and number of leaves) were recorded every three months. Canopy openness above each seedling was monitored every six months using hemispherical photographs.

Preliminary observations (after 12 months of growth) show the following results:

- Sapling growth is very responsive to canopy openness. Growth rate appears to be significantly lower in rubber agroforest than in artificial shading experiments under the same cumulative total daily Photosynthetically Active Radiation (PAR). This could partly be due to competition with weeds in rubber agroforests, as weed cover is positively correlated with the light level. It could also be related to the light intensity distribution, which is less favourable under natural shading. Below-canopy light is, in fact, characterised by brief episodes of high-energy sun flecks followed by long periods of very low light levels that hardly compensate for plant respiration.

- Overall growth performance of seedlings and wildlings seems to be slightly superior to that of clones in this environment. The best performing clone so far was PB 260.

Box C.
Story of a Javanese transmigrant farmer

The village Alai Ilir (in Block B of a large plantation) is a Javanese transmigrant village which was established in 1979 under the government's transmigration program. Under this program, each family was provided with 5 ha of land: 2 ha for a house with a garden behind it and another 3 ha further away. The houses were built by the government, and there are around 300 households in the village.

Pak Wakino comes from Java, and has a wife and four children. He received rubber plants ('Lambau') from the Dinas Perkebunan (tree crop extension service) in 1981, but the number was not sufficient for his field and mortality was high due to the poor quality of the planting material. Pak Wakino, therefore, planted seedlings which he collected from nearby villages. The final tree density was 540 trees (280 of local origin) in the 1.75 ha field. He taps about 170 kg of latex per week, and behind his house there are some fruit trees (coconut, mango (*Mangifera indica*), jengkol (*Pithecellobium jiringa*) and sawo (*Manilkara zapota*)). His wife also helps him during tapping. They also have a small vegetable field which is borrowed (not rented) from a friend. He has recently bought an additional 1 ha field in which he has planted rubber seedlings, as he believes that unselected 'seedling rubber' trees have a longer tapping life than grafted plants. With regard to the change of land use, he has no definite plans for the future although he has a preference for rubber over oil palm. However, he will accept any proposal from the government, whether it involves oil palm or rubber, if the farmers concerned receive support and compensation.

6. Technological interventions: experimental results

6.1 P and N fertilisation with low weeding levels in rubber agroforestry systems

The commonly held view about clonal rubber plantations is that high levels of fertiliser and weeding are necessary for good tree growth and good production of latex. In smallholder rubber agroforests, however, planting materials come from unselected seedlings, while fertiliser is rarely applied and weeding is very limited. What are the minimum input requirements for growing rubber trees? What is the response of different types of rubber germplasm (seedlings and clones) to low levels of fertiliser and weeding?

In smallholder rubber agroforests, competition between rubber trees and other forest species is a key factor in soil-plant interactions. Applied P (Phosphorus) fertiliser increases the availability of P in soil, and is expected to reduce plant competition. Good canopy growth will also reduce weed infestation, and so the intensity of weeding needed. On the other hand, the application of a fertiliser can also promote weed growth, especially before canopy closure. This is more often the case with applied N (Nitrogen) than with applied P. Understandably, the levels of both fertiliser application and weeding intensity are important, as these have direct implications on labour and financial requirements and, therefore, on a farmer's choice of management options.

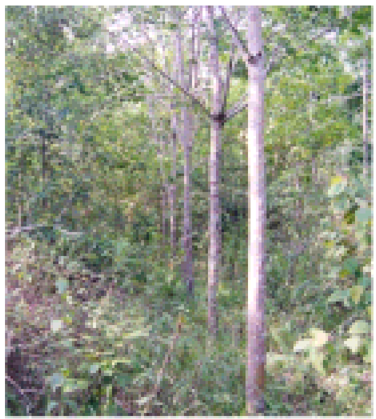


Figure 20. Five year old rubber trees in a fertilizer trial: clonal rubber trees can grow under lower fertilizer and weeding intensity regimes than normally recommended (*Photo: Ratna Akiefnawati*).

In December 1995 in a farmer's field in Jambi Province, an experiment was established (Figure 20), following the slashing and burning of old rubber agroforest. The experiment used two types of rubber germplasm - PB 260 clone (budded stumps) and clonal seedlings, hereafter referred to as 'GT1 seedlings' (these are 'illegitimate' seedlings, derived from GT 1 seeds). Various levels

Tabel 3. Levels of fertilizer application in trial.

Treatment	Urea (46% N)	SP 36 (36% P_2O_5)
Control	Not applied	Not applied
P	Only 50 g at planting time	115 g at planting time and 225 g per year thereafter up to 5 years
N + P	50 g at planting time and 75 g every 3 months thereafter up to 5 years.	115 g at planting time and 225 g per year thereafter for 5 years

of fertiliser application and weeding were tested (Table 3). Soil P content (P-Bray II) in the acidic top soil (pH KCl about 3.9) varied from 8 to 32 with an average of 20 mg P kg^{-1} of soil.

Both clone PB 260 and GT 1 seedlings grew well, even with shrub regrowth in between tree rows. No significant difference in growth increment between treatments was observed, although seedling trees (clonal seedling GT 1) were marginally bigger than clonal trees (PB 260) (Figure 21).

A medium level of P fertilisation increased rubber growth by 3%, in comparison with that of the unfertilised plot. High level fertilisation increased growth by 5%. The cost of fertilisers cannot be compensated for by the additional growth of the rubber trees. High levels of weeding increased growth by 7%, in comparison with plots of low weeding intensity, for both seedling and clonal rubber. The conclusion is that

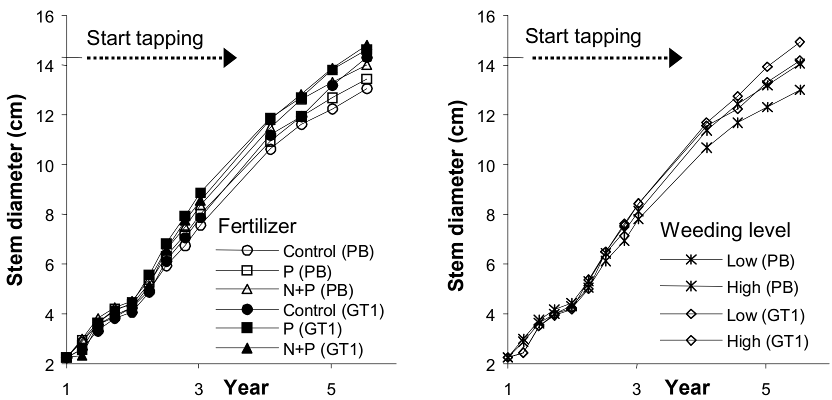


Figure 21. Diameter at breast height of rubber trees under different fertilisation treatments (left) and weeding intensity treatments (right). See Table 3 for treatment details.

fertilisers and high levels of weeding are not always necessary for good growth of rubber clones and seedlings. Current recommendations for fertiliser application in rubber cultivation do not consider the existing soil nutrient status. Although it is most likely that tree response to high levels of fertiliser and weeding in an already nutrient-rich soil will be less than in poorer soils, further investigation is required.

6.2 Rubber clone selection

The use of high yielding clones is the key to improved production of latex from rubber agroforests. The selection and development of *Hevea* clones, for higher and consistent latex production, has been going on for many decades in Indonesia. The Sembawa Research Station (of the Indonesian Rubber Research Institute) has carried out extensive experiments, and has recommended a range of *Hevea brasiliensis* clones for latex and timber production. Currently recommended clones include PB 260, RRIC 100, BPM 1 and RRIM 600 for Sumatra and Kalimantan regions. These are all high-yielding, fast growing, and considered hardy enough for farmers' field conditions and tapping regimes (Figure 22). These clones, except BPM 24, also have good secondary characteristics, such as resistance to *Colletotrichum* leaf disease and a moderate tolerance of harsh tapping methods.

PB 260, RRIC 100, BPM 1 and RRIM 600 clones were included in the numerous rubber agroforestry trials in Sumatra and West Kalimantan conducted by ICRAF over the last seven years. PB 260 and RRIC 100 clones performed best in terms of girth increment (Figure 23). All tested clones had a faster growth rate than rubber seedlings. It is possible for farmers to produce their own planting material using budwood from a certified origin or nursery (see Section 7, for example). This ensures quality material is available, instead of having to use planting material of unknown origins.

Figure 22. An important factor in improving rubber production system is the availability and use of good quality clones (*Photo: Dominique Boutin*).

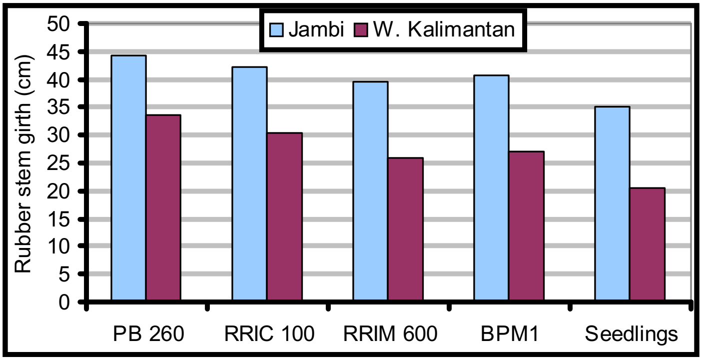


Figure 23. Girth of 4-year old rubber trees in clone comparison experiments in Jambi and West Kalimantan Provinces.

6.3 Improving rubber agroforestry systems

Jungle rubber agroforestry comprises *Hevea brasiliensis* as an introduced component within a crop-fallow system. Rubber latex is now the primary product from the system. Agricultural crops have diminished in value in comparison with latex. The jungle rubber agroforestry system is a low-input, low cost, extensive system. However, one of its failings, from a production perspective, is its low latex productivity in comparison with monoculture plantations. Research initiatives by ICRAF and its partner institutions have been undertaken to explore alternatives to enhance the production of rubber latex and other cash crops without a large investment. For several years previously, a series of participatory, on-farm trials were carried out in Jambi, West Sumatra and West Kalimantan Provinces. With the farmers' participation, different Rubber Agroforestry Systems (RAS) were developed and tested in these regions (Penot and Wibawa, 1997). The following systems offer much potential to increase the production and productivity of jungle rubber agroforestry systems.

6.3.1 RAS 1

Under RAS 1, high yielding rubber clones are used instead of unselected rubber planting material (Boutin *et al.*, 2000). Weeding is limited to 2 m-wide strips along the length of the rubber tree rows (1 m on either side of each tree). Strips between the rubber tree rows are left unweeded, allowing natural vegetation to re-establish (Figure 24). This significantly reduces the labour requirement for weeding and also allows the maintenance of natural vegetation in the inter-rows (Wibawa *et al.*, 2000a).

Figure 24. Natural vegetation growing in between rows of rubber trees do not affect growth of rubber in Jambi (*Photo: Ratna Akiefnawati*).

Trials in Jambi and West Kalimantan confirmed that the less intensive weeding under the RAS 1 system does not affect rubber tree growth (Figure 25). Rubber trees can be tapped five years after planting, just as in intensively-managed estate plantations. Natural vegetation growing more than 1 m away from rubber trees has little effect on their growth. Rubber trees and natural vegetation can actually check the proliferation of unwanted weeds and Imperata (*Imperata cylindrica*).

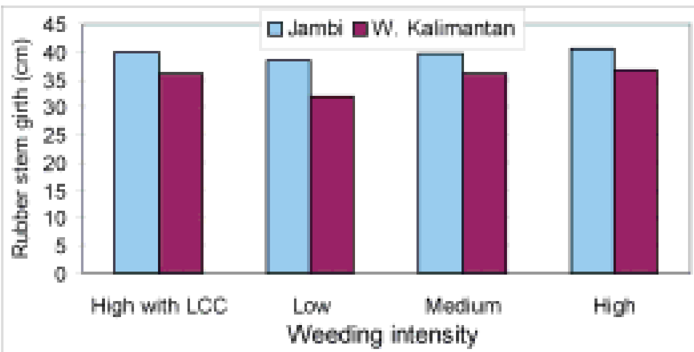


Figure 25. Little difference was observed between girths of 4-year old rubber trees under varying weeding intensities in the RAS 1 trials.

6.3.2 RAS 2

In contrast to RAS 1, the RAS 2 approach is more intensive in terms of crop mixtures. The system comprises food crops in the first few years along with rubber trees and other tree crops, such as fruit trees, timber trees and also with medicinal plants. Rubber benefits from weeding around the food crops while the associated trees shade out unwanted weeds, particularly after canopy closure. Cash crops have the potential to provide an additional income while rubber trees are being established. Fruit trees, like rambutan (*Nephelium lappaceum*) and jackfruit (*Artocarpus heterophyllus)*, can add to a household's income before rubber trees come into production. The mixture of tree and agricultural crops used can be selected based on their value in the region (see example combinations in Figures 26, 27 and 28). Inter-tree competition can be controlled by maintaining an appropriate density of rubber trees and fruit trees.

Figure 26. Interplanting durian trees (*Durio zibenthus*) with rubber in West Kalimantan. The system can potentially diversify and increase income of farmers and reduce dependency on rubber alone (*Photo: Dominique Boutin*).

Figure 27. Rambutan fruit trees (*Nephelium lappaceum)* along with clonal rubber trees (*Photo: Dominique Boutin*).

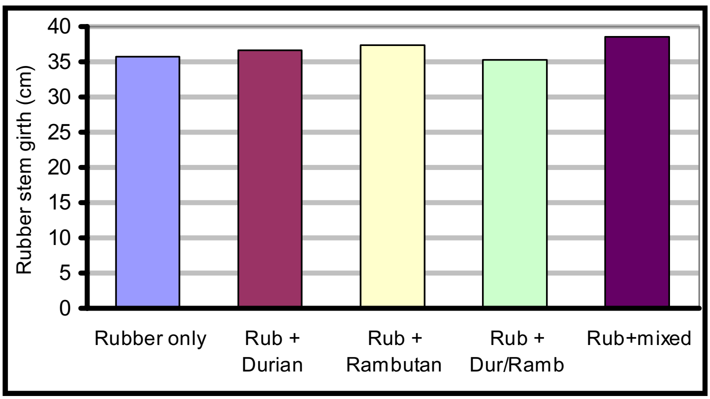


Figure 28. Girth of 4-year old rubber trees interplanted with fruit trees in the RAS 2 experiment.

In summary, the two systems, RAS 1 and RAS 2, are innovative and can be adapted to fit various field conditions and farmer preferences. RAS 1 is a low cost approach. RAS 2, while requiring more investment in capital and labour, may be suitable where agricultural land is becoming scarce or diversification of production is preferred.

6.4 Direct grafting of clonal buds on in-situ seedlings

Latex productivity in jungle rubber agroforests is low and variable, due to the inferior planting material (unselected wildlings) used. While the potential of clonal material in monocrop plantations is well known, clonal material has not been tested by farmers in a *sisipan* (gap-replanting) context. The general perception of farmers is that clonal material can be feasibly grown only under intensive management. In an experiment carried out by ICRAF, nursery-grafted planting materials of different clones did not perform well when planted inside an existing rubber agroforest. An alternative approach is to graft buds of a high yielding clone directly onto local seedlings (either transplanted or undisturbed) with intact root systems, in the field (Joshi *et al.,* in press [a]). This method can significantly increase the chances that these grafted plants will survive and grow.

It is already known that some farmers in South Sumatra (in Lubuk Bandung) actively practice direct grafting onto seedlings planted in slashed and opened fields (Figure 29). The feasibility of carrying out direct grafting under a *sisipan* context was successfully tested in a multi-location trial in Jambi Province (Figure 30). Two recommended clones (PB 260 and RRIC 100) were grafted onto existing seedlings under two levels of over-head canopy density and one under no-canopy (open plantation) conditions.

The following conclusions were drawn from the experiment:

1. The grafting of buds of high yielding rubber clones directly onto seedlings in the

Figure 29. Farmer innovation of direct-grafting of clonal buds onto rubber seedlings in the field (*Photo: Gede Wibawa*).

field is technically possible under the light overhead canopy density (Figures 31 and 32), that is commonly encountered in jungle rubber agroforests. Grafting success, and the successive growth of these buds under a light canopy, was comparable to growth in trials undertaken in the open, especially for clone PB 260.

2. However, bud growth is significantly affected by canopy and other competition factors within existing stands; hence direct grafting under a dense canopy is not feasible.
3. Among the two clones tested, PB 260 outperformed RRIC 100. Given that both these clones, as with most other clones in use, have been selected based on their performance in a no-competition environment, testing a wider array of clones for under-canopy grafting may reveal more clones which are potentially suitable for such conditions.
4. Careful overhead canopy manipulation, and a reduction of the effect of ground vegetation on newly grafted plants, will most likely enhance survival and growth of these directly grafted plants.

Figure 30. Growth of a clonal bud grafted directly onto a seedling inside an existing rubber agroforest (*Photo: Laxman Joshi*).

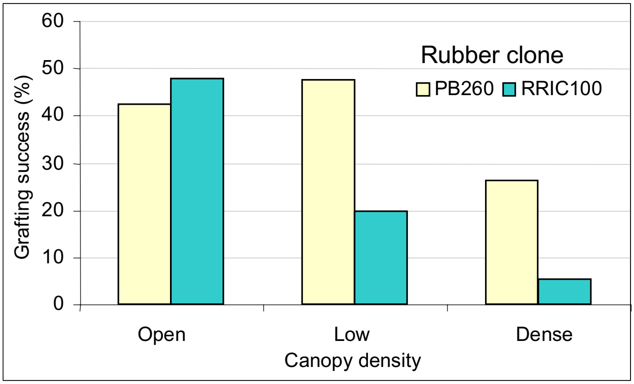


Figure 31. Grafting of buds of clone PB 260 was more successful than buds of clone RRIC 100 inside rubber agroforests.

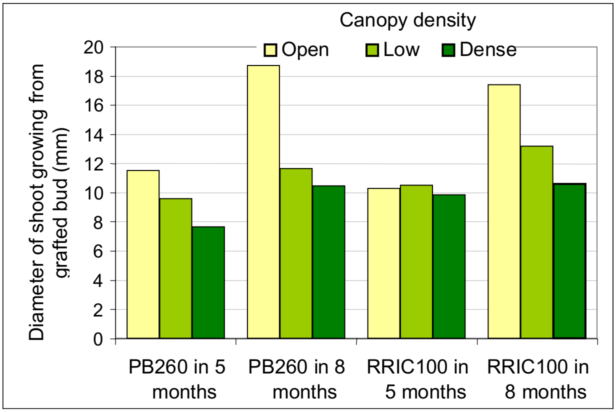


Figure 32. Stem girth of new shoots from PB 260 and RRIC 100 clonal buds is not significantly different between clones. However, girths are clearly different among the three canopy densities.

Box D.
Pak Irvan's oil palm plantation

Pak Irvan inherited an oil palm plantation from his father, who died 5 months ago. The total plantation area is about 250 ha, including 150 ha under production (yielding 15 tonnes/ha in 2001). The field consists of plantations of three ages (around 12 years old; around 8 years old and around 4.5 years old), all of which have been converted, by means of slash and burn, from old forest (possible secondary forest). In 1992-93, Pak Irvan's father bought 115 ha land from the neighbours and planted oil palm. Currently there are 24 permanent labourers, and 60-80 temporary labourers, working in the field. Recently Pak Irvan sold oil palm fruits (fresh bunches) in the neighbouring Riau Province at Rp 470/kg.

He tried to persuade his neighbours to plant oil palm trees and make arrangements for share tapping, but has not really succeeded in this because his neighbours lack the capital needed for investment. However, two farmers (both of whom are staff members of the government-owned oil palm plantation, PTPN V) have planted oil palm around his field (40 ha by Pak Tampubolon and 20 ha by Pak Susilo).

7. Farmer institutions and capacity building: self-help group approach

In an effort to test participatory research and development in rubber agroforestry in Jambi Province, a pilot initiative for a self-help group approach was implemented in a number of villages. Three villages (Rantau Pandan, Sepunggur and Lubuk) with contrasting backgrounds and characteristics were selected. The following activities were organised to make participants aware of available technology and information relevant for jungle rubber agroforests:

1. farmers' field visit to ICRAF research sites (RAS experiments and observation plot of direct grafting under *sisipan* system) (Figure 33);
2. participatory appraisal of current rubber production systems;
3. a half day training course on budwood grafting in rubber seedlings (Figure 34).

Following these activities, farmers formally established self-help groups in all three villages. The common objective of all three groups was to establish local budwood gardens, where farmers could collectively

Figure 33. Farmer visits to research sites are useful not only in dissemination of information, but also for getting feedback from them on the technology (*Photo: Laxman Joshi*).

Figure 34. Farmers are able to learn grafting techniques without much difficulty (*Photo: Laxman Joshi*).

produce high yielding planting material and grafting material of *Hevea brasiliensis* at low cost and with minimal external support.

The initial stages of group mobilisation and self-help group formation were supported by the ICRAF staff in Muara Bungo. Labour, land and other local resources for the construction and running of the nursery were provided through contribution by group members (Figure 35). Weekly labour was contributed on a voluntary basis (locally called *gotong royong*) by members for routine nursery activities such as seeding, transplanting, watering and weeding. In the first season, ICRAF contributed most of the locally-unavailable input materials, such as mother plants (the source of clonal buds), fertilisers and seed for root-stock. However, subsequently, input material was provided only when requested by the groups, and only when other alternatives were difficult to implement ("drip" support).

The budwood garden in Lubuk village (Figure 36) was the most active and successful in terms of group dynamics and nursery operation. The majority of the members were Javanese migrants, and their positive attitude towards group work has been a crucial factor in the success of their initiative. By mid 2001, each member had received his or her share of more than 60 grafted plants, either rooted or potted. More plants were being distributed later in the year. In Rantau Pandan, Pak Yani, who was a group member and also a school teacher, had established a school nursery which he used for teaching his students. By the end of the first year of establishing the nurseries, a number of farmers in these villages had established their individual "home" nurseries, often just behind their houses. A few farmers had also carried out direct grafting in their recently planted fields with very promising results (grafting success rate between 70 and 90%).

Figure 35. Members of a self-help group in Lubuk village are collecting sand for their group nursery from a nearby river (*Photo: Ratna Akiefnawati*).

However, as time went on, in Rantau Pandan and Sepunggur villages, the farmers' group approach proved less successful than in

Lubuk village. Farmer participation at nursery activities and group meetings became progressively more and more difficult. Both groups stopped functioning within about 18 months of coming into existence. These two nurseries were then given up to their respective land owners to be managed as private nurseries.

Figure 36. Some members of a village nursery group pose proudly for a group photograph in front of their nursery (*Photo: Ratna Akiefnawati*).

The following are the highlights from the self-help group initiative implemented in the three villages in Jambi:

1. Farmers understood the value of incorporating high yielding planting material into their jungle rubber agroforestry system, and made efforts to do this.
2. Visits to research and demonstration plots significantly enhanced farmers' confidence in, and awareness of, available technology and developments.
3. Farmers were keen to acquire, and adept at learning, skills necessary for local production of high yielding clonal material.
4. Farmers were capable, following a brief training session, of carrying out direct grafting of rubber.
5. It was possible to mobilise farmer self-help groups to establish and manage budwood gardens for clonal bud and plant production. However, this required intensive social mobilisation.
6. Homogeneity among group members, inter-personal relationships and committed leadership were important driving forces that influenced the level of success achieved in three villages.
7. Communication and visits between farmer groups have the potential to augment farmer interest by sharing knowledge and developing positive competition between groups.

8. The long time delay (one year of weekly labour contribution involved in establishing and managing the nurseries) before any benefits could be realised was a major reason for a decline in group participation. Involving these groups in other activities, such as the joint marketing of latex, would significantly increase farmers' interest in such a self-help group approach.

8. Policy considerations

It is estimated that nearly 10% of Jambi Province is under rubber cultivation, most of which is still managed as complex jungle rubber agroforests. Current evidence indicates that around 47% of rubber farmers in Jambi practice '*sisipan*' (i.e. a gap-level interplanting management style) in at least one of their jungle rubber plots, as an alternative to slash-and-burn rubber agroforestry. However, there is a strong indication that this is a "second best" strategy for farmers, used to address the need for a continuous income, the need for high initial capital investment to restart a new rubber cycle, and to address the issues of increasing scarcity of new land for intensification and the risk of vertebrate pest damage and subsequent crop failure.

8.1 Recognising jungle rubber agroforestry and *sisipan* as viable management options

An international workshop held in Muara Bungo (September 3 - 6, 2001) carried out a broad systems analysis of the rubber agroforests of Sumatra's lowland peneplains. The current trajectories, with their consequences for profitability and environmental services, and the options to build on farmers' ecological knowledge and decision making in new ways, to face the challenges of a changing landscape, were discussed. It is now recognised that jungle rubber agroforests are potentially one of the primary reservoirs of the fast-disappearing biodiversity of the Sumatran peneplains. Plot-level inventories suggest that jungle rubber agroforests can maintain about 50% of the biodiversity found in natural forests.

On-farm Rubber Agroforestry Systems (RAS) trials have proven the feasibility of establishing clonal rubber under less intensive management regimes (when compared with monocrop plantations), using less labour and lower levels of fertilizer. However, the regeneration of significant biodiversity values is far less than is the case in jungle rubber agroforests. Interestingly, current low rubber prices stimulate the development of *sisipan* style management of 'other tree' components of the system (for example, timber species). However, both the current price of natural rubber (the lowest in the last three decades) and the recently introduced Indonesian National Standard (SNI) regulations (Wibawa *et al.*, 2001) have jointly affected many resource poor farmers' income from rubber. The abandonment of old jungle rubber plots, and the conversion of these high biodiversity rubber gardens to oil palm or rubber monoculture, is becoming increasingly common in Jambi.

Despite the prevalence of jungle rubber agroforests in Jambi, and in many other rubber growing provinces in Indonesia, only meagre efforts have been made to develop them for higher productivity while maintaining the comparative advantages, such as biodiversity maintenance and management flexibility, they offer. All past rubber development projects have been largely geared to replacing these complex, flexible, low-input, yet diverse and less risky, systems with monocropping systems. The history of rubber development shows that most, if not all, rubber research and developments have favoured capital intensive and labour saving technologies that are less appropriate for capital-limited rubber farmers (Barlow *et al.,* 1994). It is time the Indonesian government and national institutions realized the value and importance of jungle rubber agroforests, not only for rubber producing households but also for their regional and global environmental services (Section 8.3). Recognition of the existence of extensive jungle rubber agroforests and research and development initiatives intended to improve them will be a positive step away from the eradication of these environmentally beneficial land use systems.

8.2 Agroforestry timber deregulation

The extraction and sale of timber, both from natural forests and from agroforests, is restricted in Indonesia by means of taxes, quotas and complex bureaucracy. These regulatory policy mechanisms, coupled with the fact that rubber timber needs to be processed within 72 hours of felling, are major constraints to rubber-wood harvesting and marketing. Consequently, farmers almost always burn old rubber trees, which are seen as being, essentially, a by-product of jungle rubber agroforests.

Figure 37. Large amounts of useful timber are wasted through burning because weak incentives and infrastructure do not encourage the marketing of timber (*Photo: Gede Wibawa*).

Figure 38. Conducive policies and infrastructure will increase farmers' interest in harvesting and marketing the rubber timber that would otherwise be wasted (*Photo: Gede Wibawa*).

Valuable natural resources are wasted (Figure 37), while the hazards posed by fire and smoke remain unresolved. Policy amendments, to encourage trade in rubber timber and non-rubber timber taken from rubber based agroforestry systems, will not only increase the appropriate use of timber from agroforests, but will also improve household incomes and promote polyculture in rubber-based agroforests while reducing farmers' dependency on a single commodity - latex. It will also reduce demand for other timbers extracted from natural forests, as well as diminishing the hazard posed by smoke and fire, and will cut greenhouse gas emissions. Procedures to properly identify timber extracted from agroforests, and to promote trade and processing of that extracted timber (Figure 38) need to be developed through targeted policy research and subsequent improvements in policy.

8.3 Environmental services of jungle rubber agroforests

In the context of the disappearance of natural forests, complex agroforests, such as jungle rubber agroforests, can provide external environmental services as well as meeting local production functions.

These environmental services include sequestering carbon from the atmosphere, maintaining biodiversity and retaining hydrological functions. Farmers and communities, who protect and maintain forests and complex agroforests, are not normally compensated for the provision of environmental services. Compared with more intensive monoculture plantations, and with other land-use systems, complex agroforests, such as jungle rubber agroforests, are less profitable and are currently being challenged by alternative land-use options. In the absence of incentives, farmers often opt for land use forms that provide fewer of the environmental services which are essential for external stakeholders and which often extend far beyond village, provincial and national boundaries.

Among research, development and donor communities, there is growing awareness of, and interest in that efficient payment transfer schemes, that (if implemented efficiently and fairly through appropriately-developed mechanisms) could help to preserve complex agroforests and the environmental services they provide. ICRAF has recently initiated research to quantify these environmental services, to develop methods to monitor them, and to evaluate the economic benefits of various land-use options. Farmers practising jungle rubber agroforestry are possible candidates for reward because of the biodiversity services their agroforests provide. In an institutional context, it is essential that both environmental service providers and beneficiaries of the services can freely negotiate and develop mutual agreements. Appropriate policy environments need to be developed, through appropriate negotiation and dialogue, in order to develop and nurture such reward mechanisms. All stakeholders (i.e. farmers, farmer groups, village organizations, local government, researchers, development professionals, non-governmental organizations, and donors) have important roles to play in this process.

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