The Impact of Rubber on the Forest Landscape in Borneo

20

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1. Introduction[1]

Rubber is the most widespread smallholder tree crop in South-East Asia. Although initially large estates planted the bulk of the region's rubber, smallholders soon captured most of the production. Currently, Indonesia's rubber plantations cover 3.4 million ha, of which smallholders account for more than 75% (BPS, 1999). In peninsular Malaysia, the area in rubber has declined since the 1970s, but rubber remains the second most common tree crop in terms of area, with 1.5 million ha in 1990 (Vincent and Ali, 1997). Large estates produce much of Malaysia's rubber, but smallholders dominate rubber production in the State of Sarawak (Cramb, 1988).

Some analysts blame the expansion of rubber for greatly contributing to the conversion of mature tropical forest in both Indonesia and Malaysia (Vincent and Hadi, 1993). This chapter critically examines to what extent smallholder rubber production actually led to forest conversion in West Kalimantan (Indonesia) and neighbouring Sarawak (Malaysia). Although we shall not discuss either Sumatra or mainland Malaysia in detail, it appears that parts of these regions went through similar processes (Vincent and Hadi, 1993; Angelsen, 1995).

This chapter presents two main arguments. First, as long as there was low pressure for land, swidden-fallow farmers who grew rice could easily incorporate rubber into the fallow component of their production systems. The introduction of rubber did not lead to encroachment into primary forest, nor did it greatly affect the broader forest landscape, comprised of primary forest, secondary forest and forest gardens. We use evidence related to the adoption of

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rubber by Iban Dayak in the Second Division of Sarawak and by the Kantu Dayak in the eastern part of West Kalimantan to support this argument. The Iban case and two other cases presented below suggest that, in areas where land pressure became important long after rubber was introduced, local respect for forest remnants and authorities constrained the expansion of agricultural land into unclaimed forests. As a result, rubber production did affect the amount of fallow (secondary) forest in the landscape, but not the remaining primary forest. Rubber gardens basically replaced swidden fallows.

Secondly, we argue that the introduction of rubber by swidden agriculturalists actually had a positive effect on reforestation and therefore on the total forest landscape. Many farmers combine conversion of tropical forests for agriculture with the active creation of forests, such as structurally complex and floristically diverse forest gardens (Padoch and Peters, 1991; de Jong, 1995). We develop this argument using evidence on rubber's impact in three Bidayuh Dayak villages in West Kalimantan. In particular, we look at the expansion of managed forests in the subdistrict of Noyan (de Jong, 1995) and forest management in the subdistrict of Batang Tarah (Padoch and Peters, 1991) and in Sinkawang (Peluso, 1990).

The chapter first summarizes how rubber arrived in Malaysia and Indonesia. Section 3 discusses why swidden farmers easily adopted rubber and the effect this had on the forest landscape. Section 4 demonstrates rubber's contribution to traditional reforestation practices. Section 5 draws general conclusions from the cases discussed.

2. Rubber in Indonesia and Malaysia

2.1. The arrival of rubber

The island of Borneo is geographically divided into two Malaysian States, Sarawak and Sabah, and four Indonesian provinces, West, East, Central and South Kalimantan. The local indigenous population includes many linguistic and cultural groups, commonly referred to as Dayaks. In the past, these groups all subsisted – and many still do – by growing upland rice in swiddens cleared yearly and by hunting and collecting forest products.

Rubber was first introduced in Borneo at the beginning of the 20th century and expanded rapidly. Table 20.1 gives data on the expansion of rubber in the region. By 1921, the area grown in South-East Asia had reached 1.6 million ha and smallholders already accounted for one-third of that (van Hall and van de Koppel, 1950). The crop expanded in a parallel fashion in Sarawak and West Kalimantan. Of the 86,000 ha produced in Sarawak in 1930, smallholders grew 90%. In 1924, exports from West Kalimantan (then Dutch Borneo) reached 15,247 t, implying an area of between 40,000 and 100,000 ha (Uljée, 1925).

Table 20.1. Historical development of rubber in Borneo (from Uljée, 1925; van Hall and van de Koppel, 1950; Cramb, 1988).

Year	Region	Area (ha)	Production (tonnes)
1910	All of South-East Asia	500,000	
1921	All of South-East Asia	1,600,000	
1911	West Kalimantan	500–1,000	128
1924	West Kalimantan	40,000–100,000	15,247
1930	Sarawak	30,000	
1940	Sarawak	97,000	
1961	Sarawak	148,000	
1960	Second Division	25,000	50,000
1971	Second Division	36,000	19,000

The rate of rubber's expansion fluctuated over time. In 1912, the territory now called Indonesia (then Dutch East Indies) had the world's second largest area of rubber plantations after Malaysia (then referred to as British Malaya) (van Hall and van de Koppel, 1950). High rubber prices in the mid-1920s, resulting largely from restrictions on the international rubber trade associated with the 'Stevenson Reduction Scheme', led to rapid expansion in production (McHale, 1967; Ishikawa, 1998). However, by the end of the decade, expanding rubber production in the Dutch East Indies had depressed world prices, which remained low during the early 1930s (McHale, 1967). In 1934, both the Dutch East Indies and Sarawak joined the International Rubber Regulation Agreement (IRRA), which severely limited the expansion of rubber. The agreement established a coupon system, which restricted how much rubber producers could sell and traders could buy. This especially affected smallholders (van Hall and van de Koppel, 1950; McHale, 1967; Barlow, 1978). Prices boomed again in 1950/51, leading to a new surge in rubber planting and tapping in Sarawak (Cramb, 1988) and probably in West Kalimantan as well.

Between 1960 and 1971, rubber exports from Sarawak gradually declined from 50,000 t to 19,000 t. Interest in replanting among small farmers declined, but, thanks to a government rubber planting scheme, total area increased from 25,000 ha to 36,000 ha in 1971. The scheme provided cash advances to farmers who established new rubber gardens. Between 1971 and 1977, when the scheme was temporarily halted, no new planting took place. During this period, pepper also became a prominent cash crop. In subsequent years, farmers have shifted their primary focus back and forth between pepper, rubber and off-farm work (Cramb, 1988).

Coastal Chinese and Malay farmers initially planted most of the rubber in West Kalimantan (Dove, 1993). In the 1930s, inland Dayak swidden agriculturalists widely adopted the crop. This may seem surprising given the colonial restrictions on rubber expansion at the time. But apparently many traders from Sarawak were able to obtain extra coupons, despite the restrictions, and used them to buy cheaper rubber from Dutch Borneo. Smuggling rubber from Dutch Borneo to Sarawak was common (Ishikawa, 1998) and remains so to this day. All rubber officially exported from West Kalimantan came out of Pontianak, the provincial capital. Since no good roads connected the province's remote Dayak villages to the capital, the only way villages' inhabitants could sell their rubber was to send it to Sarawak. This situation continued until better roads finally connected most of West Kalimantan to Pontianak during the early 1980s. Since that time, the Dayaks have sold all of the rubber they produce in the provincial capital. This has made rubber production more attractive and led farmers to plant more rubber.

2.2. Adoption of rubber in swidden agricultural systems

Several authors (Cramb, 1988; Dove, 1993; Gouyon *et al.*, 1993) point out that rubber production fitted the Dayak farmers' traditional swidden-agriculture systems well. In the prevailing swidden systems in Borneo, each year farmers slash-and-burn a field and plant rice. They may also plant small amounts of other crops or tree species just prior to, together with or shortly after planting rice. Once they harvest the rice at the end of the year, they devote less labour to the field. If they planted manioc there, they will still come back the following year to harvest. They also harvest fruit species and may continue to plant additional fruit-trees during the following years. However, after the third year or so, the field gradually reverts into secondary forest, with or without any planted trees. If the field contains many planted or tended trees, farmers will gradually start to clear around them. Otherwise, they will convert the field into a swidden again, once the fallow vegetation has developed sufficiently.

Rubber fits nicely into the swidden system. Farmers can plant it during the swidden stage, often before rice is planted, and then leave it virtually unattended until the trees are large enough to tap, about 10 years later. Cramb (1988) portrays rubber gardens as simply managed fallows that make the swidden-fallow cycle more productive. Farmers were already familiar with the low labour-input technique required to establish tree crops in fallow areas, as they had used them to cultivate indigenous tree crops, such as fruit, illipe nut and gutta-percha (Cramb, 1988; Padoch and Peters, 1991; de Jong, 1995). Rubber's seasonal labour demands complement those of rice cultivation. Farmers cultivate rice during the rainy season, while rubber is fairly flexible and provides work and income during the dry season. Farmers can easily dispose of the output of rubber, which provides a regular source of cash. Although rubber has quite a low ratio of value to weight, it can be stored for long periods and marketed when convenient. For many swidden-fallow farmers, rubber constitutes their main source of cash. Moreover, rubber provides a convenient bank account that can be tapped – literally – as the need arises, for example, in periods of natural and economic shocks.[2]

3. Incorporating Rubber in the Swidden-fallow Cycle

3.1. Rubber among the Iban in Sarawak's Second Division

This section discusses two cases where upland rice farmers in Borneo incorporated rubber into their swidden-fallow cycle: the case of the Iban Dayak farmers in Sarawak's Second Division (Cramb, 1988) and that of the Kantu Dayak farmers in the village of Tikul Batu, in eastern West Kalimantan (Dove, 1993).

The Iban Dayak arrived in Sarawak's Second Division in the 16th century. During the next 200 years, they converted most of the original primary forest into secondary forest, leaving only remnants of primary forest (Cramb, 1988). They farmed their swidden fields for 1 year and then left them in fallow for an average of 15–20 years. This was well beyond the minimum fallow period required to restore the nutrient content in the vegetation and avoid excessive weed invasion after slashing, which was about 7 years. Before they started growing rubber around 1910, the Iban had been growing coffee and pepper commercially for around a decade. The Sarawak government heavily promoted smallholder rubber production and the Iban took up the activity with enthusiasm. Initially, only wealthy communities could afford the plantation costs, at that time equal to about 750 kg of rice ha^{-1}. Once rubber gardens were more widely established, however, seeds and seedlings became cheaper and just about any interested household could plant the new crop. After rubber's initial expansion, planting continued more or less progressively, even during periods of low prices or trade restrictions, such as the 1920s (Cramb, 1988; Ishikawa, 1998).

The introduction of rubber led farmers to reduce their fallow periods and begin planting three to four consecutive rice crops, after which they would plant rubber and leave it there for many decades. This led to higher pressure on the remaining fallow land, but did not transform the forest landscape much. Similar areas of land remained under tree cover. As traditional rubber gardens are rich in plant species, there may have been little impact on species diversity (de Foresta, 1992; Rosnani, 1996). Farmers converted some of their previous fallow land into rubber gardens, but these contained a large amount of secondary vegetation, which developed together with the rubber. The age distribution of fields with secondary forest or rubber gardens that included secondary vegetation may have shifted, but the total forest landscape probably did not change much, nor did encroachment into primary forest accelerate.

During the 1930s, reports emerged that excessive rubber planting had caused shortages of land for rice. While some areas did experience shortages, they were isolated cases where households had only 1–2 ha of rubber, mainly planted on land that was not suited for rice in any case. The cultural importance of rice kept people from planting rubber on fallow land where they could produce rice again.

Cramb (1988) suggests that, by the time rice land became scarce, governments were able to monitor the expansion of agricultural land and to keep farmers from clearing primary forest without permission. The government widely announced that farmers could not expand their agricultural holdings into uncleared forest. Visits of government officials to villages were probably at least partially effective in enforcing these measures.

In the decades following the Second World War, population growth increased the pressure on remaining fallow land. Farmers were forced to rely more on cash crops and devote less land to growing rice. Price booms boosted rubber planting, but farmers did not respond to periods of low prices by reducing their rubber gardens. By 1960, rubber covered half of the entire territory in some Iban villages in the Second Division, and the villages had ceased to be self-sufficient in rice. Some people preferred rubber and only produced rice when they felt they had enough land to do both. Others looked for off-farm income or migrated to remote areas. By the 1980s, many Iban rubber gardens in the Second Division had gone through at least two rice–rubber cycles and hill rice farming had become only a supplementary activity for most farmers (Cramb, 1988). The province of Riau in Sumatra went through a similar process (Angelsen, 1995).

In the Iban case, by the time rubber became the dominant crop, farmers had stopped expanding into primary forest and swidden-fallow land had already expanded a great deal. Additionally, government prohibitions on converting primary forest limited further encroachment into primary forest areas. Had this not been the case, swidden cultivation might have expanded more and rubber could have played a role in that. The government in Sarawak did not consider secondary forest off limits and did not restrict rubber from replacing it.

3.2. Rubber among the Kantu in eastern West Kalimantan

The Kantu in eastern West Kalimantan underwent a process similar to the one just described. The Kantu received their first rubber seeds from their Iban neighbours, living in Sarawak's Second Division. By the Second World War, the majority of farmers reportedly had rubber, but few had full-grown rubber gardens. In the mid-1980s, an average Kantu household had two dozen plots on 52 ha of land, of which two or three plots were used each year to produce rice and an average of five plots or 4.6 ha was in rubber. Although this was mainly on land that farmers had once used for swiddens, the land was of poor quality and therefore had little value within the swidden system. These sites are, for instance, located along the river-banks or on poor heath soils. Today rubber provides the principal cash income among the Kantu and complements non-monetary incomes from agriculture and forest collection.

At least until the late 1980s, rubber gardens had no significant effect on agricultural expansion into the forests (Dove, 1993). Apparently, as in the Iban case, the Kantu have enough fallow land where they could plant rubber for them not to need to convert primary forest. Some of that land is of poor quality and farmers are willing to take it out of the rice production cycle. Given the abundance of fallow land, they could put some land aside to grow rubber without drastically reducing the length of the fallow and thereby rice yields.

The Kantu swidden agricultural labour system was apparently flexible enough to allow farmers to allocate some of their time to rubber tapping and occasional weeding of rubber gardens without significantly affecting their other main economic activities. They do not devote labour they would otherwise allocate to cultivating rice to producing rubber. Most of the time they spend on rubber production would probably otherwise go into activities such as hunting, forest-product collecting, house maintenance or leisure.

4. Rubber as an Agent of Forest Reconstruction

The introduction of rubber has not only affected the clearing of forest by Dayak farmers but also their reforestation activities. Elsewhere, we have argued that, while Dayak farmers throughout Borneo convert some forested land into agricultural land, they also transform other non-forested land back into forest (de Jong, 1997). Many of these human-made forests are similar in structure and diversity to the original primary forest (de Jong, 1995, 1999). This section discusses three cases to show the impact of rubber in this process, all of which involve the Bidayuh Dayak, who live in central and western West Kalimantan. It goes into greatest detail in the case of Maté-maté farmers in the village of Ngira, central West Kalimantan (de Jong, 1995, 1997, 1999). It also makes reference to the village of Tae, 150 km south-west of Ngira, occupied by Jangkang Dayak, and to Bagak, a village located much closer to the coast, near the border between West Kalimantan and Sarawak (Peluso, 1990; Padoch and Peters, 1991; Padoch, 1998).

4.1. Rubber in Ngira

Maté-maté Dayak, a linguistically separate group of what are identified as Bidayuh or Land Dayak, inhabit the village of Ngira (King, 1993). In 1994, the village had a population density of 14 km^{-2}. Farmers in Ngira first adopted rubber production during the mid-1930s. Much rubber was exported to Malaysia, since the road to Pontianak was very poor. As late as 1980, even though many farmers had rubber fields, rubber still occupied only a small portion of the land.

Road improvements, which made the region more accessible, changed this situation. Farmers became more integrated into the cash economy and began to consume more goods from outside the region. Rubber is now the main cash crop and many of the current rubber gardens were planted during the last 20 years. Hence, to a certain extent, the village's rubber expansion remains fairly recent compared with the coastal regions in West Kalimantan or the Second Division in Sarawak.

Villagers grow rubber both in rubber gardens and in *tembawang*, or forest gardens. *Tembawang* are forests that farmers have actively created on previous agricultural land to produce tree products and mark the sites they have occupied (de Jong, 1999). When the owners plant rubber in it, one can consider *tembawang* as mixed rubber–forest gardens.

The evolution of Ngira's forest landscape between 1984 and 1993 clearly indicates that introducing rubber can have a positive effect on land use. In 1994, the village had 1688 ha that had been slashed for swidden production at one point or another (Fig. 20.1). A small part of this was currently under swidden production (125 ha). More than half of it was in fallow (954 ha). There was 95 ha of full-grown *tembawang* forest, much of it with rubber inside. Rubber gardens covered 344 ha, of which 121 had been planted within the last 10 years. An additional 251 ha of fallow land had rubber planted on it but, since the trees were still small, the land was classified as fallow rather than rubber garden. In total, 692 ha had planted tree vegetation – 40% of the total cultivated land.

Of the 692 ha planted with trees, 280 ha had either a mixture of rubber, fruit- and other trees or fruit-trees and other species. Most of these areas were adjacent to *tembawang* areas, since villagers prefer to keep their rubber gardens close to the village. This is because they tap the rubber in the morning and collect the latex just before noon. If the villagers ultimately decide to allow abundant secondary regrowth in those fields, which appears likely, they will end up creating an additional 280 ha of *tembawang*.

In total, we calculated that 512 ha of land was replanted with trees during the last 10 years to create *tembawang* or mixed rubber gardens, which combine rubber, other planted species and spontaneous vegetation (de Foresta, 1992; Rosnani, 1996). In that same period, farmers converted only 360 ha from natural forest to agricultural land. Moreover, this increase in effective forest cover took place at the same time as population grew annually by 2.9%.

Our data suggest that introducing rubber into Ngira greatly contributed to the reforestation just described. It encouraged the expansion of forest

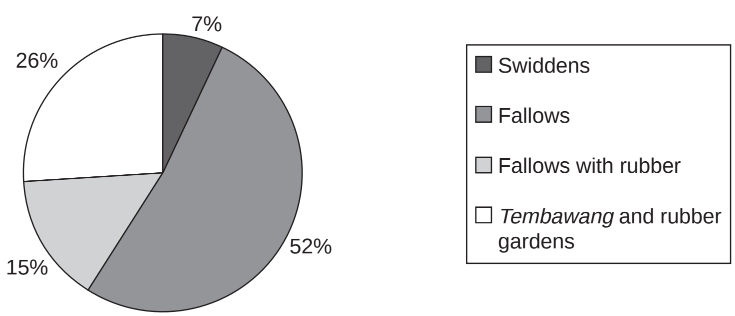

Fig. 20.1. Land use in Ngira, 1994.

gardens and the transformation of swidden fallows into rubber forests. The next two cases provide some indication of how this type of process might play out in the long run.

4.2. Rubber in Tae and Bagak

In both Tae and Bagak, the adoption of rubber has resulted in the sustained presence of forests. Tae is a village located in the subdistrict of Batang Tara, about 150 km south-west of Ngira, and has a population density of about 80 people km^{-2}. People use motor cycles on a well-kept dirt road to take valuable durian fruits (*Durio zibethinus*) to traders, who come from Sarawak (Padoch and Peters, 1991). Many farmers have turned to wet rice cultivation in permanent paddy-fields, while maintaining some upland swiddens and rubber gardens. Only the peaks of the highest mountains still have unclaimed primary forest, although significant areas of communal primary forest protected by the communities and *tembawang* remain.

Bagak, a Dayak village located along the northern coast of West Kalimantan, near Singkawang, represents another example. It has a population density of 120 people km^{-2}. It is strictly forbidden to open new fields in the Gunung Raya Pasir nature reserve, which borders the village territory, even though the village has no other remaining areas of natural forest it could convert to agriculture (Peluso, 1990). In 1990, 11% of the 1800 ha of cultivated land in the village was under paddy rice and 19% under swiddens and swidden fallows. Another 16% of the area consisted of improved rubber plantation, established in 1981 and 1982, while 39% of the land was under mixed tree cover, similar to *tembawang*. Secondary forests preserved by the community accounted for another 3% (Fig. 20.2).

These last two cases indicate that the presence of the forests tends to stabilize when swidden fallow and forest management reach an advanced state of land use. Respect for individual ownership of forest gardens, communal protection of forest remnants and agreements between communities and

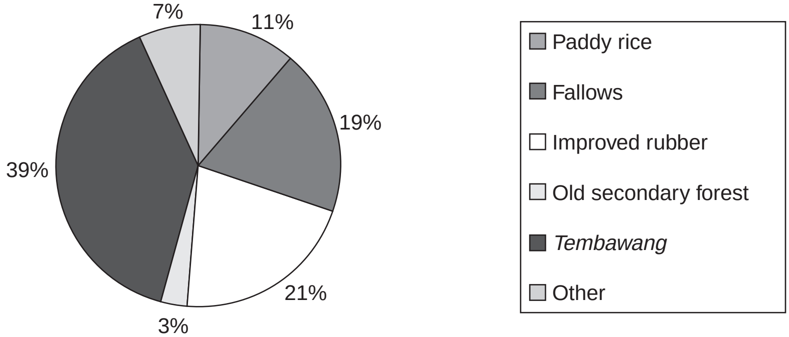

Fig. 20.2. Land use in Bagak (adapted from Peluso, 1990).

governments to preserve protected areas largely explain this tendency of forest area to stabilize. Table 20.2 summarizes the main characteristics of the five cases discussed.

5. The Effect of Rubber-like Technologies on Forest Landscapes

In several of the cases discussed above, introducing rubber had the following effects on forest clearing. At the time rubber was first introduced, farmers already had substantial areas of fallow and only planted a small portion of it with rubber. They mostly planted rubber on land that was not vital for rice production, either because they had enough other land to grow their rice or because the rubber land was of poor quality. Subsequently, further planting of rubber in fallows coincided with population growth and increased pressure on land. Farmers no longer had enough land to sustain swidden rice production and remain self-sufficient in rice. This led them to seek alternative sources of income, either cash-cropping or off-farm employment. While the expansion of rubber appears to have accelerated the abandonment of rice self-sufficiency, it probably did not result in forest encroachment. Rather than clearing additional forests to plant rice, most farmers chose to take up off-farm employment or obtain income through other means. Partly this happened because the government has, in some cases, been able to persuade communities to stop expansion of agricultural land into the remaining primary forest areas.

In some areas of West Kalimantan, the introduction of rubber seems to have actually increased forest cover. In Ngira, the expansion of *tembawang* and rubber gardens appears to have offset forest encroachment for agriculture between 1984 and 1993. The existing forest management practices can easily incorporate rubber, and rubber actually appears to have stimulated the expansion of these human-made forests, which have a diverse structure and floristic composition. On balance, rubber appears to have increased total forest cover in this area. The cases of Tae and Bagak suggest that eventually the process of forest transformation reported in Ngira will stabilize and lead to a mixture of agricultural land, mixed rubber gardens and forest gardens and primary forest, which villagers and the government do not allow farmers to convert to other uses.

One can draw several general conclusions from these cases. At the time rubber was introduced into the pre-existing extensive land-use system, significant areas of primary forest had already been converted for agricultural use. This made it possible to incorporate rubber without creating a significant demand for new land from primary forest. Rubber did not require much additional labour and the labour it did require was largely during periods when it was not needed by other agricultural activities. Farmers had little need for cash and adjusted their level of effort to what was required to meet that need (Dove, 1993). They maintained yearly swiddens as long as that was politically

Table 20.2. General characteristics of the five cases presented in this chapter.

Attribute	Second Division, Sarawak	West Kalimantan	Ngira	Tae	Bagak
Ethnic group	Iban	Kantu	Bidayuh (Maté-maté)	Bidayuh (Jangkang)	Bidayuh
Year rubber introduced	1910s	1940s	1930s	1930s	1930s
Population density	Not available	Not available	11 person km^{-2}	80 person km^{-2}	110 person km^{-2}
Accessibility	Good	Poor	Poor	Regular	Good
Stage of development	Rice cultivation being abandoned because of land pressure. Rubber replaced fallow land. Much rubber also abandoned	Rubber incorporated into swidden fallow cycle. Still little impact of rubber on general land use	Rubber fully incorporated into swidden agricultural cycle. Rubber boosts expansions of forest gardens	Rubber stable part of land use. Upland agricultural fields increasingly converted to mixed rubber fields. Rice production converted to irrigated fields. No further encroachment into forest area	All stages of forests and tree vegetation, including rubber, have stabilized. No further encroachment into forest area
Key factors that influence impact of rubber technology on forest landscape	Population pressure; government control; abandoning of rubber gardens	Incorporation of technology in extensive land cultivation	Increased cash production; existing forest management technology	Local customs related to forest ownership; communal management of forest reserves	Local customs related to forest ownership; communal management of forest reserves; control of protected area

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391

feasible and there was sufficient land for new swiddens. The fact that they continued to grow rice also reflected their cultural preference to produce their principal staple in their own private fields.

Once population density increased, the pressure for land limited farmers' flexibility. They maintained their rubber gardens, but gradually stopped cultivating rice. In three of the five cases discussed, local and/or national authorities increasingly circumscribed encroachment on additional forest areas. Pressure from within the communities to preserve the remaining forests increased and governments persuaded farmers to stop further encroachment. Simultaneously, the state and its local representatives increased their presence. In West Kalimantan, as in many other places in the world, the laws largely prohibit farmers from encroaching on forests. However, such rules only became relevant once the government had sufficient presence to enforce them.

The introduction of a new cash-based production system coincided with and was a catalyst for a number of cultural and socio-political changes, including the increased presence of the state. The rising importance of cash-based economic transactions and improved infrastructure allowed for better communication between state officials and communities. Officials at the regional level adopted national concerns about forest encroachment, and that facilitated enforcement of forest regulations.

Lastly, the cases discussed above demonstrate that new technologies involving some kind of tree or forest production may contribute to reforestation. The presence of tree crops also influences what happens to the forest landscape when other changes occur in local agricultural systems and demographic patterns. For example, land already under tree vegetation is much more likely to revert to forest when farmers shift from upland rice to wet rice cultivation or migrate to the cities. This is taking place in West Kalimantan in areas with out-migration from rural areas. One observes many old *tembawang* and rubber gardens that have developed into closed dense forests.

Tree-planting technologies, like rubber production, have a low impact on the forest landscape when they are incorporated into long-existing extensive agricultural systems. However, when population pressure and market integration increase alongside each other, these effects change. When these technologies are introduced at an early stage in a resource-use continuum from extensive to more intensive land use, socio-economic progress allows for a consensus on land use that preserves forests. This may offset negative effects that might otherwise have been caused by the impact of the technology under changing conditions, such as increased land pressure caused by higher population densities. Tree-planting technologies may be incorporated in local forest management practices and subsequently have a positive effect on the forest landscape.

These findings suggest important policy recommendations. In general, tree technologies have significant advantages when trying to improve local agriculture. Before promoting new technologies, policy-makers should take into account the degree of government presence and negotiations with communities over preservation of certain areas. The promotion of new technologies should always be considered in the light of local resource (forest) management practices, to obtain positive synergies and achieve an outcome acceptable to local farmers and national authorities, as well as limiting negative environmental impacts.

6. Conclusions

The introduction of rubber in West Kalimantan contributed little to encroachment into primary forest. On the other hand, it apparently favoured the restoration of forests in areas where land use became less intensive. It needs to be emphasized, however, that specific conditions in the local context allowed this to take place. If, for example, adoption of rubber had been accompanied by substantial migration into rural areas, that would probably have resulted in encroachment into forest areas. This has happened in places in Sumatra (see also Chapter 16 in this volume by Ruf). The impact of a new agricultural technology on forest conversion depends on the technology itself, but also on the economic and socio-political circumstances in which it happens. In addition, the impact changes over time, in part as a result of parallel economic and socio-political changes.

Tree technologies should be preferred when trying to improve local agriculture. Policy-makers should consider the degree of government presence and negotiated agreements concerning forest conservation before promoting new technologies in forested regions. Incorporation of local resource management technologies, especially tree-planting or forest-management technologies, may enhance positive outcomes in terms of increased income and forest preservation.

Notes

1 The results presented here stem partly from research conducted between 1992 and 1996 on Dayak forest management in the subdistrict of Noyan, West Kalimantan, Indonesia. The New York Botanical Garden, the Tropenbos Foundation and the Rainforest Alliance through their Kleinhans Fellowship funded the research and the Indonesian Academy of Sciences and Tanjungpura University sponsored it. I thank Noboru Ishikawa, Patrice Levang, the editors and an external reviewer for their comments.

2 A recent Center for International Forestry Research (CIFOR) study documents a sharp increase in rubber planting during the recent economic crisis in Indonesia, including West Kalimantan. The future income security and flexibility rubber provides are probably among the main reasons why farmers planted rubber in the midst of the crisis (Sunderlin *et al.*, 2000).

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