FARMING SECONDARY FORESTS IN INDONESIA

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DE JONG, W., VAN NOORDWIJK, M., SIRAIT, M., LISWANTI, N. & SUYANTO. 2001. Farming secondary forests in Indonesia. Estimates of the area of swidden fallow secondary forest in Indonesia are inaccurate, partly because swidden agricultural practices giving rise to the secondary forest are heterogeneous. Throughout Indonesia, swidden agriculture is evolving into more intensive land use. A mixed secondary forest tree crop management appears to be the first stage towards a tree crop-based production in Sumatra and Kalimantan. This changes the value of the forest/tree component of swidden agriculture, or the systems it evolves into. The trade-offs between productivity, environmental functions, biodiversity, and sequestrated carbon are only qualitatively understood. Some of the proposed large-scale estate crop production programmes in Indonesia disregard the benefits (a diverse agriculture, forest landscape, better environmental functions, higher biodiversity) that development along these endogenous trends may provide.

Key words: Swidden agriculture - secondary forests - fallow management - Indonesia - land use intensification

DE JONG, W., VAN NOORDWIJK, M., SIRAIT, M., LISWANTI, N. & SUYANTO. 2001. Perladangan hutan sekunder di Indonesia. Anggaran kawasan hutan sekunder bekas ladang di Indonesia adalah tidak tepat, antaranya disebabkan oleh berbagai-bagai amalan pertanian ladang yang meningkatkan jumlah hutan sekunder adalah heterogen. Di seluruh Indonesia, pertanian ladang kini berubah kepada penggunaan tanah yang lebih intensif. Pengurusan penanaman pokok hutan sekunder campur merupakan langkah pertama ke arah pengeluaran berasaskan tanaman pokok di Sumatera dan Kalimantan. Ini mengubah nilai komponen hutan/pokok pertanian ladang dan juga sistem yang terbentuk. Keseimbangan antara produktiviti, fungsi alam sekitar, biodiversiti dan karbon sekuestrasi hanya difahami secara kualitatif. Beberapa program pengeluaran tanaman estet secara besar-besaran yang dicadangkan di Indonesia tidak mengambil kira keuntungan (mempelbagaikan pertanian, landskap hutan, fungsi alam sekitar yang lebih baik, biodiversiti yang lebih tinggi) yang mungkin dapat disumbangkan oleh pembangunan di sepanjang trend endogen.

Introduction

Much of the original forest vegetation of Indonesia has experienced significant human disturbance and displays a major change in forest structure and/or canopy species composition. Annually, around one million ha of Indonesia's forests have been converted or significantly disturbed in the past decades (Sunderlin & Resosudarmo 1996)[1]. Until recently, official government sources attributed at least half of this forest conversion to swidden agriculturists (e.g. Kartasubrata 1993). Other sources have blamed the logging industry as a major factor (Sunderlin & Resosudarmo 1996). In recent years, logging, and the development of large-scale estate crop (especially oil palm) and timber plantations have contributed the largest part to forest conversion in Indonesia (Potter & Lee 1998). However, there is no doubt that large areas of Indonesia have experienced swidden agriculture, and large areas are under swidden fallow secondary forests. We define swidden fallow secondary forests as "forests regenerating largely through natural processes in woody fallows of swidden agriculture for the purposes of restoring the land for cultivation again" (Chokkalingam *et al.* 2000).

In Indonesia's secondary forests associated with swidden agriculture, much of the natural regeneration is blended in with a planted or tended component. The planting of trees on swiddens, a common practice in Indonesia, results in vegetation that can be classified as secondary forest gardens (Chokkalingam *et al.* 2000) or agroforests. Secondary forest gardens are considerably enriched swidden fallows, or less-intensively managed smallholder plantations or home gardens where substantial spontaneous regeneration is tolerated, maintained or even encouraged. Secondary forest gardens maintain an important component of spontaneous vegetation that is similar to the vegetation in swidden fallow secondary forests. The proportion of this spontaneous vegetation is inverse to the presence of the planted component and the amount of weeding conducted.

This paper argues that, in Indonesia, swidden fallow secondary forests at the plot level evolve into secondary forest gardens, and into extensive or intensive

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[1] Tomich *et al.* (1998) quoted a 1984–1995 forest conversion rate of 1.1% of the 109 million ha of forest lands, based on the 1997 World Development Report. Strong impressions exist that the rate of conversion has increased since the financial crisis and post-Soeuharto political reform period, but no accurate data exist in the public domain. Recent estimates mention a total of 1.6 million ha of forest that is converted every year.

smallholder tree crop production. Although this paper concentrates on the transition from swidden fallow secondary forest to secondary forest gardens or agroforests, some of the examples that will be discussed here indicate that this is by no means a unilateral transition. Under some circumstances, secondary forests do remain as forests, and secondary forest gardens can be abandoned and become old secondary forests (e.g. de Jong 1997, 2001b). In other circumstances, these swidden fallow secondary forests have degraded into *Imperata* grasslands. In order to avoid the latter, it is useful to understand the circumstances under which these different pathways occur.

This paper brings together information on the status and the dynamics of secondary forest as part of swidden agriculture in Indonesia and the transition of this secondary forest into other types of land use. Section 2 of this paper provides a discussion on the statistics that relate to swidden fallow secondary forest in Indonesia. Section 3 provides an overview of the diversity of the different types of swidden agriculture in Indonesia and the related role of secondary forests. Section 4 specifically focuses on the transition from swidden fallow secondary forests to secondary forest gardens or agroforests and smallholder tree crop production systems, providing examples from Kalimantan and Sumatra. Section 5 discusses national policy affecting swidden agriculture and secondary forest management. Section 6 briefly assesses productivity and environmental function trade-offs of the intensification of fallow management. Section 7 brings together several theoretical explanations for the transformation of the swidden agriculture-secondary forest complex. Section 8 draws some general conclusions from these discussions.

Statistics on secondary forest in Indonesia

Van Steenis (1935) stated at that time that one third of the land on the islands outside of Java had secondary forest or was under agricultural use. A lively debate on the role of swidden agriculture in forest degradation was held in the 1920s and 1930s and focussed on the need for technical developments allowing more intensive land use (Koens 1925, Hagreis 1930). Development of *Imperata* grasslands was attributed to over-exploitation of the soil in failed attempts at intensification (Danhof 1941). Richards and Flint (1994) estimate that between 1880 and 1980 the area of forest and woodland in Indonesia declined from 112 million to 84 million ha. During that same period, the area of interrupted woods declined from 17 to 15 million ha, while the area of grass-shrub complexes increased from 22 to 34 million ha. Forest and woodland include any tree vegetation with crown cover $\geq 40\%$ while interrupted woods include tree vegetation with crown cover $< 40\%$. Secondary forest, as defined by Chokkalingam *et al.* (2000), could be part of any of the three categories. Chokkalingam *et al.* (2000) define secondary forests as "forests regenerating largely through natural processes after significant human disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites".

One of the problems of estimating the cover of secondary forests is the discrepancy between official data on forest lands and the actual vegetation or land cover. The vegetation on a substantial part of Indonesia's state forest land is not actually forest. Data for the late 1980s are generally available, but more recent assessments of the actual status of Indonesian forests are subject to debate. Using the area of state forest land as a base for calculation, an upper-bounds estimate of the area under secondary forest and various forms of smallholder land use in the late 1980s can be obtained by subtracting from it the area with intact forest cover and area under coarse grassland (Table 1). This upper-bounds estimate amounts to 51 million ha, or a quarter of the land area of Indonesia.

Table 1 Area (million ha) under legal and actual forest cover in Indonesia, according to TGHK (Consensus Forest Land Use Plan)

	Legal forest category						
	Nature reserve	Protection forest	Limited production	Normal production	Conversion	Unclassified	Total
West Papua							
TGHK forest	7.3	10.9	4.6	7.7	9.6	1.3	41.5
RePPProT forest	6.2	9.5	4.2	7.0	7.8	0.3	35.0
Coarse grassland							0.5
Difference	1.1	1.4	0.4	0.7	1.8	1.0	6.0
Kalimantan							
TGHK forest	3.6	6.5	11.8	13.2	11.5	6.8	53.6
RePPProT forest	3.3	6.0	10.2	11.0	7.4	1.6	39.6
Coarse grassland							2.2
Difference	0.3	0.5	1.7	2.2	4.1	5.2	11.8
Sumatra							
TGHK forest	4.1	6.4	6.7	6.9	8.7	14.7	47.5
RePPProT forest	3.5	4.3	4.7	4.9	3.6	2.4	23.3
Coarse grassland							2.1
Difference	0.6	2.1	2.0	2.0	5.0	12.4	22.1
Sulawesi							
TGHK forest	1.4	4.3	4.6	1.4	1.6	5.2	18.6
RePPProT forest	1.2	3.3	3.5	1.0	1.0	1.2	11.3
Coarse grassland							1.3
Difference	0.2	1.0	1.0	0.4	0.6	4.1	6.0
Maluku, NT							
TGHK forest	0.8	3.0	2.4	1.4	5.2	3.1	15.9
RePPProT forest	0.5	2.1	1.9	0.9	2.9	0.5	8.8
Coarse grassland							2.3
Difference	0.3	0.9	0.6	0.5	2.3	2.5	4.8
Total outside Java							
TGHK forest	17.3	31.2	30.1	30.7	36.7	31.2	177.1
RePPProT forest	14.7	25.2	24.5	24.9	22.8	6.0	117.9
Coarse grassland							8.4
Difference	2.6	6.0	5.6	5.8	13.9	25.2	50.8
RePPProT forest + bush & scrub							135.3
RePPProT bush & scrub							17.4

Data from mid 1980s, the RePPProT study of actual forest cover on the basis of satellite imagery (with the 1982–1988 period as the basis for assessment); and the data on *Imperata* and other coarse grasslands based on a post-1985 assessment by Garrity *et al.* (1997).

Based on interpretation of satellite imagery in 1980, the area of forest fallow derived from swidden agriculture in closed broadleaf forests was estimated to be 13.5 million ha (Weinstock & Sunito 1989). At that time an estimated 12 million people practised shifting cultivation, leading to a ratio of 1 person per ha under forest fallow, which either indicates a very short fallow period or incomplete data on the area influenced. In the RePPProt (1990), the area provided was 11.4 million ha, which included both swiddens and fallow land. Sunderlin & Resosudarmo (1996), using a World Bank study from 1990 that was based on the same RePPProt reports, estimated that swidden agriculture covered an area of 14 million ha in Sumatra, 11 million ha in Kalimantan, and 2 million ha in West Papua. These totals, however, group together everything from swidden fields, fallows, shrub lands and grasslands. The existing data do not provide a clear picture of the area of secondary forest generated by swidden agriculture and how this is changing. None of these studies recognise secondary forest gardens or agroforests as a category separate from other secondary forest types, as indeed it is difficult to distinguish these in remote sensing imagery (Murdiyarso & Wasrin 1995).

Diversity of swidden agriculture in Indonesia

The lack of clarity in data regarding swidden and swidden fallow secondary forests is in part a result of the confusion regarding the agricultural practices being referred to. Swidden agriculture refers to "swiddening", or temporary removal of the woody vegetation on a plot for agricultural production, and is part of a long-term rotational land use practice that allows for the development of swidden fallow secondary forests. It is more commonly referred to as shifting cultivation, but we suggest identifying it as 'typical' swidden agricultural systems, which are still present in Kalimantan and West Papua. This practice is not properly distinguished from the opportunistic opening of forest lands for agriculture by recent migrants who arrive from densely populated islands. These farmers slash and burn small patches of forest, plant a staple crop and then a cash crop. The cash crop may be pepper, as was the case for migrants from Sulawesi to East Kalimantan. Many of these farmers continue to grow pepper for 10 to 20 years on the same plot and then move on to other areas after the soils are totally exhausted. Other examples are migrants from Java who opened new lands in Sumatra where they planted rubber. The migrants involved in these types of forest conversion may have come to the more forested parts of Indonesia via the government-sponsored transmigration programme, or have moved on their own accord to start a farm in areas where land is easier to obtain or initially to work in logging concessions or the plantation industry.

Factors that contribute to the varying prominence of secondary forest among 'typical' swidden agriculturists are the biophysical conditions of the locations (mainly soil and climate), and several economic and socio-cultural traits. Among the latter, population density is of major importance, influencing to a large extent the duration of fallow, and subsequently the kind of vegetation that develops on the fields. Additional factors include the main crop being produced and the number of cultivation cycles before the field is fallowed, which is also, to a large extent, a function of biophysical conditions. Table 2 lists shifting cultivator groups in Sumatra, Kalimantan, Sulawesi and West Papua, indicating differences in several attributes related to the land use practice.

Table 2 Features of swidden agriculture of various groups in Indonesia (adapted from Waridinata *et al.* 1990)

Location	Group	Main crop	Tenure	Cropping period (year)	Fallow period (year)	Emerging tree crop
Sumatra	Sakai	Rice	Kinship/ clan	1	3–7 (previous 15–20)	Rubber
	Akit		Patrilineal			
	Melayu		Clan	2–3	7–10 (previous 15–20)	Rubber
Central Kalimantan	Ngaju	Rice	Kinship/ villages	1	3–7 to (previous 15–20)	Rubber and rattan
	M'ayanan	Rice	Eldest son/ village	1	3–7 to (previous 15–20)	Rubber and rattan
Sulawesi	Muna		Private/ kinship	1–2	3–4	Cashew
	Noronene		Tribal/some private rights	2	2–4	Cacao
	Tolaki			1–2	3–4	Cashew
West Papua	Dani	Sweet potato, taro	Clan/tree crops private. Inherited by eldest son	2–5	3–7 (previous 5–10)	
	Butonese	Vegetables for markets	Share cropping. Land owed by clan	1–3	3–5	

Examples from Kalimantan

The native *Dayak* of Kalimantan, mostly living in interior sections, rely for their daily staple on upland rice cultivation from annually cleared swiddens. Fallow fields continue to have economic importance for the spontaneous or planted species that yield useful products. Different groups show variations in swidden agricultural patterns and related secondary forest cover. *Iban* farmers, mostly from Sarawak, historically preferred to make fields in mature natural forests rather than in secondary forests (Freeman 1955). This type of swidden agriculture led to large areas of secondary forests on land that had experienced only one cropping cycle. Groups like the *Kenyah* and *Kayan* from the eastern parts of Kalimantan cultivated the area around a new settlement for several decades, and then moved the whole village to a new site, leaving the land to recover over a long time. Jessup (1981) claims that *Kenyah* farmers purposely maintain a sufficient large area of swidden fallow secondary forest to assure the supply of useful species that can only be found in this vegetation.

A third group, *Bidayuh* farmers from West Kalimantan and Sarawak (King 1993), practised a more sedentary swidden agriculture compared to other groups. When *Bidayuh* villages became too large, they split up and only portions moved to a new area of forest to start a new settlement. Long residence in a single region implies that a *Bidayuh* farmer must have a sufficiently large holding under various stages of fallow. This holding is to be built up gradually from when a newly wedded couple becomes an independent farming household, until the area is large enough such that fields can be used and fallowed at sufficiently large intervals. However, a *Bidayuh* holding would, on average, still have less secondary forest than, for instance, the ever moving *Iban* farmers (Winzeler 1993). In a typical *Bidayuh* landscape, there is little old growth secondary forest, as may be common in old *Kenyah* and *Kayan* settlements. Among *Bidayuh* farmers, land tenure claims are strong and are held by descendants for many generations, even after a settlement splits and one part of the community moves elsewhere. *Bidayuh* farmers also place more emphasis on tree planting and the conservation of primary forest reserves. Table 3 provides some data on the areas under swidden and the areas under fallow in four villages in West Kalimantan.

Table 3 Areas under swidden and under fallow in four Bidayuh villages in West Kalimantan

Village	Year	Swidden	Fallow
Sanjan [1]	1991	* 0.89 ha/family	9.7 ha/family
Tunguh [1]	1990	1.19 ha/family	5.6 ha/family
Ngira[2]	1994	3.2 ha/family	14.3 ha/family
Koli[2]	1994	4.2 ha/family	18.9 ha/family

[1]Momberg 1993, [2]de Jong, field notes.

The importance of secondary forests in many of Kalimantan's agricultural communities is reflected in the ecological knowledge. Table 4 presents classifications of swidden fallow secondary forests from three *Bidayuh* groups and one *Kenyah* group. The classifications found among the villagers in Sanjan, West Kalimantan (Momberg 1993) and among *Kenyah* farmers in Long Ampung, East Kalimantan (Colfer *et al.* 1997) are principally based on the physiognomy of the secondary forest. On the other hand, the classifications among the two *Bidayuh* groups in Sanngau (Momberg 1993) and Ngira (de Jong 2001a) are mainly based on the land use history of the site.

Table 4 Classification of swidden fallow secondary forests among various groups in Kalimantan

Sanjan (Bidayuh, West Kalimantan)[1]	Domun mudah = low young secondary forest Domun tua = old secondary forest Jamih = secondary forest with shrubs Kukot = extremely degraded secondary vegetation
Long Ampung (Kenyah, East Kalimantan)[2]	Bekan = new fallow Jekau Bu'et = young secondary forest Jekau Dadu' = old secondary forest.
Ngira (Bidayuh, West Kalimantan)[3]	Jamie rintu = cleared once Boruat = cleared twice Doda = cleared at least three times
Sanggau (Bidayuh, West Kalimantan)[1]	Jami tuh = cleared once Jamie ongun = cleared twice Jamih risaa = cleared 3–4 times Damuh = old secondary forest

[1]Momberg 1993; [2]Colfer *et al.* 1997; [3]de Jong, field notes.

The classification of secondary forests appears to be closely related to subsequent land use. De Jong (2001a) reports on practices of tree planting, which are more prominent in fields made in a category of swidden fallow secondary forest in danger of being subject to repeated uncontrolled burning and conversion to *Imperata* grassland. On the other hand, swidden fallows subject to only one swidden cycle will mostly be used for a subsequent rotation, rather than for tree planting.

Transformation of swidden agriculture

Several studies suggest changes in swidden agricultural practices. For instance, Richards and Flint (1994) summarised land use change data for South and Southeast Asia from 1880 to 1980, and showed a decreasing level of dependence on shifting cultivation. Though swidden agriculture is still an important subsistence strategy for many rural farmers in Indonesia, its overall importance is decreasing and there are large regional differences. Van Noordwijk *et al.* (1996) distinguished four groups of provinces (Figure 1, Table 5) on the basis of the timing of the transition.

There is also ample evidence of processes of transformation from swidden agriculture to mixed rice/tree crop-based production systems as indicated by numerous cases from Kalimantan. The factors that trigger this transformation are population density and related land use pressures, engagement with the cash economy, and to some extent state agency policing (de Jong 2001b). The precise direction of this transformation is primarily influenced by two factors: existing tree planting and forest management practices; and, the opportunities to obtain cash from rubber production.

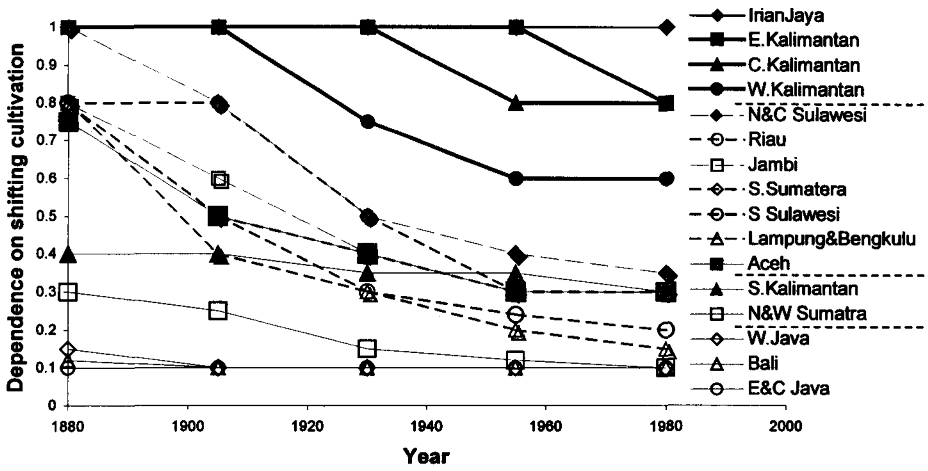

Figure 1 Historical land use change in selected provinces of Indonesia, as reflected in an index of "shifting cultivation" (based on Richards & Flint 1994)

Table 5 Provinces in Indonesia and transformation of swidden agriculture into permanent agriculture

Provinces	Status of swidden agriculture transformation
Java and Bali	Transformation to permanent agriculture was virtually completed by the end of the 19th century
N. and W. Sumatra and S. Kalimantan	Land use intensification had progressed by the end of the 19th century, but the process appeared to stall in the first half of the 20th century
Most of Sumatra and Sulawesi	Transformation essentially took place between 1880 and 1960, with remnants of swidden agriculture persisting until the end of the 20th century
Rest of Kalimantan and West Papua	Transformation started during the 20th century, earliest in W. Kalimantan and last in West Papua

Many swidden agriculturists in Borneo traditionally plant trees in agricultural fields, creating secondary forest gardens. These *tembawang*, as they are called, have economic value, but are also important socio-culturally. Although individually- or kinship-owned, *tembawang* in a village usually occur as a single contiguous area that remains as a marker of previous occupation for hundreds of years, and thus functions as a biological indicator of people's history. They also help to maintain kinship bonds as descendent groups collectively own produce from these *tembawang*.

The introduction of rubber plays an important role in the transformation of swidden agriculture, including the management of *tembawang*. Rajah Brooks in Sarawak encouraged rubber production among smallholders. Rubber planted into rice fields has many of the biological properties of a secondary forest species, which allows it to compete with the natural re-growth of a forest fallow. In West Kalimantan, many inland swidden farmers started producing rubber a few decades after it arrived in Sarawak (de Jong 2001b). Rubber is only grown as a cash crop and management intensities vary. Farmers may plant rubber in swiddens, and then just return to tap the trees some ten years later. In other places, farmers are shifting towards more intensive rubber production, and slashweed the stand several times before the rubber trees are actually tapped.

De Jong (2001b) analysed the influence of the introduction of rubber on the transformation of swidden agriculture using data from three villages in West Kalimantan. Figure 2 shows the land use distribution in one of these villages, Ngira, located in the interior of West Kalimantan. In 1993, Ngira had 40% of its land under *tembawang*, rubber gardens, or fallow lands planted with rubber and fruit species. This was largely a result of the introduction of rubber in combination with 'traditional' forest management practices. During the previous 10-year period, more land was replanted with trees than was converted from primary forests.

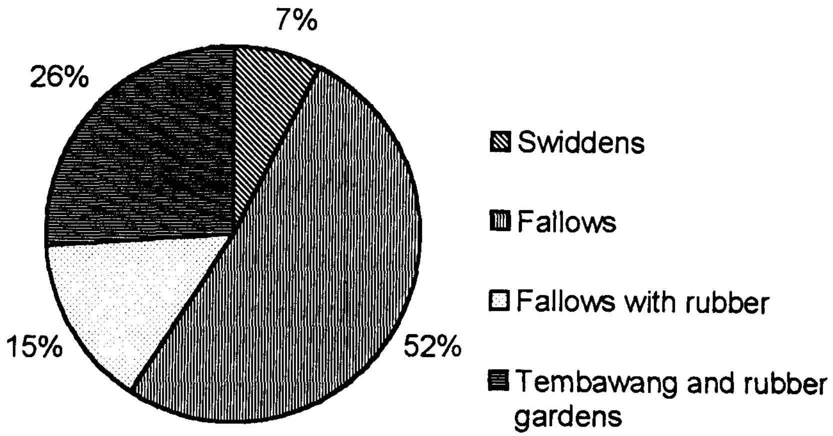

Figure 2 Land use patterns in Ngira, West Kalimantan in 1994

Potential long-term trends of these initial developments are suggested by the village of Bagak, much closer to the coast and with a population density of 120 people km^{-2}. In this village, people are strictly forbidden to encroach onto the neighbouring Gunung Raya Reserve (Peluso 1990). In 1990, 11% of the 1800 ha of the cultivated land in the village was under paddy rice and 19% under swiddens and swidden fallows. Additionally, 16% of the village area consisted of improved rubber plantation, established in 1981 and 1982, while 39% of the land was under *tembawang*-like mixed tree cover and 3% was communally preserved old secondary forest (Figure 3).

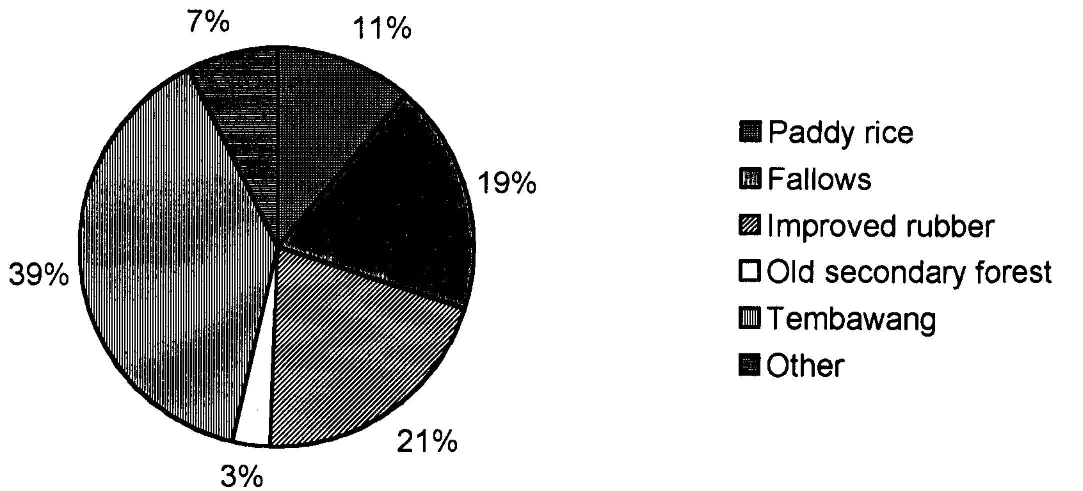

Figure 3 Land use patterns in Baak, West Kalimantan (adapted from Peluso 1990)

In most of Sumatra, the dependence on swidden agriculture decreased rapidly in the period 1900 to 1930 (Figure 1), also largely caused by the introduction of rubber. The primary focus shifted from production of upland rice combined with the gathering of swidden fallow secondary forest products to rubber production. In the latter system, upland rice is planted to pay for the cost of establishing and protecting the rubber plot. Elsewhere in Sumatra, other types of secondary forest gardens emerged, such as the *Shorea javanica* agroforests (Torquebiau 1984), and the durian secondary forest gardens, similar to the *tembawang* of Kalimantan.

The countrywide implications of these trends are reflected in the statistics on smallholder tree production. Indonesia had, in 1994, some 9 million ha under rubber, coconut and oil palm, over half of which was located in Sumatra. Smallholders grow most of the rubber and coconuts in Indonesia (Sunderlin & Resosudarmo 1996). As indicated above, much of the smallholder rubber is still produced in stands that may be considered secondary forest gardens.

Policies affecting swidden fallow secondary forests

Indonesia, like so many other countries in the region had, and still has, a policy of the condemnation of swidden agriculture. The country has implemented several smallholder tree-planting programmes to address "the problem"of swidden agriculture. A few older programmes are the Rehabilitation and Expansion of Export Crops Programme, the Tree Crop Support Project and the Smallholder Rubber Development Project. These schemes attempted agricultural intensification through tree crop production. For instance, the Rehabilitation and Expansion of Export Crops Programme offers credit to smallholders to incorporate high yielding rubber varieties in their holdings. Farmers have to be willing to organise into groups and to follow rigid guidelines of intensive management, including maintaining monospecific and cleanweeded stands (de Jong 1997, Potter & Lee 1998).

The Ministry of Forestry developed several social forestry programmes in which farmers can obtain credit for establishing tree plantations on their fields, but they also have to form farmers' groups. Another programme from the same ministry is the re-greening programme that provides funds and material for one year to plant trees on farmers' land and for two years for maintenance. However, farmers obtain no rights to the trees or the land. A more recent programme directed specifically at stabilising swidden agriculture is the Land Use Stabilisation programme aimed at converting upland swiddens to permanent rubber and fruit tree lots. Under this programme, farmers receive a hoe, planting material and fertilisers and obtain rights to a 0.5 ha lot.

Programmes directed at establishing timber, pulp and oil palm plantations probably have more influence on swidden agriculture and swidden fallow secondary forest management than smallholder programmes. Indonesia has an ambitious industrial timber programme to develop its pulp and paper industry. At one point, there were plans to develop 4.5 million ha of pulpwood plantations by the year 2000, a target that has not been achieved. Timber companies often used coercive measures to acquire the land needed for the timber plantations (de Jong 1997). New approaches are being tested that involve smallholders in the production of fast growing species (Potter & Lee 1998).

Programmes to develop oil palm started in the 1980s. The early projects followed Nuclear Estate Programmes in which para-state companies developed oil palm estates, but between 60–80% of the area was managed by farmers in smallholdings. Participating farmers gave up much of their swidden fallow land to receive facilities to produce oil palm on 2 ha. Subsequent programmes focused more on establishing such schemes for transmigrants and involving private companies. These companies must provide the funds to develop Nucleus Estate Smallholder production involving transmigrants, while swidden agriculturists provide the land. Especially during 1998 and 1999, private investors and provincial governments favoured oil palm estates over the older smallholder tree planting schemes, a trend that is likely to continue in the future.

The smallholder tree crop development schemes have succeeded in promoting the use of improved germplasm for some crops such as rubber. In general, their influence has been minimal, partly because these schemes occur mainly in remote areas where none of the larger estate crop development programmes take place, such that they do not infringe on the latter. In addition, in provinces like Jambi, many smallholders preferred to acquire planting material from private nurseries, rather than to sign up for government programmes (Potter & Lee 1998). Of more influence have been the large-scale tree planting schemes, as they largely replace swidden agriculture. This has had a negative impact on a relatively benign swidden agricultural landscape including swidden fallow secondary forest, secondary forest gardens and forest remnants. For instance, in 1990, Jambi was described as a province that was still environmentally rich because development had been based on smallholder rubber development rather than on large estate development. One decade later, this picture has changed as a result of industrial timber production and oil palm development (Potter & Lee 1998). Potter & Lee (1998) and de Jong

(1997) have questioned the social and economic benefits that the industrial timber and the oil palm development schemes bring to participating smallholders.

Environmental values of transformed secondary forests

In the analysis of the role of swidden fallow secondary forests a distinction can be made between local, regional and global concerns. Local concerns may focus on the productivity and allowable harvest of the system, both in the crop and in the fallow (secondary forest) period, that meets subsistence and cash income needs. Long-term sustainability of the system and its role in buffering against risks of rainfall, pest outbreaks, and price fluctuations are also important at the local level. Regional concerns focus on the watershed functions of providing a regular flow of clean water and increasing the residence time of water in the landscape, reducing the risk of flashflooding downstream. Global concerns include the amount of carbon stored above and below ground, and the contribution of the area to the maintenance of global biodiversity.

Intensification of swidden agriculture is likely to affect the various environmental functions in different ways. Figure 4 presents relationships between fallow length, productivity, carbon stock and biodiversity. The relationship in the upper right quadrant between length of fallow and productivity is relatively well studied. It shows a maximum crop productivity at some intermediate exploitation level and an (initially lower) annual harvestable yield from the fallow that increases with fallow age, until some plateau is reached. The combined productivity of crop and fallow may have a range of shapes, but is likely to still show a local maximum at intermediate fallow length.

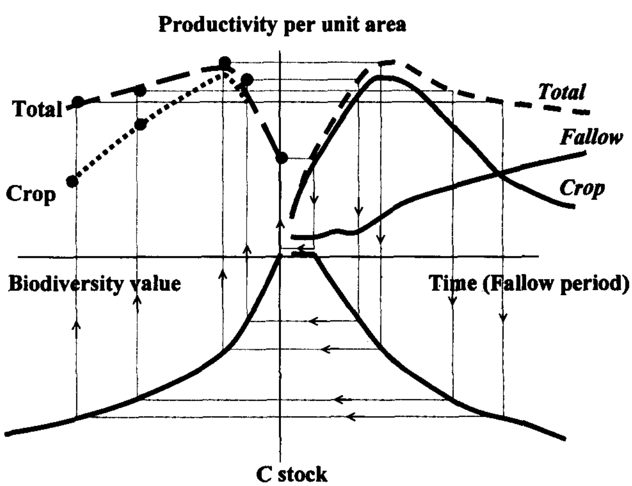

Figure 4 Schemic four-quadrant representation of the relationships between productivity (P), biodiversity (B) and carbon stocks of crop-fallow rotation system (C) as a function of the length of the fallow period (maximum age the secondary forest is allowed to attain)

The relation between C stock and fallow length (Figure 4, lower right quadrant) will generally show a saturation curve. The precise relationship between biodiversity value and C stock (Figure 4, lower left quadrant) depends on the aspect of biodiversity that is quantified (van Noordwijk *et al.* 2000). The shape of the curve in Figure 4, lower left quadrant, suggests that the initial increase in biodiversity value is slower than the increase in C stock, and is dominated by medium and late successional species. Data collected on swidden fallow secondary forests in Sumatra (Jambi and Lampung) and rubber secondary forest gardens in the same ecological zone (Figure 5) show that species richness appears linearly related to estimates of tree basal area that can be used as a correlate of total system C stock. In Figure 5, the open and filled points are very well mixed, suggesting that the plant species richness of rubber secondary forest gardens is equal to that of swidden fallow secondary forests when comparisons are made at the same basal area.

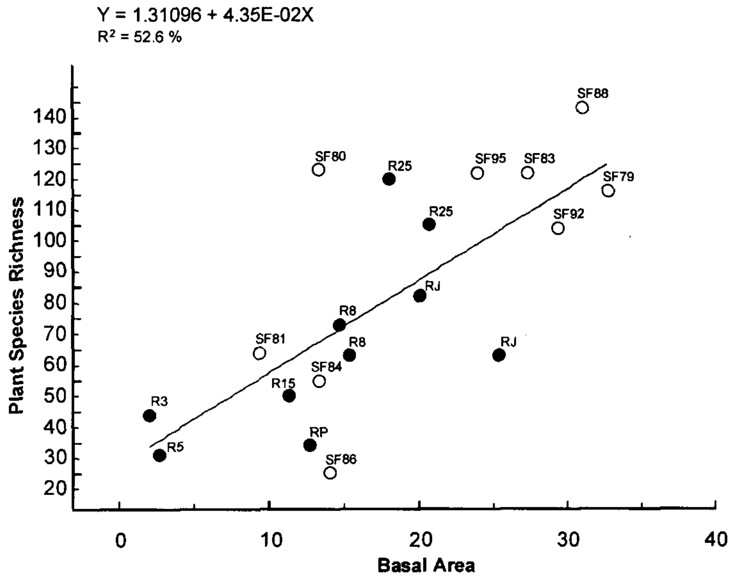

Figure 5 Plant species richness and basal area from 19 pols in Jambi and Lampung, Sumatra (solid circles indicate rubber jungle/plantation; open circles indicate secondary forest)

Finally, the relationship between biodiversity and productivity in the upper left quadrant of Figure 4 is the most controversial of all. Most of the productivity in swidden fallow systems may depend on the cropped fields, while biodiversity depends on the fallow. For the specific example given here, the trade-off between productivity and biodiversity has two stages with different signs of slope: a phase where increase in productivity (from a farmer's perspective) is linked with a reduction in biodiversity value, and a phase where both decline with further intensification of land use. Avoiding the occurrence of, or attempts at recovering from, the latter degradation may provide a win-win situation. However, the total biodiversity value that may be conserved if farmers maximise productivity of land is low, unless the benefits derived from the secondary forest show a clear increase with the age of the fallow and are high enough to offset the gains made in a cropping phase.

Explaining transformation of swidden agriculture to tree crop-based agriculture

Intensification of swidden agriculture

The transformation of swidden agricultural practices is predicted by Boserup (1965) who argued that, as population increases, forest land is increasingly converted to agricultural land. Eventually, the extensive use of land is not possible anymore. Under such conditions, investment in land improvement, such as terracing, irrigation and tree planting, is often needed to intensify land use.

Ruthenberg (1976) proposes a land use intensity value, R, to distinguish between fallow rotation systems with different fallow lengths. The R value is the fraction of time (or land area) used for annual food crops as part of the total cropping cycle (area). Fallow rotation systems, in the definition of Ruthenberg (1976), are an intermediate stage between shifting cultivation or long rotation fallow systems where land is cropped for less than one-third of the time ($R < 0.33$) and continuous cropping where land is cropped more than two-thirds of the time ($R > 0.67$). More intensive land use (higher R values) requires that the soil restoring functions of a fallow have to be obtained in less time, by a so-called improved (more effective) fallow, or that these functions have to be fully integrated into the cropping system.

Figure 6 illustrates this kind of development in Sumatra. The negative sloping diagonal shows the various types of shifting cultivation, long rotation fallow and short rotation fallow, where forest or shrub land is opened to grow food crops. This sequence of systems has fewer and fewer natural elements in the vegetation (downward movement in the graph) but also represents stronger private control over formerly communally held lands (shift to the right).

The transition from swidden fallow systems into more intensive land use systems can essentially follow three routes: food crops, tree crops or fodder supply–pasture systems (van Noordwijk 1999). The classic agronomic view on intensification of upland cropping systems (Ruthenberg 1976) is that a higher (cumulative) output per ha, and therefore a higher human carrying capacity, can be obtained by increasing the cropping intensity. Efforts to increase the harvestable output per unit area (Figure 7) can be achieved in food crop–based systems by reducing the length of the fallow period and the age at which secondary forests are re-opened by slash-and-burn methods (in the graph, this is a tendency towards the upper right corner). An increase in productivity per unit land may be accompanied by a reduction in productivity per unit labour. This will happen unless mechanisation replaces the labour needs of managing under increased weed and pest pressures, and reduced soil structure. These are the leftover consequences of a loss of fallow functions as fertilisers replace the soil fertility restoration function.

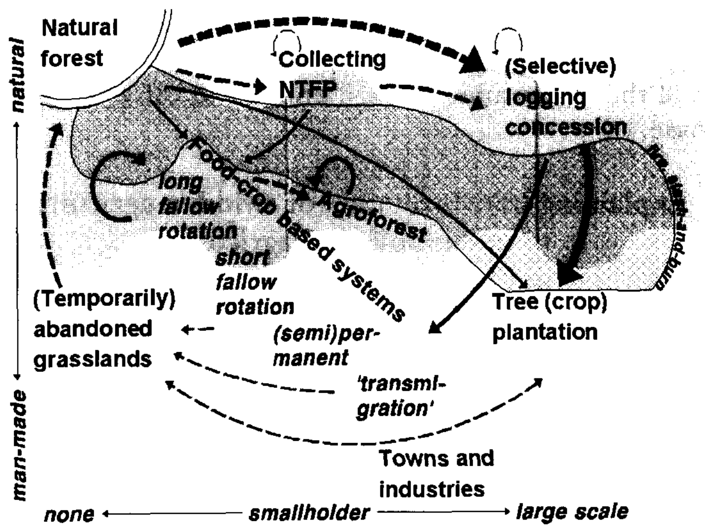

Figure 6 Two-dimensional classification of land use systems based on the type of human control and relative strength of natural processes in determining the land cover. Human control includes no claims, smallholder private claims and large-scale private claims. Relative strength of natural processes includes the continuum from completely natural to fully man-made. Transformations of forest soils to other land use types as found in Sumatra; all transformations in the shaded areas use slash-and-burn as a method for land clearing; the agroforests are the major farmer-developed alternative to slash-and-burn based food crop production systems (van Noordwijk *et al.* 1999); the shaded grey area indicates the domain of secondary forest by the definition of Chokkalingam *et al.* (2000).

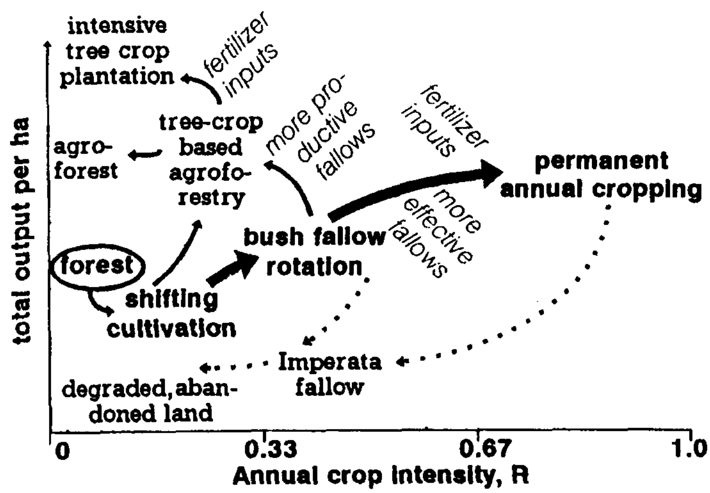

Figure 7 Total output per ha as a function of annual cropping intensity, R (the ratio of cropped and total land area). More intensive use of the soil can increase the total output per ha from shifting cultivation to permanent cropping with annual food crops, but there may be diminishing returns to labour. Intensification can also lead to land degradation and abandonment as indicated by the interrupted arrows. Tree-crop-based systems can allow a high output per ha at a low intensity of growing annual food crops (van Noordwijk *et al.* 1996)

Tree cropping development emphasises the harvestable part of the forest fallow and will lead to a reduction of annual crop intensity, as the economic lifespan of the trees dominates decisions on cycle length. Specialisation on fodder supply or pasture systems is relatively unimportant in the humid forest zone of Indonesia, but is a dominant pattern in Latin America. It appears that parts of Mindanao in the Philippines have gone through a 'ranch' stage as part of the deforestation process as well. It remains an open question as to why this did not happen in Sumatra or Kalimantan.

Intensification of fallow management

Fallows, in various stages of their succession to secondary forests can be used as grazing land, or for producing firewood, honey, thatching material, etc. The first step in the intensification of farmer management of fallow lands is usually the retention or promotion of certain plant species that appear in the fallow and are considered to be of value for one of the several functions of a fallow. During further intensification, however, choices among the multiple functions may be necessary.

If management of a fallow is aimed at increasing its direct production value, we speak of enriched (more productive) fallows, which can refer both to tree products as well as herbaceous legume fodders. If one starts from very low management intensities, fallows can be both improved and enriched, but, at a certain intensity of land use, conflicts will arise: improved fallows will be of rather short duration and many of the elements of enriched fallows require longer maturation periods. Therefore, in the centre of the graph (Figure 7), one has to choose a trend towards the upper right (more effective fallows, food crop-based production systems) or the upper left (more productive fallows, with a reduced importance of food crops). Land use systems such as the intensively managed rubber gardens of Sumatra and Kalimantan (Gouyon *et al.* 1993) have evolved from enriched fallows (e.g. de Jong 2001b) into systems where the tree fallow dominates and the food crop period has become a minor element in the total land use system.

Other commercially important trees such as cinnamon (*Cinnamomum burmannii*) and coffee (*Coffea canephora*) have been introduced in various parts of Sumatra (de Foresta & Michon 1992) and have followed similar pathways. Aumeeruddy (1994) described the development of cinnamon-based agroforestry in the Kerinci Valley, and Gouyon *et al.* (1993) provided historical perspectives on the development of rubber agroforestry in Sumatra.

A conceptual framework of farming swidden fallow secondary forest

Hayami (1997) illustrates the transformation of land use from swidden agriculture to permanent (tree) cropping. The basic conceptual framework presented there can be applied to the case of the transformation of swidden fallow secondary forest to secondary forest gardens or agroforests, as can be observed in Sumatra. In Figure 8 the curve $i_0 i_0$ represents the unit isoquant for an individual farmer to

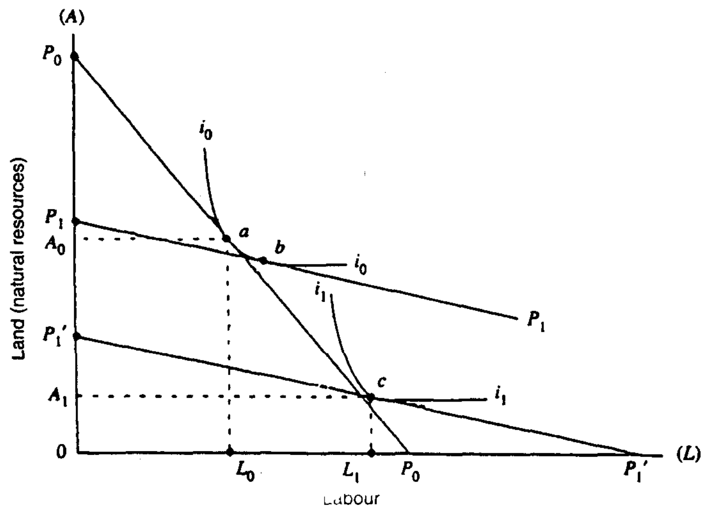

Figure 8 A model of induced institutional innovation

produce one unit of product by using land and labour under swidden agriculture at the period 0. P_0 is the relative factor price line, indicating the relative scarcity of production factors. The optimum production is achieved at point a, where the production is deemed to be sustainable, ensuring complete restoration of soil fertility. Initially, population increases and land becomes scarce relative to labour. As a result, the relative price of land to labour increases from P_0 to P_1. If the farmer maintains the swidden agriculture practice, the optimum production point moves from a to b. At this point, the fallow period is shorter than at point a.

Otsuka & Place (2000) argued that the profitability of more intensive cultivation compared with swidden agriculture will increase because of the shortening fallow period and declining sustainability under the previous practices. Increasing the commercialisation of agriculture will also reduce fallow periods. Because of the shorter fallow cycle, soil fertility declines and farming becomes unsustainable at point b. If swidden agriculture continues with the shorter fallow period under the increasing population pressure and commercialisation of agriculture, production efficiency will decline over time. With innovations improving land quality by investing in land (e.g. the construction of irrigation facilities or terracing) or by investing in trees (e.g. commercial trees such as rubber, cinnamon and coffee), production can be carried out on isoquant curve, i_1i_1. As a result, the optimum production point moves from point b to point c. With the new technology, farmers can produce one unit of output with a smaller amount of land. Therefore, for instance, a new tree production-based technology is likely to be more profitable than the old technology relying only on swidden fallow. Hayami (1997) believes that the comparative advantage in the production of commercial tree crops in Indonesia is high and hence the development of tree-based production systems will generate higher income and increase export earnings.

Conclusion

Although there is evidence that swidden agriculture is not the largest cause of the conversion of primary forest in Indonesia, there is without doubt an extensive area of secondary forest related to this type of land use in the country. Exact figures on this area are lacking, but much of the current area of swidden fallow secondary forest is subject to processes of change, a result of land pressure caused by the population growth of swidden farmer groups. Additional factors of change are government programmes like estate crop development, industrial tree plantations and transmigration. The processes of change have already resulted in decreasing dependency on swidden agriculture in several regions of the country, while further change leads to the progressive incorporation of tree cropping in the management of secondary forests. Where this happens, secondary forest gardens or more intensive agroforests become an important component of the land use, while the swidden component increasingly disappears. Gradually, these systems develop into smallholder tree crop production.

The transformation of swidden agriculture and related secondary forests into tree cropping-based land use makes sense from an economic point of view, as it allows for an increased return on land and labour resources. It is possible to identify several factors that contribute to the development of tree cropping-based agriculture, rather than the intensified production of annual or semi-annual crops, or the conversion of secondary forests into grassland for cattle production. These are:

(1) a culture of tree and forest management in many parts of the country,
(2) a history of estate tree crop production introduced by the Dutch, both the tree species and the economic infrastructure that facilitated smallholder tree crop production, and
(3) an ecological setting that made large-scale cattle ranching less feasible, as it would have resulted in widespread low productivity *Imperata* grasslands.

The intensification of swidden fallow secondary forest towards secondary forest gardens, agroforests or smallholder tree plantations has consequences in terms of productivity, biodiversity and sequestered carbon. There is some evidence regarding the trade-offs between these three attributes along the intensification pathway from swidden fallow secondary forest toward smallholder tree production. However, there is yet little opportunity to precisely calculate the cost benefits of alternative options, let alone to internalise some of the environmental externalities in any of the stages and choose options that make a higher environmental contribution economically more attractive. On the other hand, much of the transformation from swidden fallow secondary forest to secondary forest gardens or agroforests is economically motivated, and so is the reversal of secondary forest garden to more extensively managed forests where the spontaneous vegetation increases (e.g. de Jong 2001b).

The precise role of the factors that affect the direction of change need to be specified, thus allowing for the prediction of the circumstances under which the tree cropping-based transformation of the swidden fallow agricultural complex will take place. This will then enable the formulation of policies to stimulate such transformation, where considered appropriate. The net result may be land use development at a lower economic, social and environmental cost than other development options, such as oil palm estates, industrial timber production, or degradation. The intensification of swidden agriculture along the pathway described here may lead to better benefits for swidden agriculturists and the Indonesian state at large. Probably the most important conclusion that can be drawn from this paper is that swidden agriculture and the related management of secondary forest can be looked at as an early step in a progressively intensified land use. Under the right circumstances, swidden agriculture may develop into a land use that has a larger component of secondary forest gardens, agroforests, or tree cropping, with associated benefits.

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