Alternatives to Slash-and-Burn in Indonesia

A Journey of Discovery

Sponsored by:

AARD

Agency for Agricultural Research and Development

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Centre for International Forestry Research

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Guide for ASB field trip, 25-27 May 1996, Jambi, Sumatra, Indonesia

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ASB-Indonesia Report No. 5

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Section I. ASB Indonesia Overview

I.1. Introduction

Alternatives to Slash-and-Burn (ASB) stands for three thrusts, which can be linked to the forest, fire and crops parts of the slash-and-burn cycle:

Alleviate poverty - secure access to food, either via providing sufficient income or by home production is a pre-requisite for a humane development pathway,

Sinks and sources of greenhouse gasses during land use change should be better understood; mechanisms should be developed for linking local and global costs and benefits,

Biodiversity conservation is a global imperative with consequences at the local level; the relationships between human land use and biodiversity conservation should be quantified to balance local and global interests, either by a *segregation* of 'conservation' and 'production' areas or by an *integration* in multi-function land use patterns.

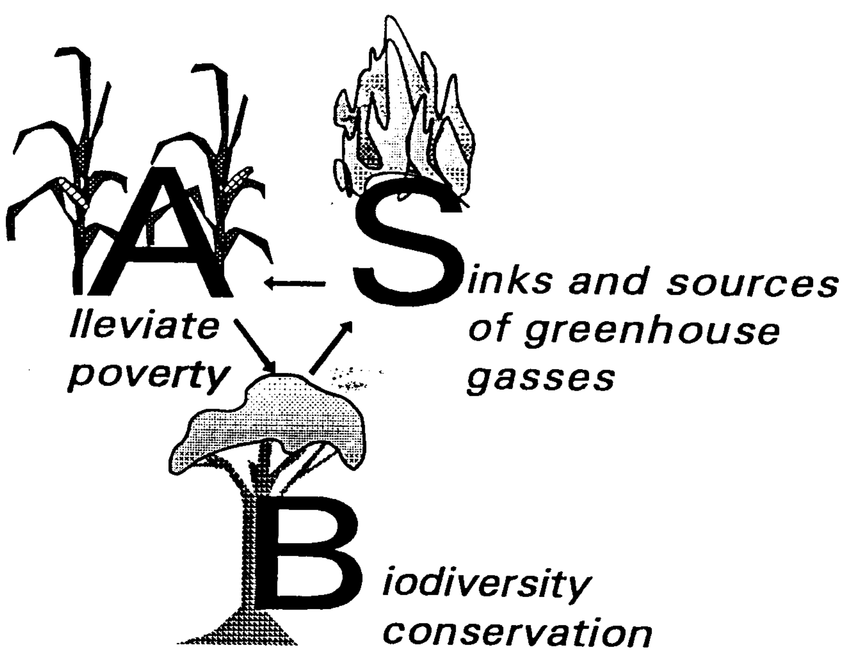


Figure 1. The three ASB 'thrusts': food security, global warming, and biodiversity.

The ASB project is implemented by a consortium of international and national government and non-government organizations, including AARD, CIRAD, CIFOR, CIAT, EMBRAPA, IRAD, INIA, INIFAP, ICRAF, IFDC, IFPRI, IITA, MAC, TSBF, and WRI. In Indonesia, the ASB consortium, led by AARD, includes researchers from research institutes under the Ministries of Agriculture, Forestry, Transmigration and Home Affairs, from several universities and NGO's.

'Intensification' of land use may contribute to solutions for all three ASB thrusts:

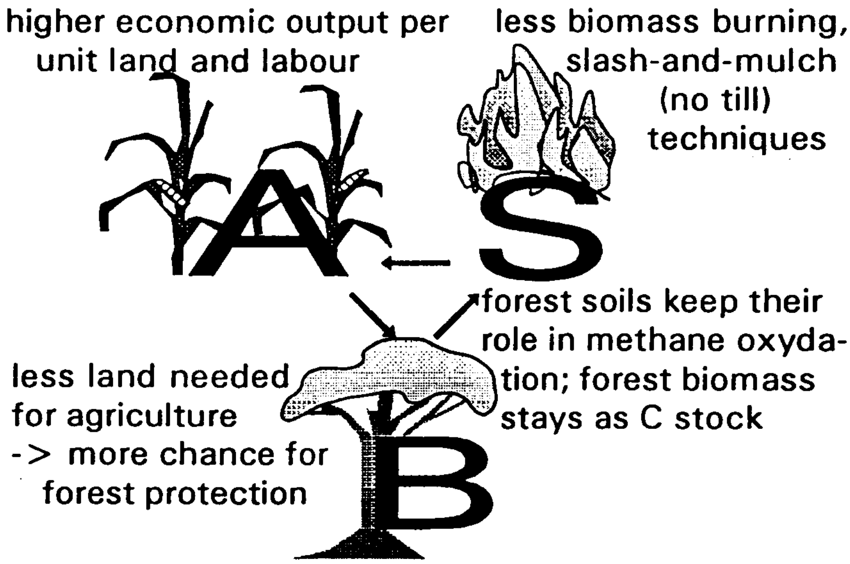
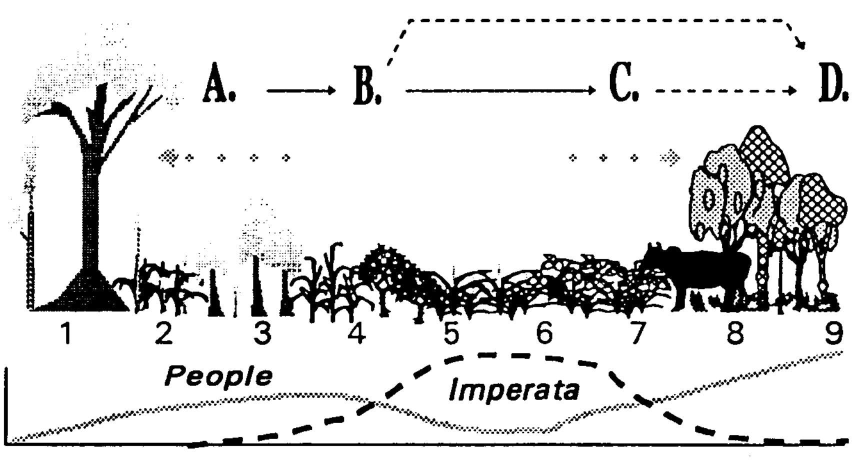


Figure 2. 'Intensifying' agriculture as a general solution.

We want to test the intensification hypothesis to determine the conditions under which it holds.

Figure 3. Stylized stages of land use change in Sumatra



A. Forest margin: slash-and-burn
B. Shorter fallows -> soil degradation
C. Imperata fire climax - people move out
D. Imperata rehabilitation via agroforestry

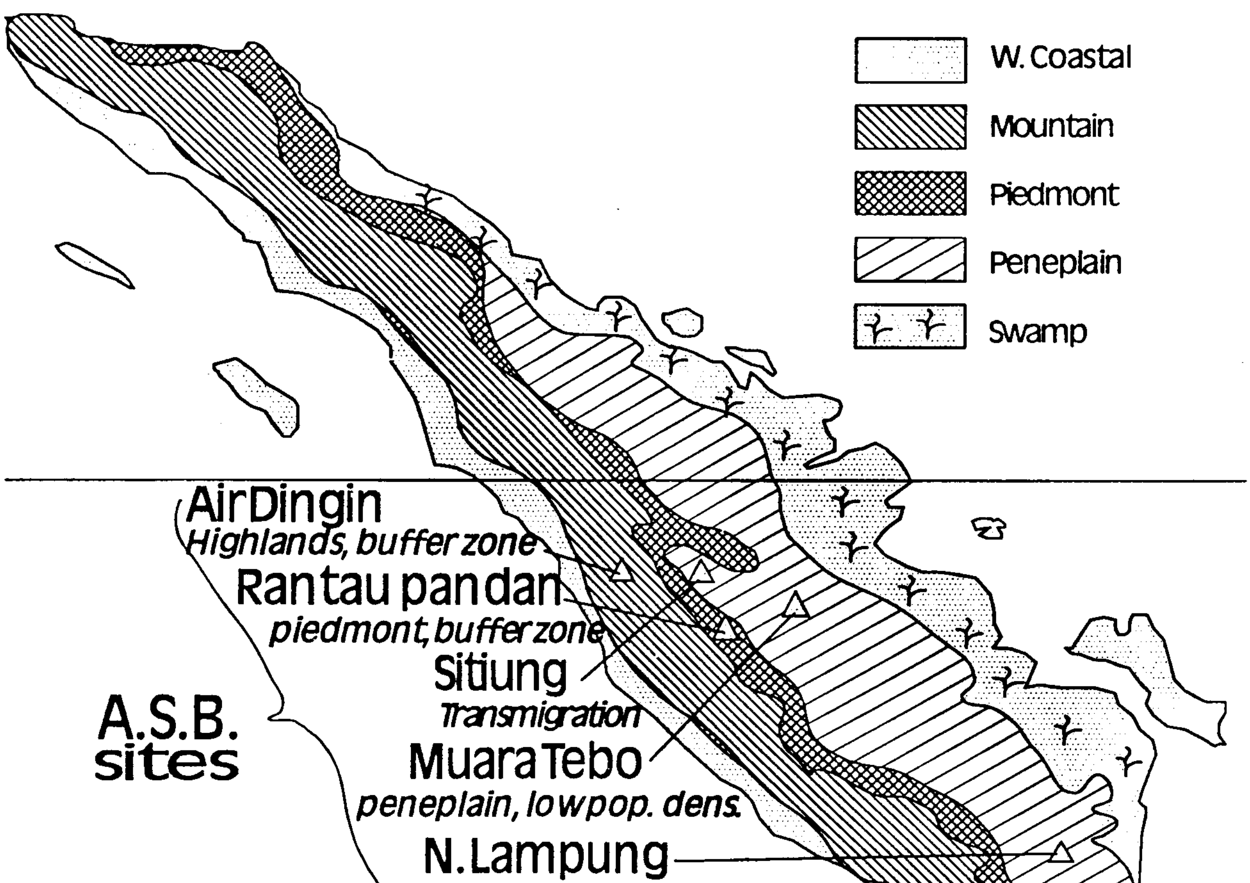
A highly simplified view of changes in land use in Sumatra proceeds through four stages (Figure 3):

A. initial conversion of natural forest in 'shifting cultivation',
B. a reduction of fallow periods under increasing local population pressure, leading to soil degradation,
C. land abandonment due to and followed by infestation with *Imperata cylindrica*, people move out,
D. rehabilitation of *Imperata* grasslands for intensive agroforestry and agriculture.

The ASB project in Indonesia is focused on two main issues:
the ***forest margin*** (stage A and B) and the possibilities to intensify land use without degradation (bypassing stage C on the way to stage D),
the ***degraded lands*** (stage C) and the possibilities for facilitating the intensification into stage D.

The ASB benchmark areas are chosen such that they represent a gradient in population density, from Lampung in the South, where stage C and D dominate, to Jambi where the 'forest margin' issues are prominent. We aim at testing the hypothesis that there is a direct link between the 'forest margin' and the 'degraded lands'.

Figure 4. ASB benchmark areas and agroecological zones in Sumatra



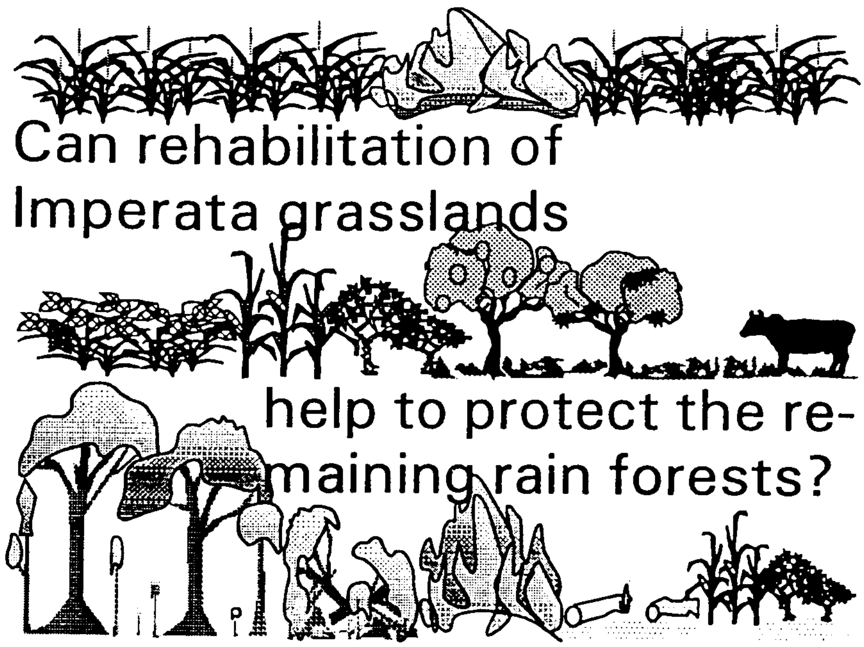


Figure 5. Exploring links between land rehabilitation and forest conservation

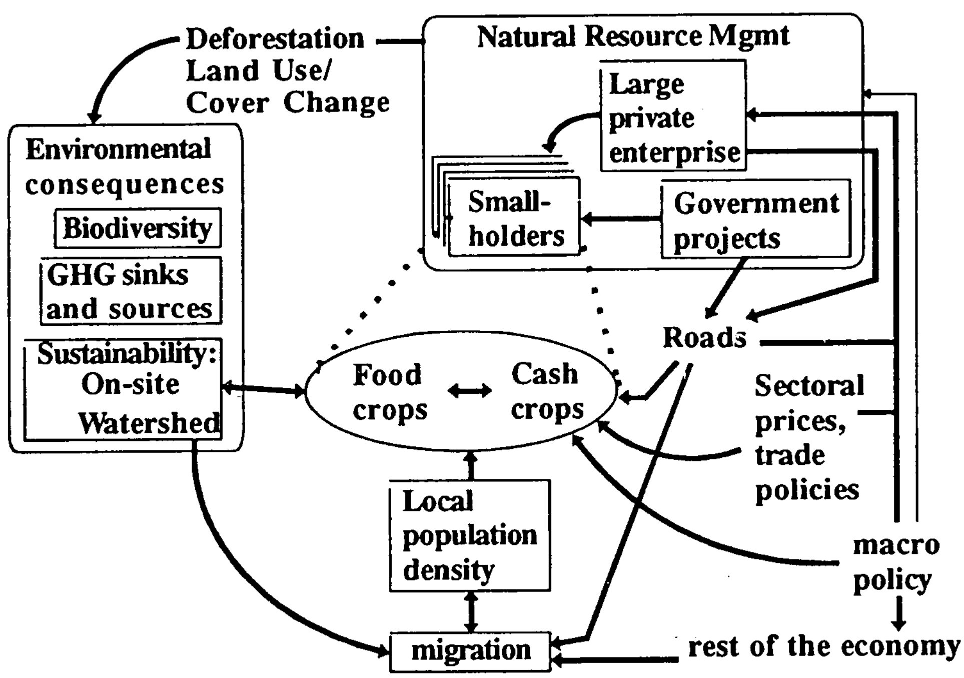


Figure 6. Forces driving deforestation

I.2. The Intensification Hypothesis

The search for 'alternatives' to unsustainable slash-and-burn derives from global problems (climate change; loss of biodiversity), but poverty reduction, household food security, and other more localized issues are central concerns of ASB too. Since many of the small-scale farmers practicing slash-and-burn appear to do so because they lack feasible livelihood options, development of sustainable land use practices that are viable alternatives to slash-and-burn could reduce deforestation.

The key hypothesis underlying the ASB project can be summarized as: **Intensifying land use as an alternative to slash-and-burn can reduce poverty, improve resource management in the uplands, *and* reduce deforestation.** Under which conditions is intensification a reasonable approach; under which ones is it not? There are at least three necessary conditions for validity of this '**intensification hypothesis.**'

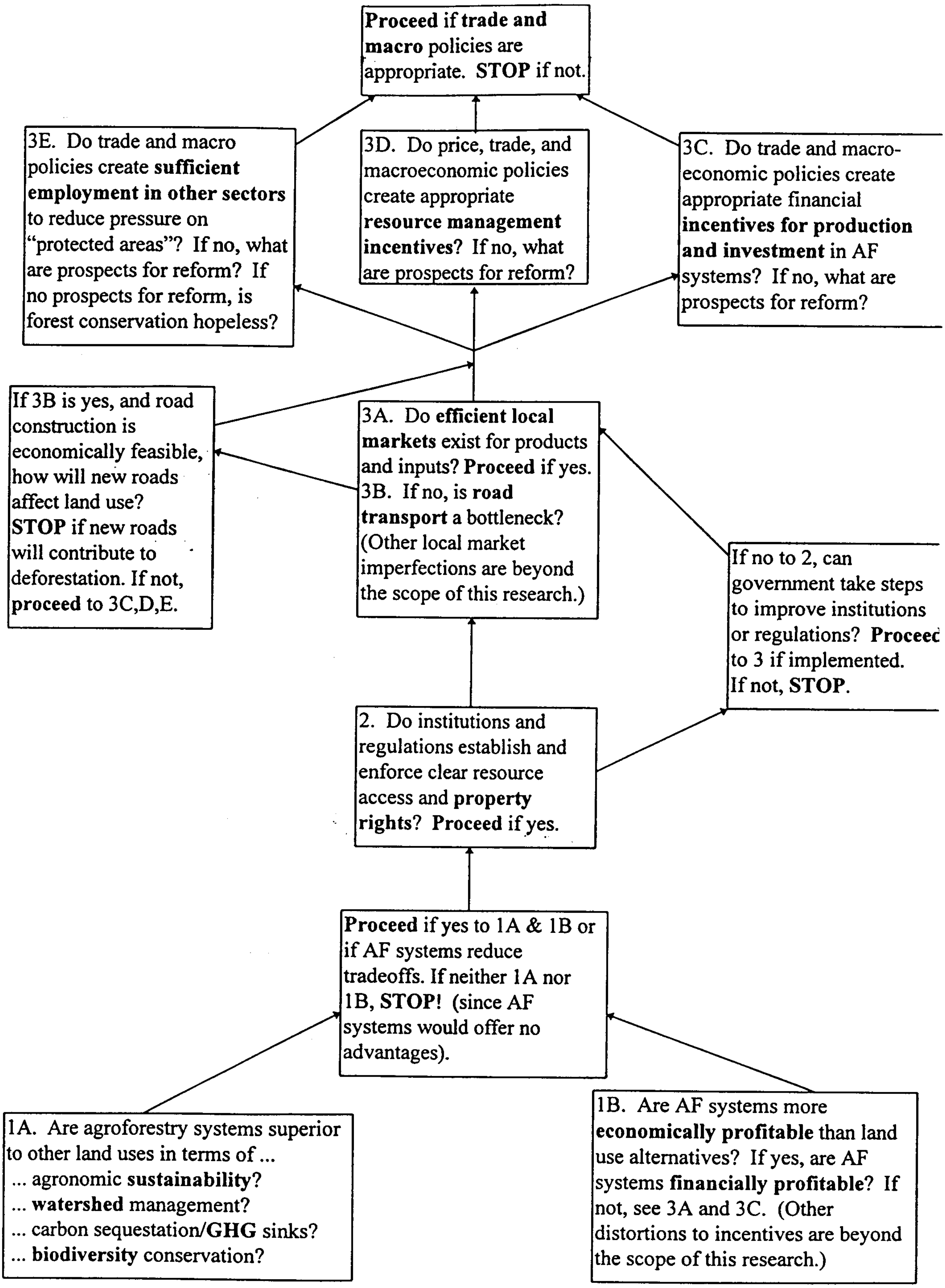
First, at the *field level*, intensification of land use must be ecologically and agronomically sound, socially acceptable, and financially profitable for smallholders. Raising productivity of existing **agroforestry systems** offers a promising intensification pathway. While conversion of primary forest has the major effect on the supply of forest functions, the subsequent land uses also matter a great deal for the supply of environmental externalities and public goods. Complex agroforests and land use mosaics involving agroforestry and other systems may approximate a number of these forest functions, thereby providing the technical foundation for community-based forest and watershed management. Quantification of these environmental consequences of deforestation and other land use changes is essential to formulating sound policy responses--or even in knowing whether intervention is needed.

Second, at the *community level*, **land and tree tenure** institutions--both formal and informal--are a key determinant of incentives (and disincentives) for sustainable resource management in SE Asia's uplands. Do formal and informal institutions and the regulatory framework create incentives that are compatible with sustainable resource management? In particular, do tenure institutions and regulations establish and enforce clear resource access and property rights? If not, what (if anything) can governments do to help improve functioning of tenure institutions?

Third, there also are **forces that drive deforestation** at the *national level*. In particular, an inflow of migrants facilitated by road construction and driven by lack of economic opportunity elsewhere can swamp the effects of field-level and community-level interventions. Priorities for future ASB research on national-level policy may be grouped in two sets: infrastructure investment, especially in road construction, and macroeconomic policies. As with agroforestry systems and tenure, the profitability of forest conversion by smallholders also is tied to decisions regarding public investment in infrastructure and macroeconomic policy instruments (exchange rates, monetary and fiscal policies).

In the beginning, ASB mainly emphasized the first requirement: getting the field-level conditions right. But many of the forces driving deforestation and natural resource degradation arise outside the forest and agriculture sectors. **One of the key results of the first phase of ASB research was greater recognition of the need to incorporate the second and third components in the ASB policy research agenda.** Think of this research programme as producing the knowledge base for a decision tree (Figure 7) to identify which policies and other elements are necessary conditions for the intensification hypothesis.

Figure 7. Decision tree for upland resource management



I.3. Intensification Pathways

The central ASB hypothesis refers to 'intensification' of land use, which in this context essentially means obtaining a higher total value of output per unit of land. Although land is only one of the factors in an analysis of 'total factor productivity', it plays a more direct role here as the land not used for agriculture can directly contribute to the 'biodiversity' values. A distinction may have to be made between situations where the intensification is essentially based on annual (food) crops, and situations where it is based on tree crops.

The literature on fallow systems largely comes from the agronomic side with a strong emphasis on the crop production aspects. A neutral definition of a 'fallow' is 'a piece of land that is not currently cropped, but has been cropped in the past and will be cropped again in the future'. The 'function' of a fallow to a farmer can come from two aspects:

- the fallow may improve subsequent crop yield (crop yields in the first year after fallow are generally higher than they would have been in the first year of the fallow if cropping had continued)

- the fallow vegetation gives directly useful products: grazing opportunities, firewood, specific tree products such as fruits, etc.

When we refer to 'improved' fallows, it can be based on an enhancement of the first function ('more effective fallows'), the second function ('more productive fallows') or a combination of the two.

'More effective fallows' should address the primary reasons why fallows improve subsequent crop yields at the given location. This reason can be:
- weed and pest control (annual and perennial weeds, nematodes and other soil borne pests),
- nutrient replenishment in the topsoil (increased N supply, modified P forms, cation relocation),
- reduction of aluminum toxicity,
- improvement of soil physical conditions (increased water storage, increased water infiltration, lower bulk density, improved structure).

Although some of these reasons may be linked (lower soil fertility makes weeds more competitive, increased soil organic matter contents may address both nutrient and soil physical issues, etc.), there may be a need for more site-specific diagnosis of which reason dominates under which conditions. As there are technical means to replace these fallow functions (herbicides, nematicides, fertilizer, mechanical tillage), the issue is here one of cost effectiveness, which depends on the relative costs and availability of labor, land and external inputs. Efforts to make fallows more effective are generally evaluated in terms of a *reduced fallow length* for the same effect on a subsequent crop. These 'faster' fallows can be based on:
- a more rapid establishment of a desirable fallow vegetation,
- replacement by the 'natural' fallow by vegetation which reduces weed and pest populations, builds up organic matter and/or recycles nutrients more rapidly.

As our 'control' here is simply 'abandoned land', the issue of how much efforts (labor, inputs) are needed to obtain this 'faster fallow' is critical. The example of legume cover crops (biologically superior but usually too much work and costs to be attractive) is a case in point. 'Improved fallows' of this kind will have to rely on plants which are really easy to propagate and get established.

Prolific seed producers, such as *Compositae*, have an advantage in this aspect. Another option is to purposely maintain rootstocks and stumps of desirable elements of the natural fallow during the cropping period and abandon the land before these stumps have died ('classical' shifting cultivation techniques). We have to consider two further parts of the cycle: land clearing and cropping period. The 'ease of clearing' is an important attribute of a fallow vegetation, because the labor demand of land preparation is of major importance. The fallow vegetation can become a 'weed' itself during the cropping period, especially the types with prolific seed production or persistent belowground organs.

'**More productive fallows**' primary add value to the fallow part of the cycle by replacing (part of) the natural vegetation by species with more valuable wood, more attractive fruits, higher nectar production etcetera. These systems have been termed 'enriched' fallows. The primary criterion is not the fallow length, but the fallow productivity. If successful components are found, the fallow vegetation may become the dominant part of the system and may be prolonged rather than shortened. Rubber and damar agroforests may have been perceived as 'more productive fallows' initially, but now the cropping period has become a secondary aspect of these systems. As the fallow vegetation has a direct value, it is economically justified to put effort in getting it established. Low cost establishment is not as important here as it is for the 'more effective' fallows.

A number of improved fallow systems may combine the two trends, but as trade-offs between the two functions are likely their further development may involve setting priorities.

Figure 8 gives a first attempt at a two-dimensional classification. On the X-axis it uses the R value of Ruthenberg: the length of cropping period as part of total cycle length. Standard terminology is: 'shifting cultivation' for $R<0.33$, 'fallow rotation' for $0.33 < R < 0.67$, 'permanent cropping' for $R > 0.67$ (N.B. Ruthenberg expressed R as a per cent, here we prefer expressing it as fraction). The R value refers both to the relative length of time and to the area of cropping. The Y-axis in the figure is the total output per unit land. The solid line refers to the standard agronomic intensification pathway, where output per unit land increases (although output per unit labor may decrease) while fallow periods are shortened and R increases. 'More effective' fallows will facilitate this transition and will generally push the system towards the upper right corner. 'More productive' fallows, however, represent a trend towards the upper left corner.

Table 1 has the same R-value as columns in a two-way classification, but uses the relative value of tree products for the rows, expressed as the $V_c / (V_c + V_f)$ ratio, where V_c is the value of the (annual) crop component and V_f the value of the 'fallow' or 'tree' component of the system. In this classification 'more effective' fallows refer to a shift to the right, 'more productive' fallows refer to an upward trend (lowering the $V_c / (V_c + V_f)$ ratio.

As a first attempt at characterizing the conditions under which the two trends are most likely to occur, we may speculate that the crop-based intensification (more effective fallows) is the primary option available in 'subsistence' and 'closed' economies, where local food production is of primary importance. The 'enriched fallow' trend may depend on markets for the products of the 'fallow' period and thus on participation in larger, more open economies, in which food can be obtained for cash.

Figure 8. Schematic relation between intensity of land use for cropping (Ruthenberg's R value) and total output per unit land; the classical agricultural intensification is indicated by the solid line, 'fallow enrichment' options are indicated by the broken lines.

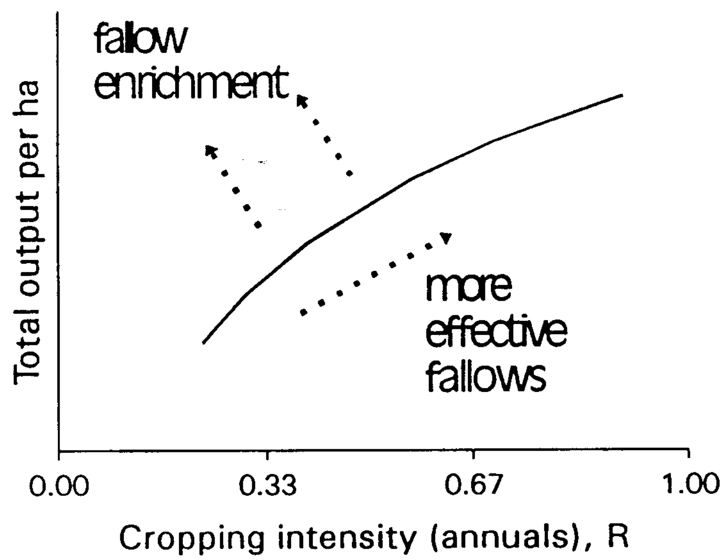


Table 1. Tentative classification of land use systems based on the relative area (or time) used for cropping (R) and the relative value of the products of the crop (V_c) and fallow (V_f) vegetation.

	$R < 0.33$	$0.33 < R < 0.67$	$R > 0.67$
$V_c / (V_c + V_f) < 0.33$	Agroforest Tree plantation Forestry	-	-
$0.33 < V_c / (V_c + V_f) < 0.67$	Enriched tree fallow	Enriched bush fallow	-
$V_c / (V_c + V_f) > 0.67$	Shifting cultivation	Fallow rotation	Permanent cropping

I.4. Rubber Agroforestry

Indonesia is poised to take first place in the world in natural rubber production. Rising wages already have reduced the competitiveness of producers in Malaysia and Thailand. Malaysia's production leveled off as a consequence; even Thailand's output seems about to reach its peak. But production costs on Indonesian estates are almost as high as Malaysia's estates and Thailand's smallholders, while production costs for Indonesian smallholders are much lower than all of these. In fact, Indonesian smallholders probably are the lowest-cost natural rubber producers in the world. So, in the future, Indonesia's competitive advantage in natural rubber production will derive mainly from its smallholders.

Smallholders already produce over 70 percent of Indonesia's natural rubber. Most of this comes from over 2 million ha of rubber agroforests (sometimes called "jungle rubber") in Sumatra and Kalimantan. These rubber agroforests are probably the most widespread complex agroforestry system in Indonesia. Besides being the key to Indonesia's future competitive advantage in natural rubber, a workable strategy to raise productivity of these rubber smallholders also could play an important role in poverty alleviation. Despite development in other sectors, increases in smallholder rubber productivity still can be an important engine of economic growth in regions of Sumatra and Kalimantan. The supply of workers continues to grow in these rubber-producing regions, while new land is getting scarce. Under these conditions, farmers will be eager to raise productivity if they have profitable options.

Rubber agroforests maintain a forest-like environment that retains biodiversity. A variety of products tend to be harvested in addition to latex, including many types of fruits and timber.

Although *Hevea* was introduced to Asia in the later decades of the 19th century, the first smallholder trees were probably planted around the turn of the century. Planting material spread through trade links that already existed for forest products such as damar, gutta percha, jelutung and rattan, as well as agricultural products such as copra and pepper. Introduction in Sumatra started in Jambi and expanded rapidly into the southern and western sections of the island.

Rubber prices boomed in 1909-1912, which led to rapid planting. With minor ups and downs, growth continued smoothly until about 1930. The colonial government had no idea about the rapid spread of rubber trees until the market was flooded with smallholder output. Recorded smallholder production increased from 150 tons in 1912 to 128 000 tons in 1925. By that time government policies attempted to discourage smallholder rubber production in order to support prices for estates.

European planters initially thought that rubber could only be grown under intensive management and clean weeding, that tapping required utmost care not to kill the trees, and that processing of the product needed special skills. The large-scale planters were wrong on all three points. Smallholders, however, quickly had learned that *Hevea* is very amenable to extensive management systems. Rubber trees fitted easily into the existing *ladang* (shifting cultivation/slash-and-burn) system. Smallholders simply planted some rubber trees in the first upland rice crop (often but not always followed by a second rice crop) and left them to grow with the fallow vegetation (*belukar*).

Rubber agroforestry systems are unique among rubber development options because they offer opportunities to provide a wide range of benefits to smallholders, processors, and the nation. This package includes greater income and employment for smallholders, expanded business opportunities for processors, a focal point for regional development, larger non-oil exports, and environmental benefits, including conservation of biodiversity.

But these important opportunities are being missed. Although smallholders are planting a lot of rubber on their own, most lack adequate access to improved planting material suited to their conditions. In the places where such planting material is available, farmers need more practical information on how to use it best.

Despite years of effort to provide smallholders full technical packages through development projects based on rubber monoculture, these have reached only about 13% of the farmers (Table 2). An additional 10-20% of the smallholders in the vicinity of these projects have had indirect benefits through technical information and improved planting material. But as the typology of rubber smallholders in Table 2 shows, some 75% of the farmers have not had access to improved systems and, as a result, continue to be locked into low yields averaging about 600 kg dry rubber/ha/year for mature trees.

Over time, these missed opportunities will threaten Indonesia's competitive advantage in natural rubber. Just as in Malaysia and Thailand, higher wages will come with Indonesia's successful economic development. If there is no increase in smallholder productivity to offset rising labor costs, the low-cost advantage of Indonesia's smallholders will evaporate and so will its natural rubber industry.

Table 2. Typology of smallholder rubber farmers In Indonesia

Class	Situation	%	System
1	Government projects	13	Estate-like monoculture
2	Non-project but good access to markets, credit	12	More intensive rubber agro-forestry; tendency towards monoculture
3	Moderately isolated	50	Jungle rubber, some improved management
4	Isolated, no access to credit, extension	25	Jungle rubber

Source: Penot, 1995.

Sustained success with agricultural exports requires a long-term commitment to invest in research and development in order to increase yields and reduce production costs. For example, when its share of the rubber market was threatened by synthetics in the 1950s, Malaysia acted to retain its competitive position. At that time, almost half the area of its estates and 2/3 of its smallholdings were planted with trees over 30 years old. An ambitious programme of research, replanting, and rural development transformed the situation. Malaysian natural rubber output grew more than 150%

from 1955 to 1988, despite competition from synthetics abroad and rising wages at home. Thailand employed a very different rubber development strategy, suited to its smallholder sector and institutional capabilities, to overtake Malaysia. Now rubber agroforestry presents an opportunity--and challenge--for Indonesia to develop its own strategy suited to its unique conditions.

To date, Indonesia's smallholder rubber development efforts have met with little success. Block-planting projects of the 1970s and 1980s, including project management units (PMUs) like SRDP and PRPTE as well as nucleus estate schemes (NES/PIR), were intended to produce large increases in yields. Achievement of the high yields necessary to justify the costs of block planting depended on application of purchased inputs at levels better-suited to large estates than to smallholders. By the mid-1980s, it already was apparent that high-cost block-planting projects had proved difficult to implement in Indonesia and had benefited only a small fraction of rubber smallholders. Moreover, Indonesia's economic situation had changed because of declining oil prices, which forced cuts in the development budget. About the same time, agricultural development projects began to fall from favor as international donors shifted their attention to environmental concerns. As a result, rubber development programmes withered.

Indonesia's tight government budget constraints make it more important than ever to develop a feasible alternative to the costly block-planting strategy. Programmes aimed at gradual productivity growth in rubber agroforestry systems seem to hold potential for productivity gains at a small fraction of the cost of block planting. Furthermore, the environmental benefits of rubber agroforests make projects aimed at development of these systems attractive to international donors. In short, compared to block-planting, rubber agroforestry programmes should put less demand on the government budget while being more likely to attract substantial funding from international donors.

An unfortunate feature of the block planting strategy that Indonesia pursued in the 1970s and 1980s was that almost all of the limited supply of improved planting material available for smallholders was restricted to project participants. Improving the supply of higher-yielding planting material and providing farmers with practical information about its use should have key roles in any smallholder rubber development programme, including one aimed at rubber agroforests. Various approaches already have attempted to improve planting material supplies for smallholders on a pilot scale, including efforts by local authorities in Jambi Province. One of the main lessons from these pilot projects is that planting material programmes need to pay attention to demand as well as supply. Since such a large proportion of smallholder rubber area is still under trees grown from unimproved seedlings, projects have taken for granted that there is a big potential demand for higher-yielding planting material. Indeed, some unassisted farmers have started replanting with improved materials. For instance, in parts of Sumatra it is common for farmers to buy improved rubber planting material, usually in small quantities obtained from small private nurseries. Elsewhere, however, smallholders' lack of awareness of these opportunities or lack of information on how to achieve the benefits of planting higher-yielding rubber may mean actual demand falls far short of apparent potential. Social marketing techniques may be a cost-effective means to address these problems by using mass media and other marketing channels to provide farmers with technical information they need to choose material that is appropriate to their economic circumstances and to help them to put it to its best use.

Figure 9. Development of jungle rubber systems over time

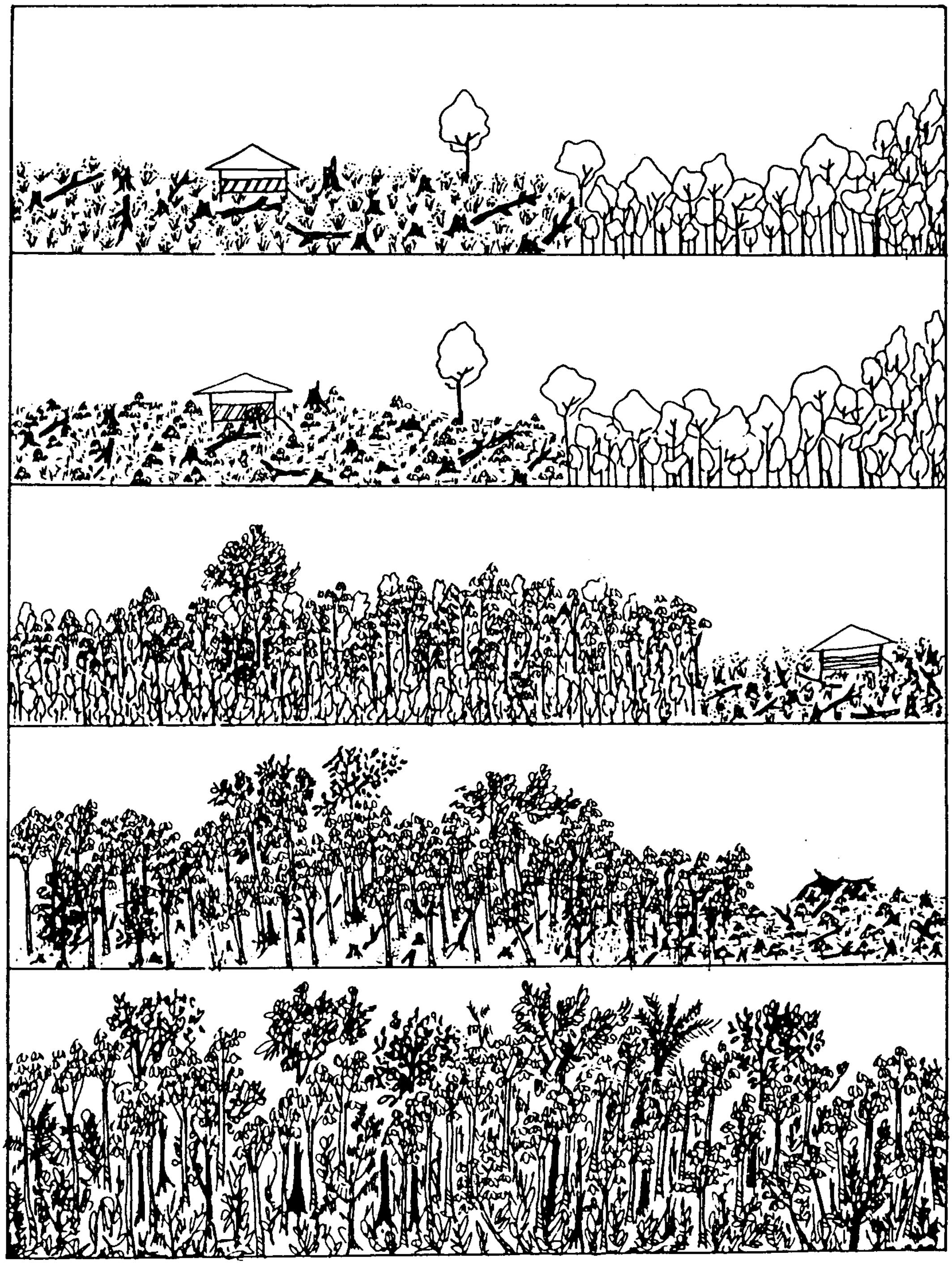
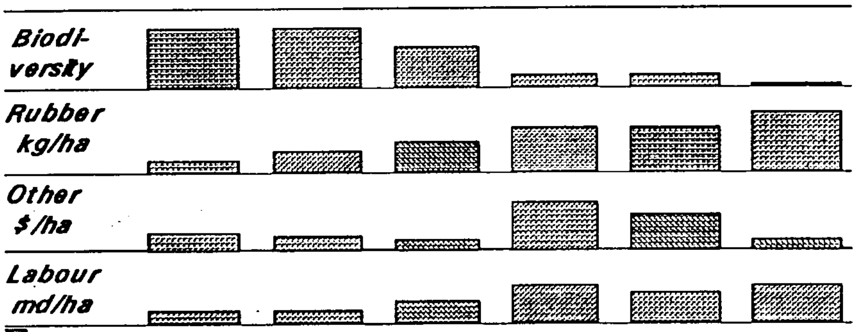


Figure 10. Terminology used for Rubber Agroforestry Systems (RAS) and their tentative characteristics

RAS	0	4	1	3	2	x
	←--- Jungle rubber ---→			←---Rubber plantation ---→		
	existing	gap replant	whole field replant	+ fruit/timber trees + extended food crops	+ shrub cover crops	monoculture + LCC



ΣOutput/ha	+	++?	++	++++	+++	+++
ΣOutput/md	++	++	++	++	++	++
ΣOutput/$	+++	+++	++	++	++	+/++

RAS	0	4	1	3	2	x
	←--- Jungle rubber ---→			←---Rubber plantation ---→		
	existing	gap replant	whole field replant	+ fruit/timber trees + extended food crops	+ shrub cover crops	monoculture + LCC

Strong points	biodiversity				high yields per ha	
Weak points	low production				weeds in year 3-6	
Researchables	-	Survival and performance of 'improved' rubber		Spacing/density tree-tree interactions Food crop prod.	Imperata control	-
Priority for ICRAF	*	**	***	**	**	-

Research on rubber agroforestry systems
Since much of the funding for rubber research has come from plantations, important scientific questions regarding application of improved technology in smallholder settings have not received adequate attention. Indeed, there is little scientific evidence on performance of improved rubber planting material under the conditions faced by roughly 75% of rubber smallholders in Indonesia. Filling this research gap is of crucial practical importance since productivity growth in rubber agroforests depends on adaptation of higher-yielding planting material to these complex agroforestry systems. There is reason to believe that rubber yields could be increased substantially by planting these materials with only minor increases in labor and inputs. Two broad classes of research questions deserve priority.

* For specific agroecological and socioeconomic conditions, which among the higher yielding rubber planting materials that are available produces the highest payoff for smallholders?

* What are the effects of productivity increases on biodiversity of rubber agroforests?

Agronomic trials and economic analysis concerning the first question can provide the foundation for new smallholder development programmes aimed, for the first time, at rubber agroforestry systems. The methods to design and conduct trials to identify improved planting material are well-understood as are the appropriate economic tools; the main barriers to research on the agronomic and economic aspects of rubber agroforestry are institutional. In particular, there is no clear mechanism for funding national research on smallholder rubber agroforestry in Indonesia. On the other hand, methods to predict the impact of productivity increases on biodiversity still must be developed.

The trials will be targeted according to three rubber agroforestry systems (Penot, 1995; Figure 10). The first system (RAS 1) will address the performance of certain improved planting materials within the current jungle rubber management system with little outlay for purchased inputs. The second system (RAS 2) will investigate the direct establishment of complex agroforests through combinations of rubber and other perennials (fruit, nut, and timber species), in which the compatibility of the species combinations will be an issue. In the third system (RAS 3), the complex agroforestry framework of rubber and associated trees is the same but there will be no food intercropping. Instead, combinations of covercrops, shrubs, and fast-growing trees will be developed as a means of weed control. In terms of agroecological conditions, RAS-1 trials are targeted to forest margins where there is an adequate supply of natural species propagules to regenerate a secondary forest-like environment. RAS-2 and RAS-3 research is targeted toward the *Imperata* grasslands, where natural forest regeneration will not occur, and the species mix in the agroforestry system must contend with the highly-competitive grass.

I.5. Segregate or Integrate for Biodiversity Conservation?

Human use of biotic resources ('agriculture' in its widest sense) and biodiversity ('nature' in its widest sense) are both needed by society at large, but there are generally conflicts between these two aspects of 'land use'. Conflicts between 'nature' and 'agriculture' can be solved in two ways:

- by *segregating* nature and agricultural land; maximizing agricultural production on a relatively small part of the land will leave as much land for nature as is possible
- by *integrating* nature and agricultural land use by intensifying production as little as strictly necessary and so maximizing the biodiversity value of land under human use.

Mixed solutions may exist as well, but the area available for complete protection of biodiversity decreases when agriculture remains below its potential productivity under the integration option. Both options have strong advocates, and it is not clear which solution is optimum under which conditions. Objective criteria are needed for distinguishing which solution may best meet the multiple goals formulated under different circumstances.

High expectations exist that 'agroforests' are an intermediate intensity land use form in the tropics that can help to conserve biodiversity while allowing sufficient production of economically attractive crops, such as rubber or resin (damar). Agroforests contain considerable biodiversity value, as their planned biodiversity of planted trees is augmented by naturally invading species of the original forest. It is not enough, however, to state that such agroforests represent a vastly higher biodiversity value than more intensively managed tree crop monoculture systems. If productivity of the monocultures is substantially higher, it might allow a large(r) area of natural forest to be conserved and, under certain conditions, this might satisfy the biodiversity agenda to a larger degree. We need a quantitative criterion to evaluate the two options.

A theoretical analysis suggests that a criterion can be formed on the basis of the 'internal' *biodiversity* value of a land use system, relative to the potential biodiversity which can be obtained by a 'conservation' strategy for the same unit of land, and the *productivity per unit land* relative to the potential productivity which can be obtained by a full 'production' strategy. For resource use systems where the relative biodiversity is larger than the relative productivity, an 'integration' pathway may be best. If systems with intermediate productivity are associated with a less than proportional biodiversity, the best solution will be to segregate and maximize production on a small area.

This analysis follows similar lines as the classical 'replaçement series' approach to intercropping. By comparing various mixtures of two plant species one can identify the combinations where the 'relative yield total' (RYT) exceeds 1 (Figure 11). We now broaden this to an approach of 'multifunctionality' of land use systems and define under which conditions combining the elements responsible for the various functions has advantages and where not.

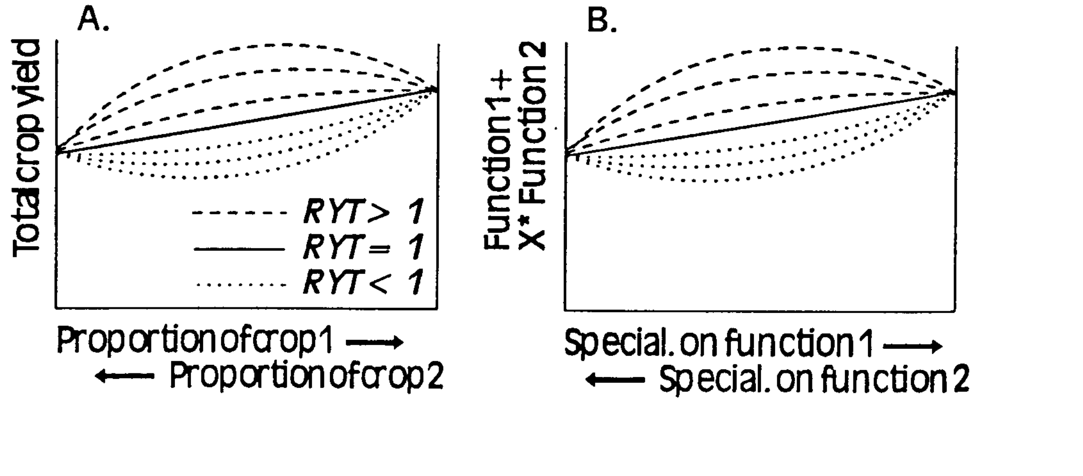


Figure 11.

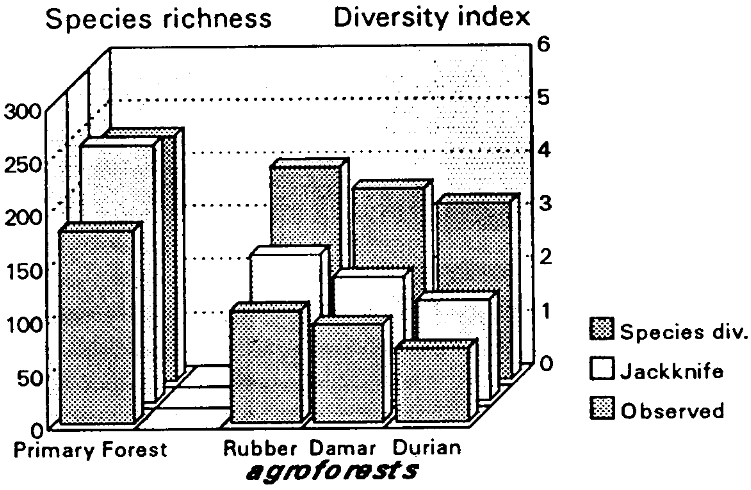


Figure 12. Agroforests and bird conservation in Sumatra (Thiollay 1995)

Most food-crop based production systems probably fall in the category where 'segregation' is the best solution, as annual plants will not grow well unless major changes in the vegetation (such as 'slash-and-burn' activities) have been made, to reduce competition. If systems with intermediate productivity allow a more proportional biodiversity, 'integration' will be the best solution, based on the lowest degree of intensification which still meets the total productive demand. From the evidence available, the jungle rubber as found in the lowlands of SE Sumatra in comparison with the best available approximation of 'primary forest' has about equal biodiversity for soil mesofauna, very similar lists of observed mammals, 30% less species of higher plants and 50% less species of birds (Figure 12). Jungle rubber yields are still about 500 kg ha^{-1} y^{-1}, but monocultures can reach 2 000 kg ha^{-1} y^{-1} (or even more) under research station conditions and at least 1 500 kg ha^{-1} y^{-1} in commercial practice.

At current production levels the evaluation depends on the relative weight one attaches to the various components of biodiversity, as it is either a borderline case, or a system where an 'integration' pathway may indeed be the most attractive one. A choice between the 'integration' and 'segregation' pathway should also be based on likely future developments. Most of the biodiversity in the agroforest does not result from a deliberate choice of the farmers to conserve biodiversity per se, but is more the logical consequence of structural features of the agroforest and of associated management practices. The main incentive for establishing an agroforest is economic and is closely linked to the market economy. Biodiversity results from two types of dynamics. One is semi-intentional, deriving from planting a combination of useful species to create a 'multipurpose tree stand' (not necessarily consisting of 'multipurpose trees'). The other one is accidental, the establishment of a diversified flora and fauna as in any sylvigenetic process.

If rubber germplasm with a higher production per tree can be integrated into the system without much need for additional 'weeding' or other measures reducing biodiversity, farmers' choices are likely to stay with the 'jungle rubber' version, until land becomes scarce and higher valued. Continuation of the system will also be favored by good markets for other components, such as rubber wood, fruits, etc.

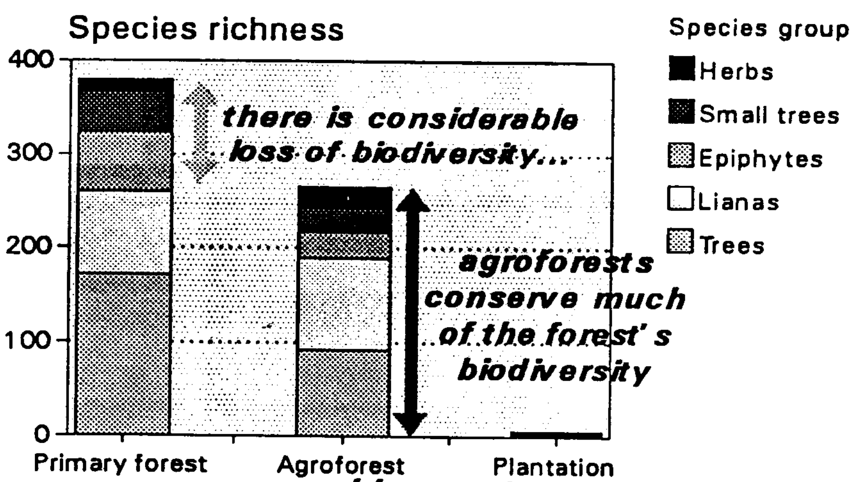
In Sumatra, efforts to conserve large national parks tend to concentrate on the mountain zones (e.g. Kerinci Seblat National Park and the Gunung Leuser National Park) while little of the rich lowland forest has been effectively protected. Allowing some utilization of highland park areas while protecting more of the lowlands would probably increase conservation efficiency, while allowing the same number of people to achieve a similar livelihood level. In the near future we hope to quantify such choices based on more specific data for the area.

What about the 'real world'?
More complex models will be needed for dealing with the social and economic costs of both the 'segregate' and the 'integrate' option, and with heterogeneity in both agricultural and biodiversity value of land classes. In view of the irreversibility of biodiversity reduction during intensification of land use, a choice for 'segregation' should not be postponed until little biodiversity remains. The impression so far is that for foodcrop-based production systems the segregate option may be best, but that for tree-based systems the outcome can be either way and more data are needed.

The myriad constraints and the more nuanced objectives of the 'real world' are likely to produce a richer mix of solutions than appear in this heuristic model. Which among these issues are likely to shift the balance most between the extremes of 'segregate' and 'integrate'? Constraints in public funds and in administrative capacity are two important practical considerations. By design -- but also by default -- these constraints will tend to favor 'integration' over 'segregation' simply because the latter requires more funds and more intensive administration.

Because *any* conversion from primary forest entails significant decline in biodiversity (Figure 13), conservation reserves always have an important potential role in biodiversity conservation. The extent that this is feasible depends on the existence of institutional arrangements and policy mechanisms for monitoring and enforcing primary forest boundaries. Bufferzone agroforestry does not seem to be sufficient in a setting like Sumatra: profitable agroforestry technologies may even induce forest encroachment under certain conditions. Until a lot more is known about effective implementation of incentive schemes and/or regulations that involve acceptable financial and social costs of monitoring and enforcement of forest boundaries, 'integration' will be the default outcome and the primary forests that survive will be residuals of the conversion process rather than planned reserves.

Figure 13. Two perspectives on higher plant biodiversity in agroforests



I.6. Trade Policy, Poverty, and the Environment: The Case of Rubber Wood

Export potential of rubber wood

The world price for rubber wood has increased since the late 1980s because of rapid depletion of ramin wood in the natural forests of Southeast Asia. As a result, the wood of rubber trees has emerged as an important by-product of natural rubber production. **Indonesia could be a big rubber wood producer because it has the world's largest stock of old rubber trees. Yet Indonesia lags the other two major natural rubber producers in utilization of this resource.** In 1993, Thailand made use of over 80% of its available rubber wood (exporting it under labels like "white teak" and "Thai oak") and Malaysia used more than 60%, while Indonesia was using (at most) only 27% of its potential supply.

Most of Indonesia's rubber wood goes up in smoke when smallholders cut old rubber trees to clear land for replanting. Although large-scale rubber plantations also use this 'slash-and-burn' technique to clear land, a growing portion of the rubber wood from large estates now is being processed instead of burned. Some of this rubber wood is used to manufacture fiber board while choice pieces can be sawed into high-value lumber that is a substitute for ramin, which is among the most valuable timbers. Large-scale plantations have a number of technical advantages over smallholders as rubber wood suppliers, especially for processors of higher-value sawn wood. Better infrastructure and economies of scale also make it more profitable for processors to focus on plantations for their rubber wood supplies. Despite these technical disadvantages, there are viable marketing opportunities for smallholder rubber wood, especially as raw material for medium density fiber board (MDF) and plywood core. **Small-scale, mobile processing equipment now is available that has improved the economics of smallholder rubber wood, even for choice sawn wood.**

Benefits of marketing rubber wood as an alternative to burning it

Poverty reduction and smallholder development. Rubber wood sales can generate economic benefits for smallholders, who produce 70% of Indonesia's rubber and operate an even greater proportion of the old rubber trees. Rubber typically accounts for 60% of the standing trees in the so-called 'jungle rubber' systems that predominate in Sumatra and Kalimantan. If they can sell this rubber wood when it is time to replant, farmers can cover costs of land clearing and still net Rp 500,000 or more in cash per hectare--even under current policies. It will not be feasible to market all smallholder rubber wood; much simply is too isolated. But **where marketing is feasible, revenue from rubber wood sales can cover at least half of the costs of higher-yielding planting material and other inputs that dramatically increase future income for smallholders.** (Farmgate prices of rubber wood vary depending on distance to markets, transport costs, and the local levies discussed below.).

Environmental benefits. Burning rubber wood releases carbon dioxide and methane, which are 'greenhouse gases' linked to global warming. **Each year, burning rubber wood in Indonesia releases emissions equivalent to over 5 million tons of carbon dioxide.** (This includes the 'greenhouse gas' effect of methane, which is 25 times the effect of carbon dioxide.) Although these emissions from burning rubber wood are insignificant compared to greenhouse gases released by deforestation, the smoke from these fires can be a highly visible nuisance.

Trade policy barriers to rubber wood marketing

Rubber wood exports -- and the opportunity they offer to increase smallholders' incomes while providing environmental benefits -- continue to fall short of their potential because of local and national policies that inhibit marketing.

Export taxes. Export taxes are applied to rubber wood as one among a group of woods, including species that occur in natural forests. The world's major source of natural rubber (*Hevea brasiliensis*) is native to the Amazon. In Indonesia, most of this natural rubber was planted by smallholders, some was planted by large-scale estates, and *none* occurs in natural forests. **Indonesia's prohibitive export taxes on sawn timber and logs are intended to promote downstream processing of forest products. Rubber wood, however, is a by-product of land clearing for replanting of tree crops. If this wood cannot be marketed, it is wasted.**

Local levies and trade restrictions. Local levies and restrictions on purchasing rubber wood from smallholders have proliferated in Sumatra and Kalimantan. In Jambi, a nine-step administrative procedure required *each time* a company wishes to purchase rubber wood from a smallholder is a bigger barrier than the local levy of Rp 5,000/cubic meter on rubber wood. **This administrative burden combined with confusion from frequent changes in regulations results in an effective ban on purchases of smallholder rubber wood.**

These and other local levies and provincial-level trade regulations retard development of rubber wood markets. It is no surprise that only one rubber wood factory remains of three that started in Jambi or that it obtains its raw materials from large-scale estates in North Sumatra and South Sulawesi instead of Jambi smallholders. For similar reasons, the only rubber wood factory in West Kalimantan now is operating at only 30% capacity and several rubber wood factories in South Sumatra have closed.

The levies and restrictions stem, in part, from concern that processors will exploit smallholders, enticing them to cut their rubber trees prematurely. **There is no evidence to support this official anxiety that smallholders will cut young rubber trees to sell them for wood. In fact, the available evidence indicates that official fears are groundless and local trade restrictions are *not* required to protect smallholders.** ICRAF's analysis of the economics of replacing rubber trees at different ages indicates that farmers are unlikely to cut rubber trees for wood before trees are 25 years old. This is consistent with the results of other researchers. For example, a survey in Lampung showed the average age of rubber trees cut for wood was 27 years and only 16 percent of respondents reported cutting trees less than 20 years old (with the average age of trees for that group being 19 years).

Farmers do not cut young rubber trees. Instead they wait until yields are low and the number of trees on the plot has decreased. In any event, it is the older rubber trees that are valuable to processors, who are free to buy wood from large-scale plantations anywhere in Indonesia. **Local levies and trade restrictions that increase the costs processors face in purchasing rubber wood from smallholders are (unintentionally) biased in favor of large-scale plantations. These policies reinforce the plantations' technical advantages over smallholders as rubber wood suppliers.**

I.7. Highlights from ASB Phase I

For a more detailed account of results of Phase 1 of the ASB project in Indonesia, we refer you to the 'Summary Report', with the following contents:

Section II. ASB Research in Jambi

II.1. Overview of ASB Benchmark Areas in Jambi

Agroecological zones

The island of Sumatra was chosen to represent the humid tropical forest zone in Asia for the global ASB project. Within Sumatra five major agro-ecological zones (Figure 4, page 3) are identified with boundaries running from NW to SE approximately parallel to the coast:

1. a narrow Western **coastal zone,**
2. a **mountain zone**, dominated by andosols and latosols of reasonable to high soil fertility
3. a narrow **piedmont (foothill) zone**, the lower slopes of the mountain range on the NE side, dominated by latosols and red-yellow podzolics;
4. a broad **peneplain zone**, almost flat land with Tertiary sediments, deposited in the sea; at present its altitude is less than 100 m above sea level and it consists of about 10% river levees and floodplains with more fertile alluvial soils and 90% uplands with a gently undulating landscape and mostly red-yellow podzolic soils
5. a **coastal swamp zone** with peat and acid sulphate soils

Population and regional migration

A clear gradient in population density occurs from Lampung Province in the south (174 people per square km in 1993) to Jambi Province in the middle of the island of Sumatra (39 people per square km in 1993). Because they contain the most fertile soils, the Western coastal plane, mountain zone, and the piedmont have been inhabited for long periods of time. Historically, the peneplain was inhabited sparsely with human population concentrated along the river banks on relatively favorable sites. With the advent of rubber a century ago, population spread in the peneplain but still was tied to the pattern of river transport. After the completion of the Trans Sumatra Highway in the 1980s, Jambi has become a popular destination of migrants. Since many 'spontaneous migrants' or 'forest squatters' are unrecorded, the official statistics on annual population growth rates in the Jambi benchmark area may be too low (Table 3).

Biophysical characteristics of the Jambi sites

Five Sumatran sites were chosen for detailed characterization for the ASB project, including two sites in Jambi Province. **The Bungo Tebo site is a dissected peneplain,** consisting of acid tuffaceous sediments, generally below 100 m.a.s.l. The **Rantau Pandan site ranges from 100 to 500 m.a.s.l. and represents the piedmont zone**, which was built mainly by granite and andesitic lava. Soils in Bungo Tebo are very deep, well drained, very acid, and have low soil fertility status. Soils in Rantau Pandan are more varied and complex, ranging from shallow to very deep, moderate to fine in texture, well to moderately-excessively drained, but also very acid and have low soil fertility. Both Jambi sites average 7-9 wet months (> 200 mm rainfall) and less than 2 dry months (100 mm rainfall) per year, with annual rainfall in the range of 2100-3000 mm.

Jambi's economy

Forestry and the rubber processing industry (crumb rubber) contributed virtually all (99%) of the exports from the province in 1993. In the rubber industry, smallholder rubber plays a crucial role. The total area of rubber cultivation in Jambi in 1993 was 502 642 ha, of which only 3 447 ha was planted with high-yielding varieties under intensive management and the rest was 'jungle rubber' (rubber agroforests).

Table 3. Population

	Jambi Piedmont Rantau Pandan 1983	1993	Δ%	Jambi Peneplain Pelepat 1993	Tebo Tengah 1983	1993	Δ%	Jambi Province 1983	1993	Δ%
Population	19636	22543	12.9	17962	30380	34325	11.5	1572701	2099489	33.5
Area, km^2	820	820	0.0	1022	3000	2841	-5.6	53435	53435	0
Density (# km^{-2})	24	27	11.1	18	10	12	16.7	29	39	34.5
Population Growth rate (%/yr) 1983-1993				1.39				1.23		2.93

1. No data for 1983, as boundaries changed; Pelepat was still part of Muarabungo subdistrict in 1983.
Source: BPS Jambi 1983 and 1993.

Table 4. Survey Respondents by Site and Stratum

Benchmark Area	Local Farmers		Transmigrants		Spontaneous Migrants		Total	
	n	%	n	%	n	%	n	%
Rantau Pandan	37	100	0	0	0	0	37	23
Bungo Tebo	37	29	32	25	57	45	126	77
Total	74	45	32	20	57	35	163	100

Table 5. Migration to Jambi sites

Benchmark Area	Years of Residence of Family Head (%)			Birth Place of Family Head (%)			Reason Moved					
	0-5	5-15	>15	Same District	Different District in Sumatra	Java	Get New Land	Get Better Life	Hard Life in Orig'l Home	Join Rela-tives	Re-settle-ment	Other
Rantau Pandan												
Local People	3	8	89	100	0	0	-	-	-	-	-	-
Bungo Tebo												
Local People	5	14	81	100	0	0	-	-	-	-	-	-
Transmigrants	0	97	3	6	0	94	19	28	3	6	38	6
Spontaneous Migrants	39	28	33	11	7	82	24	44	0	26	0	6

Table 6. Household characteristics

Benchmark Area	Household Size (persons)	Age of Head of Household (% of hholds)			Education of Household Head (% of hholds)		Working in:	
							Agriculture	Non-Agriculture
		<30 years	30-40 years	>40 years	<6 years	>6 years	%	%
Rantau Pandan								
Local People	4.2	19	22	51	73	27	100	8
Bungo Tebo								
Local People	5.6	22	35	25	95	5	100	3
Transmigrants	4.8	16	47	32	72	28	97	75
Spontaneous Migrants	4.5	28	26	38	83	17	98	7

ASB characterization surveys

Five institutions in the ASB-Indonesia Consortium collaborated with ICRAF staff to adapt the ASB global characterization guidelines for research in Sumatra. This process yielded two instruments that have been used for fieldwork on land use and socioeconomic characterization. One instrument is a structured questionnaire for use in a stratified random-sample survey of households. The three strata are: local farmers, spontaneous migrants, and government-sponsored transmigrants (Table 4). (The other instrument is an informal checklist for open-ended discussions as part of community-level appraisal.)

- **Local people at the Rantau Pandan (piedmont) site.** Virtually all the residents of this site are local people; there are very few spontaneous migrants and no transmigrants. 97% of the land in Rantau Pandan sub-district is categorized as state forest land. However, "forest status" was declared long after local communities had already settled here. In practice, a large part of the forest land outside the Kerinci Seblat National Park is used for rubber agroforests and other forms of agriculture.

- **Local people at the Bungo Tebo (peneplains) site.** Senamat and Muara Kuamang villages in Pelepat Sub-district represent the local farmers of the Jambi ethnic group. The original Jambi villages are located along the Pelapat River and the Tebo River as river transport used to be dominant and because soils along the river tend to be better.

- **Spontaneous migrants at the Bungo Tebo site.** Mangun Joyo village in Muara Tebo Sub-district and Lubuk in Pelepat Sub-district have a high proportion of spontaneous migrants (ethnic Javanese, many of whom resettled here from Lampung). Residents of Lubuk migrated decades ago, first to work as rubber tappers later establishing their own rubber trees. Presence of the spontaneous migrants in Mangun Joyo is closely linked with logging activities. These migrants gained access to the forest via logging roads and their plots are quite isolated.

- **Transmigrants at the Bungo Tebo site.** Purwosari, Bangun Hardjo and Abuaran Bungo Tebo in Muara Tebo Sub-district represent transmigration villages that were settled over a decade ago as part of the government-sponsored Kuaman Kuning transmigration project. Settlers had to follow the project plan for five years, which emphasized foodcrops. Later they were free to switch to alternative land uses, including abandoning plots that were infested with *Imperata cylindrica* (*alang alang*).

Spontaneous migration to the Jambi sites

The ASB characterization surveys revealed that the Bungo Tebo peneplain site has a considerable proportion of migrants while the Rantau Pandan piedmont site has very few spontaneous migrants (none were in the sample), even though the soils are better than in the neighboring peneplain (Table 5). This difference may be linked to tenure or topography. Research is underway in the Rantau Pandan site (Section II.11) to explore relationships between tenure and land use in detail. For the spontaneous migrants in the Bungo Tebo sample, one third came to Bungo Tebo more than 15 years ago. At first, they worked as rubber tappers or as laborers opening forest to establish rubber. Typically, they traveled between Java and Sumatra as cyclical migrants before settling in Jambi. Often they were joined by relatives or friends from Java and established new villages with a majority of Javanese. Spontaneous migration has continued until now: 28% came between 5-15 years ago and 39% came less than five years ago. 82% of spontaneous migrants came from Java and only 18% came from other areas in Sumatra. The major reasons given for migrating were: getting a better life (44%), seeking new land (24%), and to join relatives (26%).

Government-sponsored transmigrants

94% of transmigrants come from Java; only 6% were resettled from the surrounding area (Table 5). Half of the transmigrants said they joined the program to get a better life (28%), to get new land (19%), or because life in their original home was hard (3%). Of the rest, 38% reported "resettlement" as the reason for their move.

Household characteristics

Among local people, the average household ranged from 4.2 persons per household in Rantau Pandan to 5.6 in Bungo Tebo, comparable to 4.8 persons for the sample of transmigrants and 4.5 persons for the spontaneous migrants (Table 6). More than half of the heads of households in the Rantau Pandan sample were over 40 years old, while this proportion ranged between 25-38% in Bungo Tebo. The vast majority of household heads did not complete primary school: this proportion exceeded 70% in each case and was as high as 95% for the sample of local people in Bungo Tebo. Virtually every household surveyed is engaged in agriculture. Less than 10% of households of local farmers and spontaneous migrants engage in non-agricultural activities. This is in strong contrast to transmigrants. Although non-agricultural activities may not be the main occupation of transmigrants, 75% of these households reported non-agricultural work (in trading, services, and paid labor).

Slash-and-burn

'Slash-and-burn' is both a *technique* for land clearing and a land use *system* ('slash-and-burn' agriculture, shifting cultivation). Of course, it is inaccurate to equate 'slash-and-burn' agriculture with permanent forest conversion and unsustainable land use. Traditional shifting cultivation of foodcrops, as practiced for generations by local people in Sumatra, obviously was sustainable as long as population densities were low enough to allow long fallow rotations.

Figure 14 shows the natural succession and the various types of 'shifting cultivation', 'long rotation fallow' and 'short rotation fallow', where forest or shrub land is opened to grow food crops. The grass fallows that are formed, especially after prolonged cropping, tend to be perpetuated by fire and can lead to an 'arrested succession' in the form of large ('sheet') alang-alang (*Imperata cylindrica*) grasslands. Figure 15 includes the major 'alternative to slash and burn' in Sumatra, in the form of 'agroforests' or man-made forests, with a large share of directly useful trees. These can be seen as the ultimate form of 'enriched fallow systems', in the sense that the trees planted in the fallow are the major source of income for the farmers and the food crops grown in the initial years are no longer the 'raison d'être' of the land use system.

Traditional shifting cultivation is disappearing in Sumatra, but slash-and-burn as a technique of land clearing is used by virtually all actors (public and private, large and small-scale) contributing to forest conversion. The slash-and-burn technique continues to be attractive to all these actors because fire is the cheapest, most effective means to clear land. Preliminary data suggest that most slash-and-burn by smallholders is for replanting of old jungle rubber instead of conversion of primary forest. The remotest villages in Rantau Pandan, which are adjacent to the Kerinci Seblat National Park, are a possible exception . Elsewhere, however, and particularly in the peneplains, there is little primary forest left to convert.

Land use

The ASB survey included eight different land use categories for Sumatra. Of these, five clearly are important in Jambi: wet rice fields, upland fields, perennial plots, bush fallow, and home gardens (Table 7). Fish ponds are not common yet, but may be increasing. No sample households had pastures. Mainly because most forest use by smallholders is (formally) prohibited, it was not possible to obtain reliable data on forest land use with this survey instrument. For the same reason, the survey probably understates the number of plots of upland fields, perennials, and bush fallow because farmers are reluctant to report plots that have been opened in state forest land. A more complete understanding of households' forest use patterns will require more detailed studies over a longer period complemented by analysis of remote sensing data (see Section II.12).

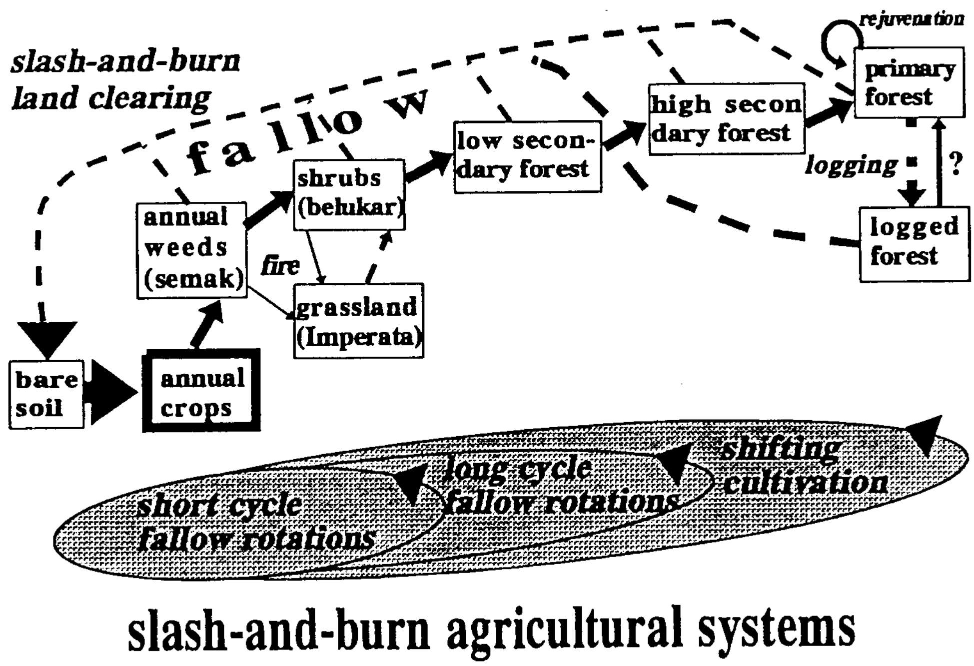


Figure 14. Shifting cultivation

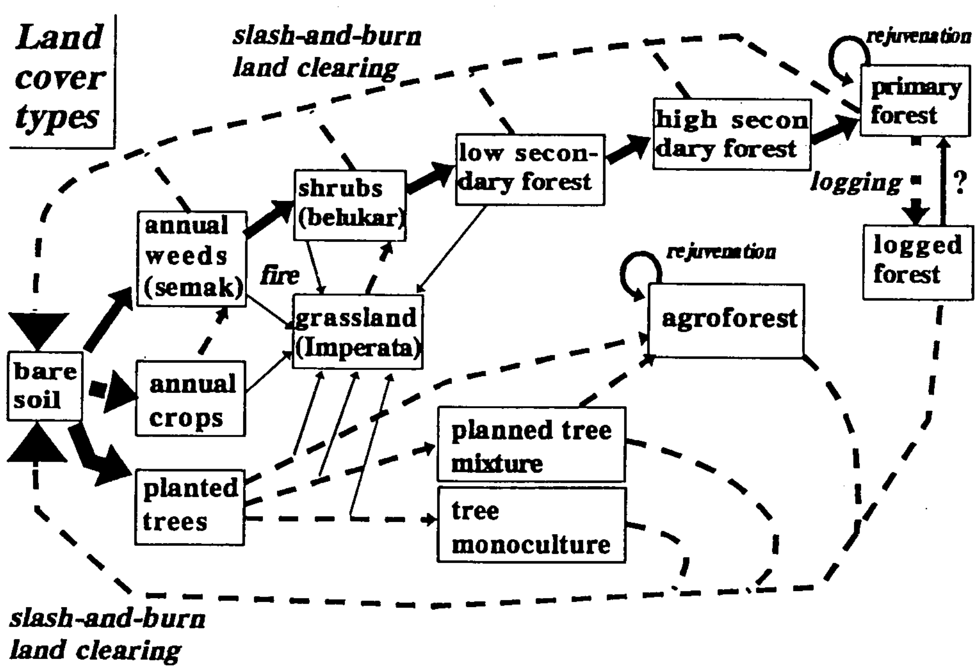


Figure 15. Tree-based systems, including agroforests, also start with slash-and-burn

The five main agricultural land use categories in the Jambi benchmark areas are:

1. **Wet rice fields** (*sawah*). Except for local farmers in Bungo Tebo (who reported none), households typically have one wet rice field. The average area of wet rice per household is 0.31 ha for the sample of transmigrants and 0.68 ha for spontaneous migrants in Bungo Tebo compared to 0.84 ha for the sample of local people in Rantau Pandan.

2. **Upland fields** (*ladang*). The 'upland fields' category includes both (a) the shifting cultivation rotation of foodcrops followed by fallow and (b) upland fields that will be -- or already have been -- planted with perennials, such as rubber. Local people and transmigrants both average about one upland plot per household. Spontaneous migrants have more upland plots (1.6 per household) and operate a larger area (1.6 ha per household on average compared to less than one ha for other groups).

3. **Perennial plots**, including **agroforests** (*kebun*). As noted above, perennial plots also begin with intercropping of upland foodcrops, but the primary objective is establishment of treecrops like rubber (the main land use for these sites), various fruit species, and, recently in Rantau Pandan, cinnamon. For Bungo Tebo, the local people have two perennial plots (mainly rubber) per household and operate over 3.6 ha per household, on average. The spontaneous migrants at that site have somewhat fewer plots (1.8 per household), but on average they operate a bigger area (4.3 ha). Transmigrants reported averages of 1.4 plots and only 1.8 ha per household. Surprisingly, data from the sample of local people in Rantau Pandan yielded averages similar to the transmigrants in Bungo Tebo. This probably reflects underreporting of plots located on state forest land.

4. **Bush fallow** (*belukar*). Bush fallow comprises two categories. *Semak*--covered by grasses, shrubs, and small trees--is the first fallow stage. *Belukar tua*, which often resembles secondary forest, is covered by larger trees and may even include old rubber trees that no longer are productive. In Rantau Pandan, sample households reported an average of 1.7 bush fallow plots and 1.5 ha per household, while in Bungo Tebo the number of plots per household is somewhat lower (1.2-1.3 plots) but the average area per household is larger (1.6-2.8 ha).

5. **Home gardens** (*pekarangan*). Home gardens (including a variety of annuals and perennials used for a multitude of purposes) are cultivated intensively by transmigrants and spontaneous migrants, but are less important for local people.

Land use change in the Jambi benchmark areas

Figure 16 gives the changes in land cover for Jambi province as a whole for the 1986-1992 period. The size of the boxes reflects total area in the category, the size of the arrows represents absolute changes, and the numbers in boxes and arrows give relative changes (%). Figures 17 and 18 give estimates for land use change in the Rantau Pandan and Bungo Tebo benchmark areas for the period 1986 - 1994, as interpreted from satellite images. This study by BIOTROP showed that 'jungle rubber' (rubber agroforests) are the predominant agricultural land use system. In the 1986 vegetation map, large areas were indicated as 'mosaics of rubber and shrub' or 'mosaics of rubber and forest.' On the 1992 and 1994 satellite maps, however, the major part of the 'rubber complex' is indicated as 'old secondary forest.' It is not clear whether this change is in fact a result of maturation of rubber agroforests or is simply a result of the coarser scale of the 1986 map. A pilot study is planned to assess the feasibility of distinguishing rubber agroforests from secondary forests in satellite images (See Section II.12).

Table 7. Average Number of Plots and Area Operated per Household

Benchmark Area	Wet Rice Fields		Upland Fields		Perennial Plots		Bush fallow		Home Gardens	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Rantau Pandan										
Local People	1.2	0.84	1.0	0.75	1.4	1.8	1.7	1.5	1.0	0.06
Bungo Tebo										
Local People	-	-	1.1	0.94	2.0	3.6	1.2	2.7	1.0	0.11
Transmigrants	1.2	0.31	1.0	0.77	1.4	1.9	1.2	2.2	1.0	0.18
Spontaneous Migrants	1.2	0.68	1.6	1.6	1.8	4.3	1.3	1.6	1.0	0.25

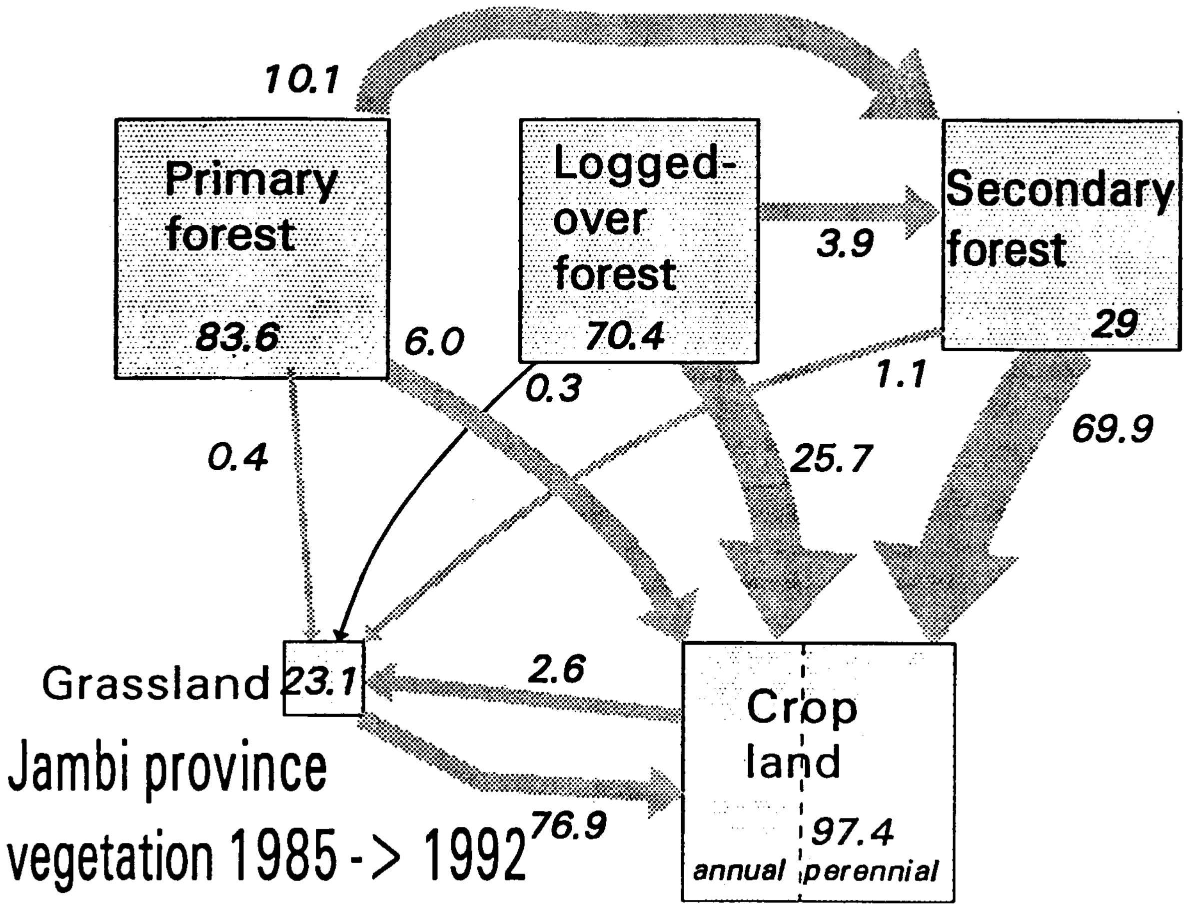


Figure 16. Land use change in Jambi province, 1986-1992
Source: Murdiyarso and Wasrin (1995)

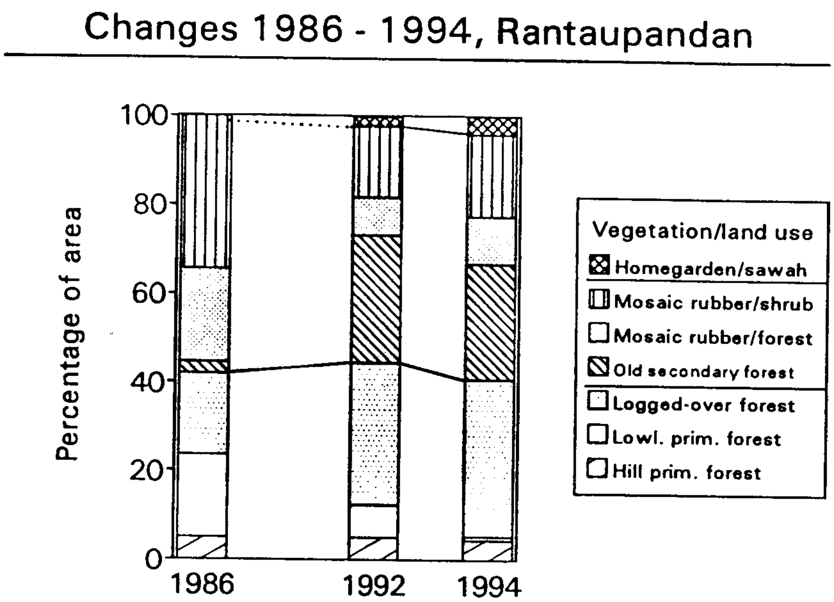


Figure 17. Land use change at the Rantau Pandan site, 1986-1994.

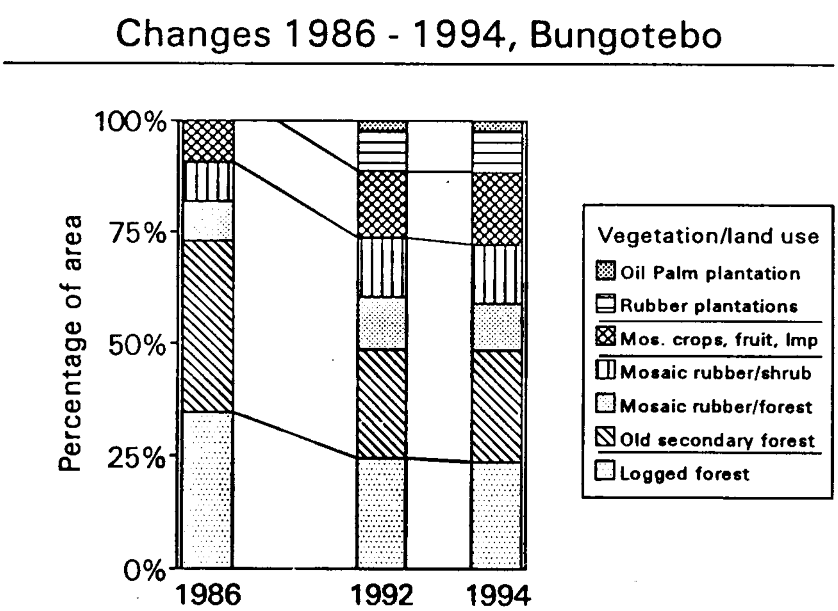


Figure 18. Land use change at the Bungo Tebo site, 1986-1994.

II.2. Integrating Research on Land Use Change, Environmental Impacts, and Policy

The economic and environmental implications of the mix of forest and derived land uses is a focal point of ASB research in SE Asia. At the forest margins, are agroforestry systems superior to other major land use systems in profitability, agronomic sustainability, and environmental impact? If the answer is mixed (which seems likely), what are the tradeoffs and under which circumstances do particular agroforestry systems offer an attractive balance of these development objectives? Alternative land uses at the forest margins differ significantly in their ability to substitute for forests as sources of biodiversity conservation, carbon sinks, and soil and water conservation. While conversion of primary forest has the major effect on the supply of forest functions, the resulting land uses also matter a great deal for the supply of environmental externalities and public goods.

A comprehensive set of biophysical measurements are necessary to understand the "who cares" question: are the environmental effects of land use change big or little? When we know how big the differences are among the various land use systems (and we already have a good idea), we will have a basis for identifying the major opportunities to make a difference and, hence, to provide a more precise focus for policy analysis. The next phase of ASB research in Indonesia will focus on a better quantification of greenhouse gas (GHG) sources and sinks, biodiversity (above- and belowground), 'best bet' technologies as alternatives to slash-and-burn, and policy options.

The sampling scheme for the biodiversity and GHG studies will focus on 8 land use types, which were chosen to cover the spectrum of soil biodiversity values and which are defined in such terms that counterpart land use types may be found in the other ASB sites (Cameroon, Peru, Brazil, Thailand). The sample will be stratified over the Jambi peneplain and the Lampung peneplain, aiming for at least three replicate observations on each land use in each benchmark area.

1. Primary forest (not available in Lampung)
2. Secondary or logged-over forest
3. Agroforest (Jungle rubber/ multi-story agroforestry system)
4. Intensive tree-crop plantation (rubber)
5. Newly opened crop field (ladang) with upland rice
6. Long term cropped/ degraded crop land with cassava
7. Shrub-fallow (about 5 year since last crop)
8. *Imperata* grassland

Not all of these categories can be distinguished on remote sensing data, but for the major ones spatial data can be collected. Not included in this scheme, but potentially relevant for the ASB benchmark areas, are: oil palm and industrial timber plantations (HTI), sugarcane fields, and wet rice fields (sawah).

Sampling sites should be chosen on the 'typical' soil type, based on the soil maps for the ASB-benchmark areas. The 'ages' of the system are indicative, the aim is to sample the various systems in a 'characteristic' stage of their life-cycle.

For the aboveground surveys more land use types can be covered, but wherever belowground measurements are done, aboveground work should be done as well. Aboveground biodiversity assessment will include an estimate of standing biomass (based on basal area).

The belowground work will focus on the peneplain. The target is to have at least 5 replicate observations per land use type for Indonesia. As we split over a 'Lampung' and 'Jambi' stratum, this means 3 replicates per land use per stratum.

Figure 19. Sampling scheme for coordinated above- and belowground sampling.

Land use	Agro-ecological zone/ ASB-benchmark area				
	N. Lampung, peneplain, high pop.	Bungo Tebo, peneplain, low pop.	Rantau Pandan, Piedmont	Air Dingin, Highlands	Berbak??, coastal swamps ?
Primary forest	-	A,B	A	A	A
Secondary/ logged-over forest	A,B	A,B	A	A	A
Rubber agroforest 15 year old	A,B	A,B	A		
Rubber monoculture 15 years old		A,B			
Cinnamon agroforestry 5 years old			A	A	
Industrial timber estate: 5 years old	A	A			
Oil palm plantation 10 years old	?	A			
Upland field - 1st year, w/upland rice	A,B	A,B	A	A	
Upland field - 3rd/4th year, with cassava	A,B	A,B			
Bush fallow, 5 yrs since last crop	A,B	A,B	A	A	
Imperata grassland (annual burn?)	A,B	A,B			

A = Above-ground measurements (biodiversity, carbon stock)
B = Belowground measurements (biodiversity, net GHG emissions, soil C and N)

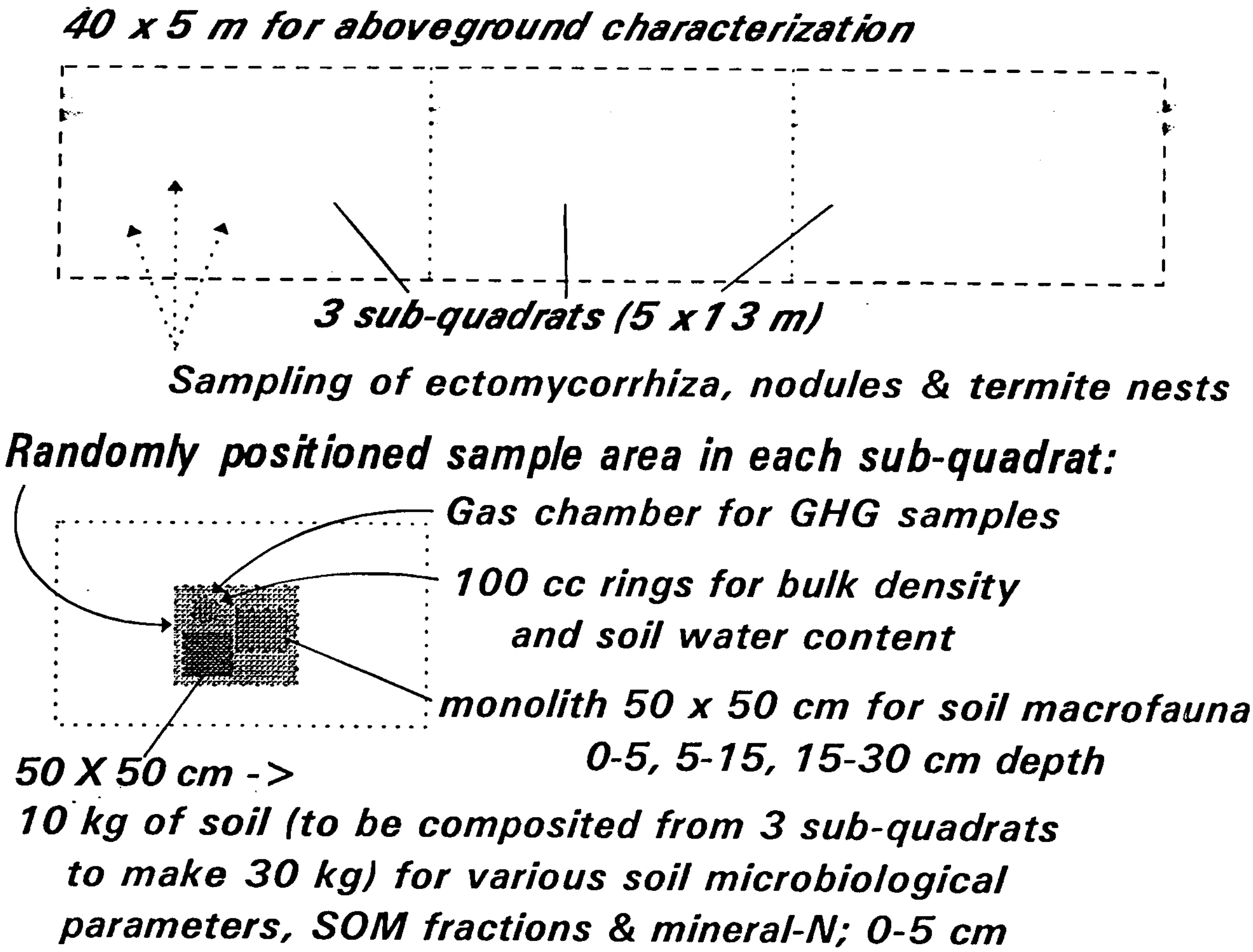


Figure 20. Plot layout for coordinated above- and belowground sampling.

Figure 21. Preliminary results for measurements of methane sink strength