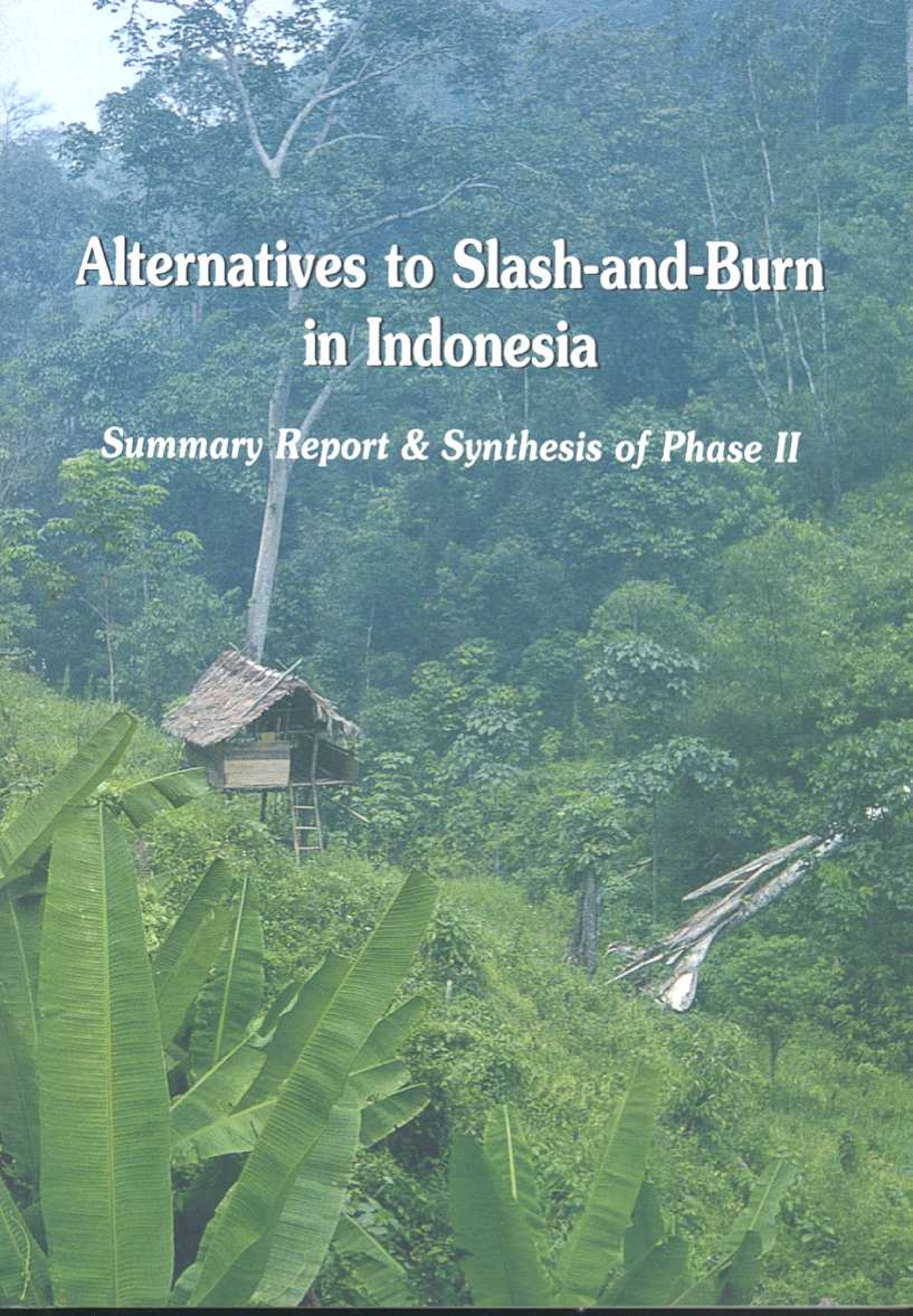
Alternatives to Slash-and-Burn in Indonesia

Summary Report & Synthesis of Phase II



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ICRAF
S.E. Asia

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For more information an the Alternatives to Slash-and-Burn initiative (ASB), or to subscribe to the ASB quarterly newsletter, *Slash-and-Burn: Update on Alternatives*, contact: ASB/ICRAF, PO Box 30677, Nairobi, Kenya; Fax: (254-2) 521 318; e-mail: ECF3@Cornell.edu

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Table of contents

Table of contents, continued

List of maps, tables, and figures

***List of maps, tables, and figures**, continued*

ASB-Indonesia PHASE II REPORT
Overview & Summary in UNDP-MANDATED FORMAT

I. DEVELOPMENT PROBLEM & IMMEDIATE PROBLEMS ATTACKED

Conversion of tropical forests reduces biodiversity and releases stored carbon. Although a part of tropical deforestation resulting from slash-and-burn is linked to poverty of people living at the forest margins, the conditions necessary for increased productivity of agroforestry and other land use systems to reduce poverty *and* reduce deforestation are not well understood. The key hypothesis underlying Phase II of the ASB research project in Indonesia can be summarized as: *Intensifying land use as an alternative to slash-and-burn simultaneously can reduce deforestation and reduce poverty*. This research problem was identified at the conclusion of Phase I of the project and has remained the focus of research through Phase II.

The research programme in Phase II was designed to better understand how the Government of Indonesia and donor agencies could balance global environmental objectives with economic development and poverty reduction. While conversion of primary forest has the major effect on biodiversity and carbon stocks, the resulting land uses also matter a great deal for the supply of these global public goods. Measurement of differences among environmental consequences of the various land uses provides the basis for quantifying major tradeoffs involved in land use change.

II. OUTPUT PRODUCED & PROBLEMS ENCOUNTERED

Two of three main goals of Phase II were assessment of the implications of alternative land use practices on 'climate change' (carbon sequestration and greenhouse gas fluxes) and on biodiversity (richness above and belowground). Results of these studies, and the new tools developed by ASB to obtain the necessary data, are reported in separate documents by their respective global working groups.

This report draws on these and other data to focus on outputs associated with the third main goal of Phase II: *linking global environmental benefits to sustainable alternatives to slash-and-burn in Indonesia.* If alternatives to slash-and-burn are to have hope for significant impact in Indonesia (or any of the countries involved), it is obvious immediately that the scope of the research had to expand beyond climate change and biodiversity. This 'linking' goal, which necessarily involves assessments of tradeoffs (and complementarities) among impacts spanning the plot, household, landscape, watershed, and national level--as well as global environmental phenomena—could not be achieved meaningfully without assessment of sustainability and adoptability of the alternatives. So this report also draws on the methodological innovations and empirical results of two other global working groups, one on agronomic sustainability of land use alternatives and the other on socioeconomic and policy issues that affect adoptability of these alternatives by smallholders.

Because of these gaps, additional funding had to be sought for work in Indonesia – and was secured from the Asian Development Bank (ADB), the Ford Foundation, DANIDA, the Government of Japan, the United States Agency for International Development (USAID) and others. Nevertheless, funding has not been adequate to pursue the full range of high-priority issues relevant to ASB-Indonesia within the timeframe of Phase II of the GEF grant administered by UNDP.

The process of seeking additional funding delayed work on key components of the research, most notably the socioeconomic assessments, which could not begin until funding was secured in mid-1997. Fortunately, results of those socioeconomic assessments are available to be included in this report. There were only limited opportunities for trials to assess the sustainability and profitability of land use alternatives in farmers' fields because of constraints on time as well as funding. And local, regional, and national environmental problems linked to land use change and slash-and-burn are other key examples of national priorities that still need to be addressed to fully understand the sustainability of these land use alternatives beyond the plot level. Although some work was undertaken on technologies and policies underlying the transboundary smoke problems that stole headlines in 1997 and 1998, work is only beginning to 'scale-up' biodiversity assessments to the landscape level and to assess implications of land use alternatives for watershed functions, which are a top concern of Indonesian policymakers.

III. OBJECTIVES ACHIEVED

Goal 1. Climate Change

- Carbon stocks were measured for sample plots in natural forests, shifting cultivation, and five other major land use alternatives in the peneplains of Sumatra. Progress was made in resolving weaknesses in the methods for estimating above as well as belowground stocks. The point data from the samples were used to estimate the 'time-averaged carbon stock' for major land use systems. Land use change can thus be translated into a net release or net sequestration of carbon. Together with data from Brazil and Cameroon, the data for Sumatra provide a clear picture for carbon sequestration (Section II.1).
- Greenhouse gas emissions (methane and nitrous oxide) were measured for the same land use systems as studied for their C stocks. Pronounced seasonality was discovered in greenhouse gas emissions, so additional measurements will be necessary to derive reliable estimates of annual fluxes (Section II.2).

Goal 2. Biodiversity

- A team of national researchers was formed for belowground biodiversity studies and the methodology was coordinated with studies in other ASB countries (Section II.3).
- Indicators for rapid assessment of aboveground biodiversity were developed and validated in an intensive study in Jambi Province, central Sumatra (Section II.4).
- Indicators of above- as well as belowground biodiversity were measured in the same land uses where the C stocks and greenhouse gas emissions were measured.

Goal 3. Linking environmental benefits to sustainable land use alternatives

- A matrix technique to link environmental, agronomic, policy, socioeconomic, and institutional indicators was developed in collaboration with scientists from other ASB sites (Section I.4).
- Climate change and biodiversity indicators were organized in a matrix format for natural forests, shifting cultivation, and five other major land uses in the peneplains of Sumatra, along with quantitative data on indicators of agronomic sustainability, national policy objectives, and smallholders' production incentives and qualitative indicators of market imperfections and other institutional barriers to adoptability by smallholders. This complete matrix is the basic tool for integrated assessment of options to balance environmental benefits with sustainable agricultural development (Part V).
- Policy and institutional barriers to adoption of alternative land uses were analyzed and workable options to address tenure insecurity and certain trade policy distortions were developed in consultation with policymakers and other stakeholders (Part V, VI and VII).

IV. KEY FINDINGS & LESSONS LEARNED

For reasons discussed in II above, the scientific findings and lessons of Phase II exceed the scope of its original goals and objectives.

Significant conclusions

- Carbon stocks of tree-based land use systems depend largely on the typical cycle length of these systems, as annual C increments are similar. Thus, time averaged C stocks are similar for long-rotation tree-based systems, which are superior to all other land uses in this regard except for natural forests themselves. Where treecrop systems can be rejuvenated without clear felling, a substantial increase in C stock may be possible (Section II.1).

- Methane oxidation capacity of upland soils (which partly offsets methane emissions in other land uses, such as paddy rice fields) declines with soil compaction (Section II.2).
- Nitrous oxide emissions appear related with (temporary) abundance of soil mineral N, which can occur in forests as well as derived land use systems; no consistent relation between land use and net emissions of nitrous oxide over a system's life span has been found yet (Section II.2).
- Alternative land uses at the forest margins differ significantly in their potential for conservation of aboveground biodiversity, with a range of alternatives falling between the extremes of smallholders' complex, multistrata agroforestry systems (agroforests) and large-scale plantation monoculture (Section II.4).
- There appears to be less variation among land uses in belowground biodiversity compared to aboveground biodiversity (Section II.3).
- The direct impacts of slash-and-burn on soil microbial properties and earthworm activity is limited and of the same magnitude as effects of a long dry season (Section II.3).
- Despite little aboveground biodiversity, *Imperata* grasslands appear to provide a healthy belowground ecosystem. There is no evidence of serious soil biological constraints to conversion of *Imperata* grasslands to other agricultural land uses (Section II.3).
- All tree-based alternatives appear to be agronomically sustainable (Section II.4).
- Prior to the monetary crisis that began in Indonesia in 1997, unsustainable shifting cultivation was not financially profitable in much of Sumatra. This appears to have changed since the collapse of the Indonesian currency in 1997, which may reverse the long-term decline in shifting cultivation (Section VI.4).
- Also because of the currency collapse, profitability of many tree-based systems has increased substantially, which boosts incentives for forest conversion by smallholders and large-scale operators alike (Section VI.4).
- There may be a tradeoff between potential profitability and aboveground biodiversity in tree-based production systems, but this requires furter verification (Section V.2).
- Potential profitability of some tree-based alternhatives for smallholders (such as rubber agroforestry with higher yielding varieties) appears to be comparable to large-scale oil palm estates, but this also requires further verification (Section IV.6).
- There are, however, some important institutional questions that must be addressed to enable widespread adoption of profitable agroforestry alternatives by smallholders (Section V.4).
- Fire can be used both as a tool for land clearing (to increase physical accessibility and soil fertility) and as a weapon in conflicts over access to land (Section VI.5).

'Lessons learned'

- Forest-derived land uses differ significantly regarding their abilities to substitute for specific functions of natural forests. Because of the multiple objectives regarding production and environmental services of forests, 'deforestation' must be viewed as a multidimensional phenomenon. Sometimes this policy problem may simplify to a few key dimensions (tradeoffs) (Part V).
- Efforts to develop land use alternatives and policy options to pursue global environmental objectives (biodiversity conservation and carbon sequestration) are futile without simultaneously considering agronomic sustainability and environmental services at other scales, objectives of farmers and policymakers at various levels, and weaknesses in markets and other institutions that influence the adoptability of land use alternatives by smallholders (Part V).
- Tenure institutions, trade policies, and macroeconomic shocks affect households' livelihood options and, thereby, reduce (or intensify) forces that push migrants to forest margins; this policy and institutional 'environment' also has a powerful effect on the natural resource management decisions made by people at the forest margins (Part VI).
- Ongoing collaboration, contact, and presence by national and international members of the research team are essential for real impact on policy and technology options (Part VII).

- Building effective multi-disciplinary teams to study complexities of land use change is feasible, but involves high ‘transaction costs.’

V. RECOMMENDATIONS FOR FOLLOW-UP

The following priorities were identified by scientists active in the ASB-Indonesia Research Consortium at a national meeting held in Bogor on 6 May 1998:

- National teams are preparing proposals for development activities for consideration by GEF and other donors, including additional on-farm trials for development of land use alternatives for *Imperata* grasslands.
- A wider range of tree-based ‘best bet’ alternatives for smallholders should be examined regarding their environmental, agronomic, and economic impacts and feasibility of adoption (Section V.3 and Table V.2).
- Teams are prepared to follow-up as necessary on implementation of land and tree tenure pilot efforts in Lampung and trade policy changes (Sections VII.1 and VII.2).
- Additional training and research is needed to gain better understanding of relationships among aboveground and belowground biodiversity, production sustainability, and potential profitability (Section V.2).
- Work is needed to expand the assessments of sustainability from plot-level agronomic issues to include environmental externalities at the landscape level and watershed functions (Section IV.5).
- In order to complete the landscape transect, it is necessary to expand from the present focus on the peneplains and piedmont agroecological zones in order to include the montane zone and coastal swamps (Section I.5).
- Because of catastrophic fires and severe smoke problems in 1997/98, a proposal was developed for research on the underlying causes of fires, including both policy issues and technological alternatives. A portion of this research recently was funded by the US Government.
- The ongoing monetary crisis in Indonesia creates both a need and an opportunity to analyze how macroeconomic shocks affect land use change, environmental services, poverty, and household food security.
- The ASB-Consortium will use these research results to inform key planners and policymakers about the potential environmental, social, *and* economic benefits of a smallholder-based development strategy as an alternative to large-scale plantation monoculture.

I. Biophysical and socioeconomic context for assessment of land use alternatives

The goals of the global Alternatives to Slash-and-Burn (ASB) research project are to identify means to reduce the rate of tropical deforestation driven by slash-and-burn and to reduce poverty of smallholders dwelling at the forest margins. ASB was formulated as a partnership among national and international institutions to undertake research on sustainable upland systems as alternatives to unsustainable slash-and-burn in various parts of the tropics. This report presents results from ASB study sites ('benchmark areas') in Jambi and Lampung provinces on the island of Sumatra in Indonesia, which are part of this ongoing global research project.

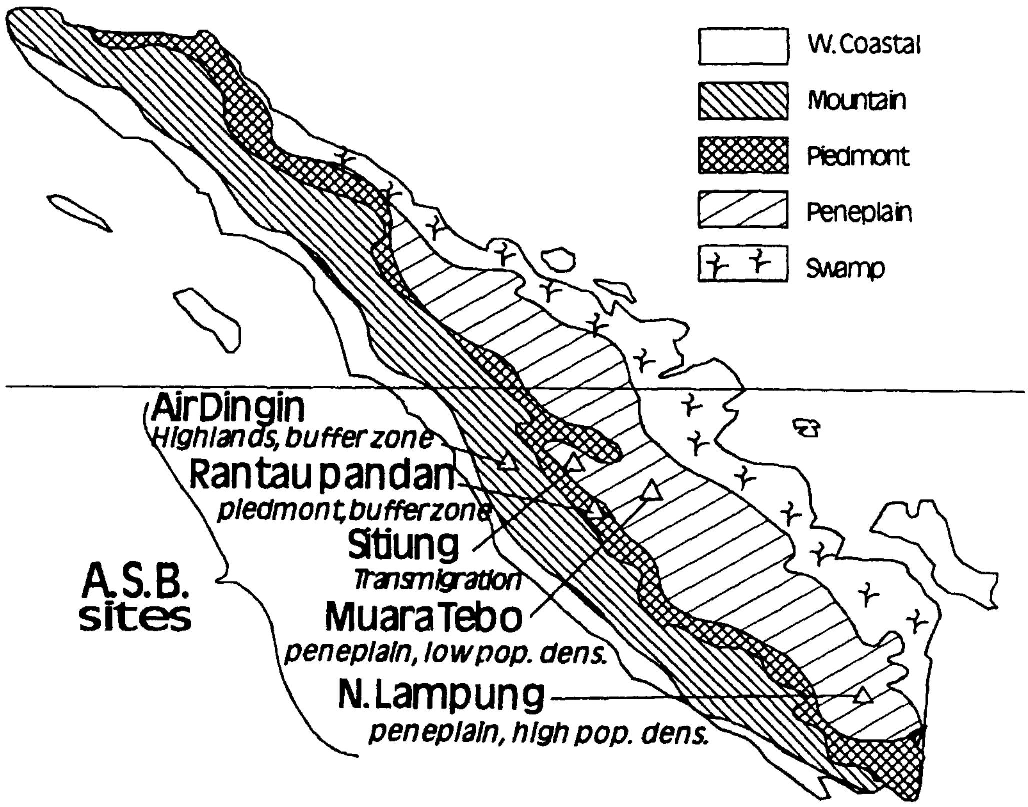
Indonesia, Brazil, and Cameroon were the first three countries to join in the ASB research effort in 1994. Indonesia's forests covered over 1 million square km in 1990 (World Bank 1997) and ranked third in area – behind the Amazon and the Congo Basin – among the world's remaining tropical rainforests. Table I.1 presents comparative statistics for three ASB countries (Brazil, Cameroon, and Indonesia) and, where data are available, for Sumatra. In terms of the key ratios in Table I.1, agriculture's role in the gross regional product of Sumatra – because of its mineral wealth -- was comparable to Brazil and lower than Indonesia as a whole. On the other hand, the share of Sumatra's labor force that depended on agriculture was almost as high as Cameroon. Agricultural land of 1.9 ha per worker in Sumatra was almost twice the average for Indonesia, but was less than for Cameroon and only a fraction of the ratio for Brazil. Another key contrast is that over 20% of Brazil's agricultural land is permanent pasture, while that proportion is less than 5% for Sumatra and for Cameroon.

I.1 ASB-Indonesia benchmark sites and associated study areas

The island of Sumatra was chosen to represent the **lowland humid tropical forest zone in Asia** for the global ASB project. Within Sumatra five major agro-ecological zones (Map 1) 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

Ongoing work seeks to span this full landscape gradient, but because of the emphasis on lowland tropical rainforests (and derived land uses) in ASB Phase I and Phase II, most of the work in Indonesia to date has focused on the peneplains and piedmont.



Map 1. Agroecological zones of Sumatra

Table I.1 Comparative statistics for Brazil, Cameroon, Indonesia and Sumatra

	Brazil	Cameroon	Indonesia	Sumatra
Levels				
GNP, mid -1995 (US$ billions)	688.7	8.7	189.4	35.5
Population, mid-1995 (millions)	159.2	13.3	193.3	40.8
Labor force, 1990 (millions)	65.8	5.1	78.5	18.1
Agricultural GDP, mid-1995 (US$ billions)	96.3	3.1	33.7	4.7
Agricultural land (millions ha)	238.3	9.0	45.7	16.0
Agricultural labor, 1990 (millions)	15.1	3.5	44.8	8.6
Forest land, 1990 (thousands sq. km.)	5,611.0	204.0	1,095.0	265.0
Key Ratios				
GNP/Capita - US$ (1995)	3,640	650	980	870
GNP/Capita - US$ PPP (1995)	5,400	2,110	3,800	--
Poverty : population w/<US$ 1 PPP/day	28.7%	--	14.5%	--
Income distribution : share of top quintile	67.5%	--	40.7%	--
Agriculture's share of GDP, 1990	11.1%	26.6%	19.0%	12.9% *)
Agriculture's share of labor force, 1990	23.0%	70.0%	57.0%	66.3%
Ag GDP / Ag labor, US$/person	6,377.5	885.7	752.2	548.8
Ag GDP / Ag land, US$/ha	404.0	343.3	737.1	294.3
Ag land / Ag labor, 1990, ha/person	15.8	2.6	1.0	1.9
Cropland / Ag land, 1994	78%	96%	93%	97% *)
Permanent pasture / Ag land, 1994	22%	4%	7%	3%
CO2 from industrial sources, MT/capita, 1992	1.4	0.2	1.0	--
Rates of change (per year)				
GDP growth 1990-1995	2.7%	-1.8%	7.6%	7.7%
Agricultural GDP growth, 1990 - 1995	3.7%	2.2%	2.9%	3.3%
Population growth, 1990 – 1995	1.5%	2.9%	1.6%	2.2%
Labor force growth, 1990 – 1995	1.6%	3.1%	2.5%	3.5%
Agricultural labor force growth	2.0%	0.4%	-2.3%	-1.0%
Agricultural land area growth	0.5%	0.0%	-1.1%	1.4%
Forestland area growth, 1980 - 1990	-0.6%	-0.6%	-1.1%	-1.2% **)

Note: for Sumatra, GNP and GDP refer to Gross Regional Product (GRP)
**) 1995*
***) 1984 - 1995*
Sources :
World Development Report 1997
Statistical Year Book of Indonesia, BPS, 1985, 1990, 1991, 1996

Map 2

Within Sumatra, a clear gradient in population density occurs from Lampung Province at the southern tip of Sumatra (174 people per square km in 1993) to Jambi Province in the middle of the island (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 peneplains were inhabited sparsely with human population concentrated along the riverbanks on relatively favorable sites. With the advent of rubber a century ago, population spread in the peneplains but remained tied to the pattern of river transport until major road construction projects were completed over the past 20 years. In addition to road construction, the peneplains have been the focus of government-sponsored settlement schemes (called transmigration), large-scale logging, and various large-scale public and private land development projects since the 1970s.

Because of these activities, most remaining fragments of lowland tropical rainforest are in the piedmont zone and little natural forest remains in Sumatra's peneplains. This process of deforestation, which is almost complete in lowland Sumatra, seems likely to be repeated elsewhere in Indonesia. By understanding this process and its consequences in Sumatra, ASB researchers hope to identify policies and technologies that can ameliorate the effects of deforestation and contribute to conservation of the remaining rainforests in Asia.

To assess how well ASB's Sumatran research sites in Jambi and Lampung represent lowland tropical rainforests of Asia and the rest of the world, domain software (Carpenter, Gillison and Winter 1993) was used to conduct a spatial analysis of an index of similarity combining 7 biophysical variables (spanning ranges of precipitation, temperature, evapotranspiration, and altitude). The results for Asia indicate a high degree of similarity between the ASB sites in the peneplains and piedmont of Sumatra and significant areas of Borneo, New Guinea, and mainland Southeast Asia. For the rest of the world, the same analysis of biophysical indicators shows a high degree of similarity between the Sumatran sites and areas of the Amazon Basin and West Africa.

Jambi sites. Two sites in Jambi Province were chosen for detailed characterization for the ASB project (Map 2). (For detailed results of ASB Phase I characterization studies see van Noordwijk *et al* 1995; Tomich and van Noordwijk 1996; van Noordwijk and de Foresta 1998). 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 are 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.

Forestry and the rubber processing industry (crumb rubber) contributed virtually all (99%) of the exports from Jambi 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' (the rubber agroforests). 64% of the land in Jambi is categorized as State Forest Land. However, 'forest status' often was declared long after local communities had already settled here. In practice, a large part of the forestland is used for rubber agroforests and other forms of agriculture.

After the completion of the Trans Sumatra Highway in the 1980s, Jambi has become a popular destination of migrants. Characterization studies in the ASB benchmark area indicate that over 25% of spontaneous migrants came between 5-15 years ago and almost 40% came less than five years ago; over 80% of spontaneous migrants came from Java and less than 20% came from other areas in Sumatra.

Virtually every smallholder household interviewed in the ASB characterization surveys in Jambi 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). 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.

Lampung sites. ASB research in Lampung now has two foci: the ASB benchmark site in the peneplains of North Lampung and an associated research site at Krui in the western coastal strip (Map 3). (For reasons discussed in Part IV, planning is underway to add a third site on watershed functions.)

Lampung is sometimes described as 'North Java', indicating its nature as a transition between the densely populated island of Java and the rest of Sumatra, where population densities are below or around the national average. The spontaneous movement of people between Java and Lampung, and additional efforts by the government during various periods in this century are key to understanding its landscape dynamics. Only a minority within the province can claim Lampungese descent.

The **ASB peneplain benchmark area in North Lampung** was chosen to represent the landscape degradation that can follow forest conversion if intensive food crop production is pursued on these soils. Government-sponsored transmigrants generally have found the lowland peneplain soils are not suitable for their crop-based systems. Only in depressions and valleys, where paddy rice fields could be created, has agriculture become a major source of their livelihoods. Otherwise off-farm labor has had to provide the income that kept people here; a substantial number of transmigrants left the area in the first few years. This exodus may have accelerated as conditions worsen because of drought and the national financial crisis; 11 out of 30 households interviewed 4 years ago had left the village when a repeat survey was done in 1998 (Elmhirst 1998).

Some migrants settled on their own accord, despite the hardships in the area, including the second generation of government-sponsored transmigrants for whom there is no land in the village. Spontaneous migrants tend to use agricultural systems intermediate between the local and Javanese food-crop based system, with a greater emphasis on tree crops.

The indigenous Lampung people, who live along the rivers, still have their semi-permanent food crop production on flooded river banks, but two decades ago gave up on the extensive shifting cultivation of the lowland peneplain. Along the rivers, their old 'jungle rubber' gardens exist as this is on the margin of Sumatra's rubber belt. Recently there has been renewed interest in rubber production, but as a whole the indigenous Lampungese now aim to secure their livelihoods outside of agriculture (Elmhirst 1997, 1998).

The ASB benchmark area in Lampung has been selected as one of the sites for a new proposal to the Global Environment Facility (GEF) for rehabilitation of *Imperata* grasslands that the Central Research Institute for Food Crops (CRIFC) is preparing on behalf of the ASB-Indonesia consortium. On the edge of the Lampung benchmark area is the **Biological Management of Soil Fertility (BMSF) research site,** which is managed by Brawijaya University. Long term soil fertility trials and process level research on organic matter and nitrogen dynamics, comparing farmer practices with systems with increased organic inputs (hedgerow intercropping, improved fallows, leguminous cover crops), have been conducted at this site. ICRAF and the ASB-Indonesia Consortium have been partners in this research over the past 5 years.

Krui is on the west coast, across the mountains of the Bukit Barisan range, where a relatively narrow coastal strip has had a long history of settlement but relatively little immigration over the last century. Here an extraordinary form of agroforestry was developed by local farmers about a century ago, the damar agroforests. More than 15 years of research by ORSTOM, BIOTROP, and ICRAF with national partners (united in the 'team Krui') has helped in obtaining government recognition for the value of this land use system (Fay *et.al.*, 1998). This work culminated in the signing by the Minister of Forestry of a decree creating a special class within State Forest Land where local communities can maintain and develop their environmentally benevolent practices (see Part VII). Current activities are following up on the implementation of this decree. Research on the ecological interactions within these agroforests, focused on a better understanding of management options which include timber harvesting, and patch-level rejuvenation as an alternative to the field scale slash-and-burn methods practiced elsewhere, are ongoing.

Map3

I.2 Conflicting interest groups

The comprehensive measurements undertaken in ASB Phase II are intended to add to our understanding of the balance of economic and environmental effects of forest conversion and the resulting land uses. At least six distinct interest groups have a stake in the trajectory of land use change in Sumatra, but there are crucial differences among them in the weights they place on the various economic and environmental outcomes.

- The growing **'international community'** concerned with global climate change, extinction of species, and loss of distinctive ecosystems. It can be argued that all humans belong to this group since we share a collective interest in the global public goods of climatic stability and biodiversity conservation. These interests are served by preserving as much tropical rainforest as possible.

- Several thousand **hunter-gatherers** who continue their traditional migratory lifestyle within remaining forest fragments and national parks in Jambi Province and elsewhere in central Sumatra. These small family groups do not contribute to deforestation, so they have not been emphasized in the ASB research project. However, because their livelihoods depend heavily on extraction of forest products, they also benefit from preserving as much natural forest as possible in Sumatra. Thus, although their interests in maximum forest preservation coincide with the 'international community,' this derives from private benefits in terms of forest products and access to forests that are necessary for continuation of their lifestyle. (It also can be argued that all humans share an interest in the survival of this culture.)

- Although there can be conflict among indigenous groups, spontaneous migrants, or government-sponsored transmigrants over land, these millions of **small-scale farmers** all depend primarily on land converted from forest in order to make a living. Significant numbers also gather products from the forest and they share everyone's (diffuse) interest in the global environment, but their over-riding interest is in the profitability of their agricultural production systems and sustainability of their livelihood strategies.

- **Large-scale public and private estates** (operating forest concessions and plantations of 10,000–300,000 ha or more) pursue profitable resource extraction and land use alternatives. Like smallholders, these large operators presently receive few if any incentives or sanctions regarding the environmental impacts of their activities. But large estates and smallholders compete for a limited area of land, which contributes pressure for forest conversion. Moreover, the land uses and management strategies of large-scale estates differ significantly from smallholders' land uses in their social, economic, and environmental impacts.

- **Absentee farmers with medium-sized holdings** of 10-25 ha or more. They often live in nearby towns and are referred to as 'petani berdasi;' which means 'farmers with neckties.' These operators use similar technology to smallholders, but may be able to exert substantial influence, especially on local officials. Thus this category is intermediate between smallholders and large-scale estates.

- **Public policymakers**, who increasingly are 'caught in the middle' of these various groups, especially since Indonesia has been swept by political uncertainty. Ideally these policymakers would seek to balance their primary public policy objectives (often summarized as 'growth, equity, and stability') with pressures they face from the international community and various domestic interest groups. Since civil servants are not paid enough to live, those members of society who can pay the most – large-scale operators – can influence public policy. This means that bureaucrats and managers of large-scale estates often share a *private* interest in conversion of forests to large-scale plantations.

I.3 Criteria used in assessment of land use alternatives

Conversion of tropical forests causes release of stored carbon, which has been linked to global climate change, and the extinction of species. The search for 'alternatives' to unsustainable slash-and-burn derives from these global problems (climate change; loss of biodiversity), but objectives of smallholders and policymakers also are central concerns of ASB. Since many small-scale farmers practicing slash-and-burn appear to do so because they lack other feasible livelihood options, land use alternatives must meet these smallholders' objectives and fit their adoption constraints if they are to be viable.

Global environmental concerns. Alternative land uses at the forest margins differ significantly in their ability to substitute for the global environmental services of forests. Quantification of at least 3 indicators of the global environmental consequences of deforestation and other land use changes is essential to formulating sound policy responses--or even in knowing whether intervention is needed. Two of these indicators are linked to global climate change: ***carbon stocks*** and ***net absorption of greenhouse gases,*** carbon dioxide, methane and nitrous oxide. ASB researchers have taken an innovative and eclectic approach to measurements of ***biodiversity*** in order to assess richness of the alternative land use systems for major groups of organisms above and belowground. Aboveground measurements are done for plant functional groups as well as the more conventional taxonomic approach. Gillison's 'plant functional attributes' (PFA) approach provides an overall indicator of biodiversity richness that is suitable for cross-continent comparisons. Belowground assessments focus on organisms that influence agronomic sustainability. Results of these measurements for Indonesia are presented in Part II below. The techniques and protocols used are described in greater detail in the global working group reports (Gillison 1998; Palm *et al.,* 1998; Swift 1998; Weise 1998).

Agronomic sustainability. Agronomic sustainability refers to long term production capacity at the plot level, but researchers and farmers may differ in their assessment of what 'sustainable' means. Soil scientists and agronomists collaborating in ASB research identified a minimum set of seven components of agronomic sustainability, including adequate soil organic matter and nutrient balances (Weise 1998). Discussion of results for agronomic sustainability assessments undertaken for major land use systems in Sumatra is presented in Part III. Although it has not been possible to arrive at a single summary indicator for agronomic sustainability, it has been possible to use a mix of indicators of this multidimensional issue to assess the major land use systems of Sumatra's peneplains.

Smallholders' socioeconomic concerns. A minimum set of 3 quantifiable socioeconomic objectives were judged necessary for assessment of land use alternatives from the smallholders' perspective (Vosti *et al*. 1998; Tomich *et al*. 1998):

- ***Production incentives.*** Is the alternative profitable for smallholders? In other words, does it pay smallholders to invest in this alternative compared to other options?

- ***Labor constraints.*** Is it feasible for these households to supply the necessary labor themselves or to hire workers?

- ***Household food security.*** Even if the alternative is profitable and feasible given household labor constraints and labor market conditions, is it so risky (either in terms of variance in food yields or as a source of income to exchange for food) that adoption would jeopardize food security for the household?

Policymakers' concerns. Before the severe recent setback, Indonesia's development strategy had simultaneously pursued growth, equity, and stability—called 'the development trilogy'—with considerable success for over 30 years. Each of these broad goals yield criteria for assessment of land use alternatives. The following is *not* a comprehensive list of concerns of policymakers at the national and local levels; instead this list emphasizes the policy objectives that are most affected by land use change.

- ***Growth***. What is the **potential profitability** of the activity? In other words, does the country have comparative advantage in the activity? If so, expansion of this activity can contribute to economic growth.

- ***Equity*.** Would expansion of this activity create **employment opportunities**, especially for unskilled rural workers? Or would it displace these workers, forcing more to migrate to Indonesia's cities? If it is profitable, **is it adoptable by smallholders?** If so, the activity may have the potential to contribute to **poverty alleviation**.

- ***Stability*.** 'Stability' has many possible interpretations. Stability of staple food prices **-- national food security** – has been a hallmark of Indonesian development strategy. However, since none of the land use alternatives considered below could make a significant contribution to national food security, this topic receives no attention in the analysis. Loss of **macroeconomic stability** over the past year has led to even more emphasis on export promotion, including primary products from forestry and agriculture. (After petroleum, plywood, rubber, and coffee are among Indonesia's major primary exports.) And the present lack of **social and political stability** is related, at least in part, to obvious inequities in the political economy. As mentioned above, **employment opportunities** and other **poverty alleviation** measures are components of the equity goal and alternative paths of land use change can have significant effects on these objectives. Finally, as brought home by the catastrophic El Niño of 1997/98, **environmental stability** increasingly makes its way onto policymakers' agendas. Examples linked with land use change include the recurring regional problem of smoke and long-standing concerns about watershed functions.

One of the strategic challenges facing policymakers will be to reinterpret the 'development trilogy' in light of the fundamental structural changes that are occurring in Indonesia. Because of the financial crisis that has swept Southeast Asia, 'stability' may seem to be of paramount importance in the near- to medium-term. But, as in the past, there are options to seek stability along with equity and growth.

Institutional barriers to adoption. Quantitative measures of the concerns of smallholders and policymakers need to be supplemented by (usually qualitative) assessment of institutional endowments as they affect land, labor, capital, and commodity markets as well as availability of information on production technology. In turn, markets and other institutions affect feasibility of adoption of technological innovations by smallholders. Formal and informal land and tree tenure institutions, often operating at the *community level*, appear to be key determinants of incentives (and disincentives) for investment in productive assets and for sustainable resource management. Do formal and informal institutions and the regulatory framework create incentives that are compatible with sustainable resource management? Could banks supply initial capital requirements of land use alternatives? If not, are interest rates in the informal market prohibitive? Do infrastructure bottlenecks inhibit input supply and output marketing? Can formal or informal channels of communication provide useful information about new techniques and land use alternatives that are not already familiar? These issues are addressed in Parts V and VI.

I.4 The ASB Matrix

The central task of the ASB research program is to identify which land use systems (and technological innovations to raise their productivity) have the best chance of attaining these multiple environmental, agronomic, socioeconomic, and policy objectives and to quantify any tradeoffs among these objectives. Measurement of field-level differences in the economic, agronomic and global environmental consequences of the various land use systems provides a starting point for quantifying some of the major tradeoffs involved in land use change and for identifying 'best bet' alternatives that provide an attractive balance among competing objectives.

What do we mean by *best bet*? Tomich *et al* (1998) define a *best bet* land use alternative as 'a way to manage tropical rainforests or a forest-derived land use that, when supported by necessary technological and institutional innovation and policy reform, somehow takes into consideration the local private and global public goods and services that tropical rainforests supply.' This implies a significant contribution to each of the broad sets of criteria discussed above regarding the global environment, agronomic sustainability, smallholders' concerns, and policymakers' objectives.

The ASB 'Meta' Matrix. Ultimately the complexity of the process of identifying one or more 'best bets' for a specific setting depends on the extent of complementarity or conflict across criteria. Even the parsimonious approach of the preceding section identified 4 broad classes of criteria corresponding to diverse, sometimes conflicting, interests of various international, national, and local groups. Moreover, as we discuss in detail in Parts II-IV below, each criterion comprises many possible indicators to be considered in assessing 'best bets.'

If measurements reveal many tradeoffs across objectives, either a multidimensional decision-scheme or some system of weighting competing objectives is needed to identify a 'best bet'. Economic valuation provides a suitable weighting scheme for some of the indicators, but is problematic for others (e.g., biodiversity). The difficulty of this task is compounded by the differing perceptions of these criteria across the various interest groups concerned and the difficulty in identifying appropriate indicators for the various criteria. Thus it is unlikely that this problem of choice of 'best bet' land use alternatives (and possibilities for development of suitable technological innovations) can be captured in a single, summary measure.

A general matrix format was developed (Tomich *et al.*, 1998) as an alternative to a futile quest for a single indicator. This matrix is a framework to organize the data for assessment of possible tradeoffs and complementarities across specific indicators used for assessment of the broad classes of criteria discussed so far. The general version of this framework, the 'ASB Meta Matrix,' appears in Figure I.1. The columns of this matrix are the general classes of criteria discussed above. The rows are seven 'meta' land uses that were selected for global comparisons across ASB study sites. These rows correspond to specific land uses found in Sumatra, which are described below. Sections II-IV of this report will test specific indicators of general criteria. The ASB-Indonesia matrix derived from those specific indicators is presented in Part V as the basic tool for linking assessment of global environmental benefits with sustainable land use alternatives.

Figure I.1 *ASB Matrix For Evaluating Land Use Systems as Potential Best Bets for Alternatives to Slash-and-Burn at Forest Margins*

Meta Land Uses	Global Environmental Concerns	Agronomic Sustainability	Smallholders' Socioeconomic Concerns	Policy & Institutional Issues
Natural Forest				
Forest Extraction				
Complex, Multistrata Agroforestry Systems				
Simple Treecrop Systems				
Crop/Fallow Systems				
Continuous Annual Cropping Systems				
Grasslands/Pasture				

I.5 ASB 'meta' land uses and major land uses in Sumatra

Seven 'Meta' land uses were selected to organize the national ASB research agendas in a way that would facilitate cross-site comparisons (Table I.2). Because deforestation is among the primary concerns of this research, natural forests provide the basic reference point for global environmental concerns. Grasslands and pastures are included as reference points at the opposite ecological extreme. In between, a representative range of five generic upland, rainfed land use systems were selected for cross-continent comparisons of alternatives: extraction of forest products; complex multistrata agroforestry systems, also known as 'agroforests'; simple treecrop systems, including but not limited to monoculture; crop fallow systems, which include the textbook version of 'shifting cultivation' or slash-and- burn agriculture; and continuous annual cropping systems, which may be monocultures or mixed cropping. This sampling scheme was chosen to cover the spectrum of land use intensification and to provide counterpart land use types that can be found in the other ASB sites (Brazil, Cameroon, Thailand, and Peru) as well as Indonesia.

Table I.2 ASB 'meta' land uses & corresponding land uses of Sumatra's peneplains

'Meta' land use	Corresponding land use in peneplains of Sumatra	Scale of operating unit
Natural forest	Natural forest	n.a.
Forest extraction	Community-based forest management	Community-level
	Commercial logging	Large-scale enterprise
Complex, multistrata agroforestry systems	Rubber agroforests	Smallholdings
Simple treecrop systems	Rubber monoculture	Smallholdings participating in a government project
	Oil palm / industrial timber monoculture	Large-scale estate enterprise
Crop / fallow systems	Upland rice / bush fallow rotation	Smallholdings
Continuous annual cropping systems	Monoculture cassava degrading to *Imperata cylindrica*	Smallholdings in a government settlement project
Grasslands / pasture	*Imperata cylindrica*	Sheet *Imperata* (>10,000 ha) used for grazing, hunting & other activities by local communities.

Table I.2 also indicates major land uses of Sumatra's peneplains that correspond to each of the 'meta' land use systems. Not all of these categories can be distinguished in remote sensing data, but for the major ones spatial data can be collected. These systems were selected for study in ASB Phase II, but this is by no means an exhaustive list of land uses in Sumatra's peneplains. For instance, there are countless complex, multistrata systems (agroforests) that could be studied. **Rubber agroforests** were the obvious choice for study at this stage because they are by far the most extensive smallholder land use in the peneplains of Sumatra and portions of Kalimantan. In future work, we hope to extend our studies to the damar agroforests of Krui and other agroforest systems because of their economic and environmental features. Similarly, **rubber, oil palm, and timber monoculture** are not the only simple treecrop systems, but they are the most extensive examples for this 'meta' land use category. On the other hand, in stark contrast to ASB sites in the Western Amazon, pastures are extremely rare in Sumatra. Thus, the pattern of **monoculture cassava degrading to *Imperata cylindrica*** was used for two 'meta' land uses, continuous annuals and grasslands/pasture. Phase I characterization revealed that many households operate at least one **wet rice field** (*sawah*), but this important example of a continuous annual cropping system was not studied in Phase II because wet rice does not account for a significant share of ongoing forest conversion.[1]

Coordinating data collection for ASB Phase II required a great deal of attention to specific characteristics of the major land uses selected for detailed study. Along with additional descriptive information for each land use, Table I.3 also provides information on two characteristics of Sumatran systems – type / scale of operation and landscape mosaic – that are particularly important in Indonesia.

The Sumatran sites, and Indonesia's Outer Islands more generally, are distinctive among ASB study areas because of the intense competition for land between smallholders and large-scale operators. This **dualism in the type and scale of operation** is central to assessment of 'best bet' land use alternatives in Indonesia. (It also is embedded in Indonesia's colonial history and its recent development strategy.) While the smallholder systems seem to offer clear benefits in terms of certain of the indicators presented in the balance of this report, the conventional wisdom among planners and some donors has been that large-scale systems are the 'best bets' in terms of economic development potential. In Part IV, however, we stress that this presumption is questionable. To study this issue of scale, paired comparisons of smallholder and large-scale land use alternatives were included in the research design for forest extraction, contrasting community-based forest management with large-scale commercial logging, and for simple treecrops systems, contrasting smallholder rubber monoculture with large-scale oil palm and industrial timber monoculture. (There are no large-scale systems corresponding to complex, multistrata agroforestry, crop / fallow systems, or continuous annual crops.)

The dualism in scale of operation produces an important distinction in **landscape mosaic context** between the ecological functions of an indigenous smallholder landscape mosaic and the landscape produced by large-scale plantation monoculture. These landscape scale issues are beyond the scope of ASB Phase II, but this is expected to be a major thrust in future ASB research in Indonesia and elsewhere in Southeast Asia. The matrix that will be compiled in this report is for the **forest margins** – i.e., it takes conversion of natural forest as the point of departure. (Future plans include application of the same tool to assess alternatives for rehabilitation of '**degraded lands**' such as *Imperata* grasslands—but values in the matrix must be adjusted to reflect that scenario.) Table I.4 summarizes the succession of land covers at the forest margins,

[1] **Home gardens** (*pekarangan*), which include 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. Little forest has been converted to establish home gardens, so like wet rice, this example of complex multistrata agroforestry systems was not a priority for study in Phase II.

Table I.3 Specifications for major land uses at the forest margin of the peneplains of Sumatra, Indonesia

'Meta' land use	Corresponding land use in lowland Sumatra	Type / scale of operation	Landscape mosaic context	Description
Natural forest	Natural forest	25 ha fragment within a logging concession	Forest mosaic	Reference point: primary baseline for assessment of land use alternatives. Undisturbed for at least 100 years.
Forest extraction	Community-based forest management	Common forest land of 10,000 ha to 35,000 ha	Indigenous smallholder landscape	Reference point/possible ASB best bet: products are honey (every 2 years), fish, petai, rattan, songbirds, jengkol, and durian, among others.
	Commercial logging	Logging concession of 35,000 ha or more	Forest mosaic	Reference point / best bet from official perspective: simulation of Indonesian 'sustainable logging system'; 40 yr cycle. Reference point: based on estimates of actual harvesting behavior for a concession that recently has been renewed; 20-25 yr cycle.
Complex, multistrata agroforestry systems	Rubber agroforests	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape	Indigenous system: forest clearing followed by upland rice and planting of 'unselected' rubber seedlings, with natural regeneration of forest species. This is the dominant smallholder land use.
	Rubber agroforests with improved planting material	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape	Possible ASB best bet: forest clearing followed by upland rice and planting of rubber clones, with natural regeneration of natural forest species.
Simple treecrop systems	Rubber monoculture	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape	(Formerly) best bet from official perspective: upland rice and planting of rubber clones, with intensive use of inputs and labor to prevent regeneration of natural forest species.
	Oil palm monoculture	Large-scale private estate of 35,000 ha or more	Monoculture plantation	Best bet from official perspective: plantation oil palm grown in close association with processing mill. (Processing not included in the economic analysis.)
	Industrial timber monoculture	Large-scale private estate of 35,000 ha or more	Monoculture plantation	Best bet from official perspective: plantation timber grown for pulp (*Acacia mangium*) or for sawn timber (*Paraserianthes falcata*). (Processing not included in the economic analysis.)
Crop / fallow systems	Upland rice / bush fallow rotation (shifting cultivation)	Smallholders' plots of 1-2 ha per year, often located in community land	Indigenous smallholder landscape	Reference point: One year of upland rice followed by bush fallow of 10 years of more. The dominant smallholder land use of 100 years ago, now rare. Reference point: One year of upland rice followed by a short bush fallow of 5 years or less. Now found only in isolated areas.
Continuous annual crops / grasslands	Continuous cassava degrading to *Imperata cylindrica* grassland	Smallholders' plots of 1-2 ha within large-scale settlement project	Large transmigration project divided into small plots	Reference point: monocrop cassava with little use of purchased inputs. (See land cover table for pattern.) Reference point: monocrop cassava with intensive use of purchased inputs.

from initial forest clearing in cases where forest conversion occurs through the subsequent 25 years for the major land uses studied in Sumatra's peneplains.

It is worth emphasizing that **'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. Although traditional shifting cultivation has been disappearing as rural population densities increase, 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 -- sometimes in systems that are unsustainable but often in systems that apparently are sustainable for the foreseeable future. For example, agroforests begin with slash-and-burn clearing and intercropping of upland foodcrops, but the primary objective is establishment of treecrops like rubber and various fruit and timber species. Although created by local people, the management system accommodates natural regeneration. As a result, agroforests replicate certain elements of forest structure and ecology (Michon and de Foresta, 1995). For some agroforest systems, most notably the damar agroforests of Krui, the initial slash-and-burn event may also be the last because the climax system can be sustained through gap replanting.

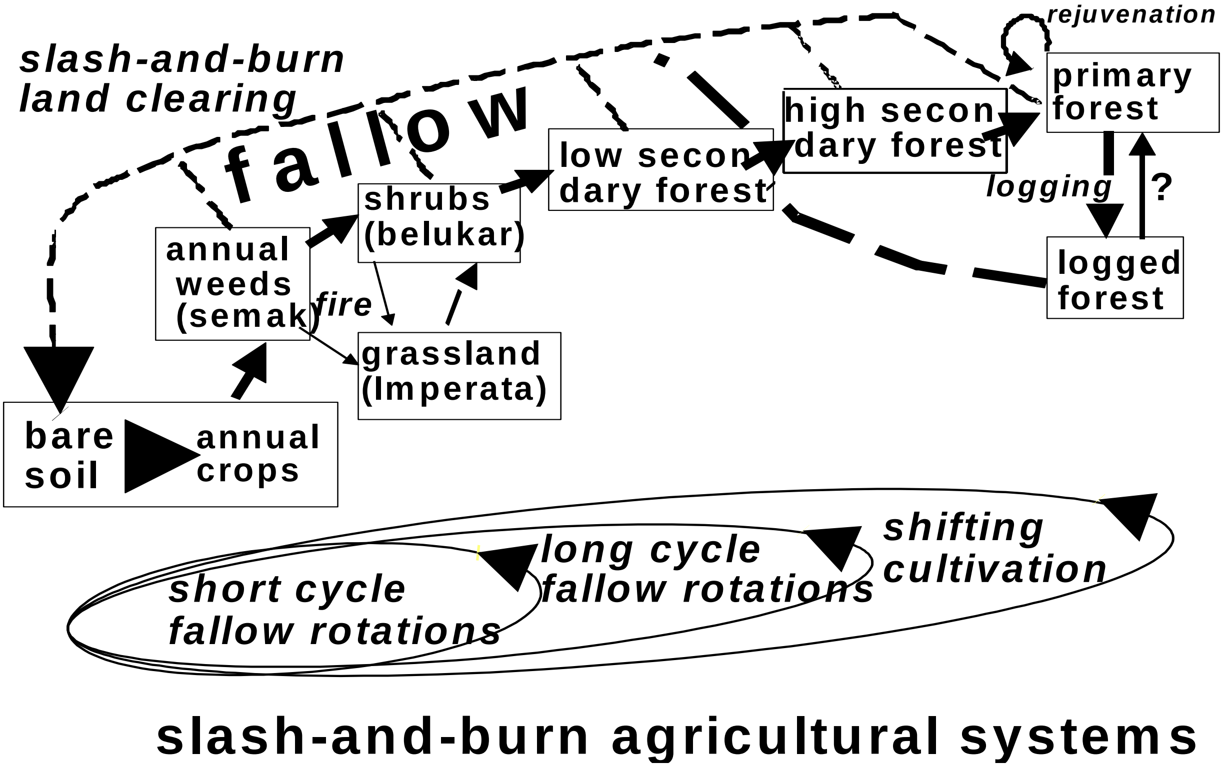


Figure 1.2 *Transitions between land covers as part of fallow rotation systems*

Figure I.2 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 I.3 includes the major 'alternative to slash-and- burn' in Sumatra, in the form of agroforests, with a large share of directly useful trees.

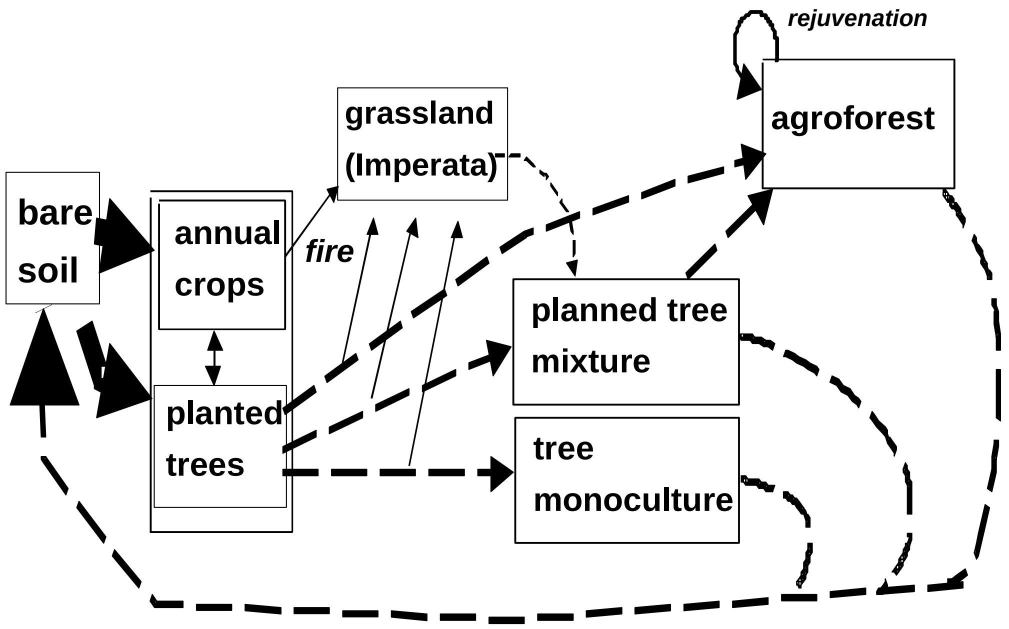


Figure 1.3 *Land use systems that are alternatives to traditional slash-and-burn systems.*

Table I.4 Land uses of Sumatra's peneplains: changes in land cover over time, from '0' (original cover) to 25 years

Land use	*'R' value**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Natural forest	0	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
Community forestry	0	NF	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Commercial logging	0	NF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF
Rubber agroforest	0.08	NF	UR SR	UR SR	SR	SR	SR	SR	SR	SR	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h	SR h
Rubber monoculture	0.08	NF LF	UR CR	UR CR	CR	CR	CR	CR	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h	CR h
Oil palm monoculture	0	NF LF	OP	OP	OP	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h	OP h
Industrial timber monoculture	0	NF LF	IT	IT	IT	IT	IT	IT	IT	IT h	IT	IT	IT	IT	IT	IT	IT	IT h	IT	IT	IT	IT	IT	IT	IT	IT	IT h
Upland rice / 5-year bush fallow rotation	0.17	NF	UR	BF	BF	BF	BF	BF	UR	BF	BF	BF	BF	BF	UR	BF	BF	BF	BF	BF	UR	BF	BF	BF	BF	BF	UR
Low-input cassava degrading to Imperata cylindrica	0.6	NF LF	CA	CA	CA	CA	CA	CA	CA	IC	IC	IC	CA	CA	CA	IC	IC	IC	CA	CA	CA	IC	IC	IC	CA	CA	CA

** The Ruthenberg 'R' value = years of foodcrops / 25 years*
NF=natural forest; FE=extraction of forest products; LF=logged forest; UR=upland rice; SR=seedling rubber; CR=clonal rubber; OP=oil palm; IT=Acacia mangium or Paraserianthes falcataria; BF=bush fallow; CA=cassava; IC=Imperata cylindrica; h=harvest of perennials

The following operational definitions are used for the six land uses analyzed in the balance of this report.:

1. **Community-based forest management**, including extraction of non-timber forest products but *not* timber. Data for this study were collected in a community-managed forest in the Jambi ASB benchmark area. These estimates are a lower bound for profitability of this land use for two reasons. First, it was not possible to cover all the myriad commodities collected from the forest by local villagers. A comprehensive study would require much more time than was feasible in ASB Phase II. Researchers focused on the commodities that villagers reported were most important to them. These included honey, fish, durian (*Durio zibethinus*) fruit, jengkol (*Pithecelobium jiringa*) pods, and petai (*Parkia speciosa)* pods, which appear to be harvested sustainably, and various species of song birds and rattan, which apparently are not. Two estimates--one based on sustainable harvests only and another including songbirds and rattan--are reported in Tables IV.3-5. Second, because restrictions banning logging by villagers are enforced actively it was not possible to obtain data about villagers' timber extraction from this forest.

2. **Large-scale commercial logging** was studied on forest concessions in Jambi. The Department of Forestry faces serious problems in regulating logging companies. This study emphasized concessions that were among the better managed. Data reported here are for a logging company that is (one of the few) to have its concession renewed, indicating better compliance with regulations for the 'Indonesian Sustainable Logging System.' Two sets of estimates are reported; one represents complete compliance with those regulations, the other is closer to actual practice. Note that all the other land use alternatives in the ASB-Indonesia matrix that involve forest conversion could sell timber as a product of land clearing. Since this rarely happens in the case of smallholders, this timber is not valued in the other systems.

3. **Smallholder rubber**, including both **rubber agroforests** and **rubber monoculture.** The initial study of rubber agroforests ('jungle rubber') planted with seedlings was supplemented with data from another ongoing ICRAF study (Suyanto *et al.*, 1998). Subsequently additional data from an ICRAF/ CIRAD project in Jambi (E Penot *pers comm.*) were used to add an analysis of rubber agroforests planted with higher-yielding PB 260 clones. Since smallholder rubber monoculture is rare in Sumatra outside of government projects, the study of rubber monoculture is based on a specific project in Jambi province using GT1 clonal seedlings, which are the most widespread in Sumatra and Kalimantan. *The rows in the ASB Indonesia matrix for rubber agroforests planted with clones and for rubber monoculture are in italics because they may not be widely representative of smallholder experience.*

4. **Large-scale plantations of oil palm and industrial timber estates** have been established in Jambi and in Lampung, but none have reached maturity. These studies were conducted in Riau Province in Central Sumatra where these plantations were established earlier and already are productive. Conditions in Riau are similar to the forest margins of Jambi. Estimates for large-scale industrial timber were not yet available at the time of this report.

5. **Upland rice with bush fallow** has nearly disappeared from the peneplains and is only found in isolated pockets of Sumatra's piedmont, including some villages in the Jambi benchmark area where customary law prohibits tree planting on certain village lands. Two sets of estimates are presented, one for the short-fallow cycle of 5 years or less that now prevails, and which may not be sustainable, and one for the longer fallow cycle of 10 years or more, which no longer is feasible because of population pressure.

6. Transmigration systems, focusing on **cassava and *Imperata cylindrica*** (*alang-alang*) represent the continuous annual cropping and the grasslands 'meta' systems. Wet rice (*sawah*) is ubiquitous, but other forms of continuous annual cropping are rare in Sumatra except in transmigration settlement sites. On the transmigration site in Lampung, continuous monoculture of cassava and maize and rotations of cassava and maize are common. These fields often are plagued by *Imperata cylindrica*. Estimates for continuous cassava monoculture degrading to *Imperata* are reported here because these were intended to be comparable with other ASB sites.

I.6 Some caveats regarding the ASB Matrix approach

To obtain estimates of regional or global impact directly from measures like those described here, which are estimated per ha, it is necessary to assume independence--and hence additivity--across space. This assumption is reasonable for some measures (e.g., carbon stocks), but it is only a first order approximation for others. Among these measurements, biodiversity is the most sensitive to scaling issues. For example, this research alone cannot answer the question of how much biodiversity will be lost for each hectare of forest converted to another land use. The main methodological gaps concern scaling over space and over time. As one samples biodiversity over larger and larger areas of a particular ecosystem, the number of additional species observed will increase, but at a decreasing rate. Some of the species found in each new sample plot already will have been encountered in previous plots; only a fraction will be observed for the first time and this fraction tends to decline as the sample size increases. This complementarity across space means that one cannot simply add biodiversity values across plots. Nor can the number of species seen on a small study area tell us how much land is needed to conserve those species. If that piece of land were to be surrounded by land under different uses, the number and type of species could change dramatically. These species' long-term survival prospects depend on the extent of their habitat, but this is influenced by the pattern of land cover in the landscape. For example, although the plots of Sumatran rubber agroforests studied so far may harbor half to two-thirds of the biodiversity of an equivalent area of natural forest, it is not known whether the same is true if one were to compare a million hectares of rubber agroforests to an equal amount of natural forest. Even less is known about what happens if these million hectares occur in a mosaic with undisturbed forest patches.

Spatial scale also affects profitability of land use alternatives in at least two ways. First, transport costs, a function of distance, affect farmgate prices. Second, the extent of a particular land use affects aggregate supply for specific commodities, which, depending on their elasticity of demand, affects their price. And while the agronomic sustainability measure used here concerns only the on-site, field-level effects, the extent and spatial arrangement of land use alternatives also produces environmental externalities (e.g., siltation, smoke, fire, and floods). Similarly, net greenhouse gas emissions to the atmosphere probably are influenced by the spatial arrangement of sources and sinks at the landscape scale. One of the key challenges of future ASB research is to develop methods and to extend existing databases to be able to assess these phenomena at the landscape level. Ultimately, *best bets* probably will not refer to a single land use system or technology, since the most attractive way to achieve the various objectives is likely to come from combinations of complementary land use practices in a given spatial context (van Noordwijk *et al*., 1997). This whole-farm and landscape-level analysis is not feasible now. The land use-specific analysis presented here is a necessary precursor to that work.

II. Global environmental impacts: criteria and indicators

Land use at the forest margins has an impact on two global environmental concerns: the net emissions of greenhouse gasses (carbon dioxide, methane and nitrous oxide) which are believed to have an impact on global climate change, and the conservation of biodiversity.

The criterion for effects of land use change on net greenhouse gas emissions can be explained by reference to the effects on natural forests. When considered over large enough scales (in space and/or time) the net carbon exchange between vegetation and atmosphere shows a small flux, equal to the export of organic compounds in soil and water into non-terrestrial ecosystems. The current C stocks in forest systems are large relative to these fluxes and the main issue is in the fate of this stock during land cover change. The two other greenhouse gasses of main global interest (methane and nitrous oxide) can show net emissions or absorption, depending on local soil conditions. Wetland sites (swamp forests as well as rice paddies) generally emit methane, while upland forest soils can absorb and oxidize methane. Nitrous oxide is emitted from all soils where mineral nitrogen is present under relatively wet and warm conditions (so including natural forests), but there may be absorption into green vegetation under certain circumstances. Effects of land use change on greenhouse gas emissions can be measured and expressed in units that allow comparison with industrial emissions, and in the end an economic comparison can be made between the costs of reducing emissions in various sectors of society. Hence, it is important to quantify the effect of land use and land use change on these gasses as fluxes (amount of gas molecules per unit land surface area and unit time).

For biodiversity the criterion is the maintenance of global diversity and the role a particular area plays in that respect, but there is no currency equivalent to the one for greenhouse gases -- diversity measures can be expressed per unit area and per unit time, but can not be converted easily to other units of area or extrapolated in time. For example, if two areas both contain 100 different species, the combined area can contain anywhere between 100 and 200 species, depending on the species overlap. The contribution of a particular site to global biodiversity conservation depends largely on the number of unique flora and fauna elements it contains. Although survey data can show what plants and animals are currently present in a given sampling area, the really important question of how many of these species (or other taxonomic units or genes which are taken as the basis of comparison) would survive over a time frame of X years, can not be directly assessed (Rosenzweig, 1995). Dynamics of local extinction and recolonization depend on the landscape mosaic in which land use systems occur, as well as on the means of dispersal of the organisms concerned. As a very first step into such a dynamic analysis, local species richness is often used as an indicator, largely for lack of better measures. Local species richness can not be compared across ecosystems or even between continents, however, and the best we can do is express local species richness for various land use types *relative* to that of natural forest. We have to realize, however, that these ratio's can not be added or subtracted, and that their value probably depends on the scale at which measurements were made. For example, previous comparisons of plant diversity in rubber agroforests showed a local species richness of at least half that of a natural forest, for a 40 m line transect. This does not mean, however, that 1 ha of rubber agroforests will contain (let alone conserve) half the species of 1 ha of natural forest; comparisons at the level of Jambi province are even more uncertain, as it may well be that the 50% forest species in the jungle rubber are generalists, occurring throughout the province and the species not present in the jungle rubber are local specialists, with a different diversity/scale relationship. Despite all these caveats, we will present data here comparing biodiversity indices based on higher plants, which indicate the similarity between sample sites in forest and non-forest, based on a new technique of 'plant functional attributes' (Gillison 1998).

We also collected data on belowground biodiversity, as this is an aspect on which little data exist. Parts of the belowground biodiversity may be directly relevant to the farmer, as they effect 'ecological service functions' (mineralization, soil structure maintenance, symbionts, soil-borne diseases and their control).

II.1 Carbon stocks

Lowland tropical rain forests have the highest standing biomass and aboveground carbon stocks of any vegetation in the world, and total C stocks of rain forests are only equaled by the deepest peat soils. Measurements in Jambi (Fig. II.1) indicate that the total carbon stock of natural forests on the peneplain (above a soil depth of 30 cm) can be up to 50 kg m^{-2} or 500 Mg ha^{-1}, with roughly 80% in live trees, 10% in dead wood and 10% in the soil. In logged forests (about 10 years after the logging event), live tree biomass is substantially reduced, but there is more C in dead wood and at least as much in the soil. In cassava fields total C stock can be reduced to about 10% of that in the forest, but soil stocks are still similar to those in the forest. (These data have not been corrected for differences in soil texture, however; compare the Corg/Cref ratio's described in chapter III).

Conversion of rain forest to other land uses, regardless of the technique used for conversion, is thus bound to reduce the amount of C stored in terrestrial ecosystems. As the total net release rate of carbon dioxide (CO_2) into the atmosphere from land use change and fossil fuel emissions exceeds the rate at which the ocean surfaces can absorb additional CO_2, atmospheric CO_2 concentrations increase.

Imperata	1.7135	2.4135	1.266125	1.314088	0.043425	0	0.091575	0				
Chromolae	2.724	2.992	1.638	1.785186	0.25065	0	0.15075	0				

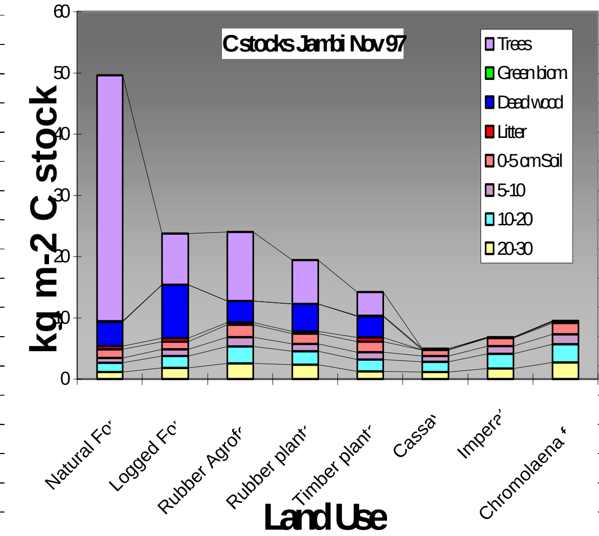


Figure II.1 *Carbon stocks in a range of land uses in Jambi*

In combination with other greenhouse gases, CO_2 is held responsible for increasing the ‘greenhouse effect’ of reflecting radiation from the earth, leading to changes in circulation patterns affecting local climate, as well as causing an overall warming of the planet and an ensuing rise in sea levels. Apart from accepting and adjusting to these climate changes, the main mitigation options are to reduce fossil fuel use and slow down or reverse the trend of declining C stocks in terrestrial ecosystems. In all terrestrial ecosystems C sequestration (fixation) and C dissipation (release) are approximately in equilibrium, with the vast majority of carbon dioxide (CO_2) molecules captured by photosynthesis in leaves during the day being respired at night or during decomposition of litter. Only during phases of build-up of biomass (aboveground or in roots) does the C stock of an ecosystem increase. But in all natural ecosystems, phases of decline and rejuvenation follow phases of growth. And in managed ecosystems, harvest procedures arrest accumulation and usually lead to a period of rejuvenation. In evaluating the C stock of land use systems we have to choose a time frame: following CO_2 molecules at a day or seasonal scale is not necessary, as long as annual increments over the typical life span of a system can be predicted.

Averaging the C stock over the life span of a system gives a simple measure of its role in the global C balance, as long as different stages of the system may be expected to occur in roughly proportional areas at any point in time. If we can assign a typical ‘time-averaged Carbon stock (Mg ha^{-1})' to each land use type, we can directly evaluate how 'land use change' will lead to net C release or net C sequestration, depending on the sign of the difference of 'Cstock(after) – Cstock(before)'.This means that an evaluation of the C stock of a land use depends on the context and the types of comparisons made: compared to natural forest all other land use types lead to net C release to the atmosphere, compared to continuous annual crops, all other land uses lead to C sequestration.

Of particular relevance here may be the C stock of shifting cultivation systems. Fig. II.2 shows how the 'time-averaged C stock' depends on the length of fallow and the rate of C sequestration per year during the fallow. For very low land use intensities the time-averaged C stock of shifting cultivation may approach that of a natural forest, as the maximum C stock may be the same and the short episode of slash-and-burn and production of food crops may resemble what happens after a mature tree dies, falls and creates a gap. During intensification of shifting cultivation systems, the time-averaged C stock will decrease rapidly (note the logarithmic scale used for the Y axis in the graph). This analysis emphasizes the systems context of forest clearing: if it is done in the context of long-fallow rotations it will decrease the C stock much less than when it is done for (supposedly) permanent food-crop cultivation.

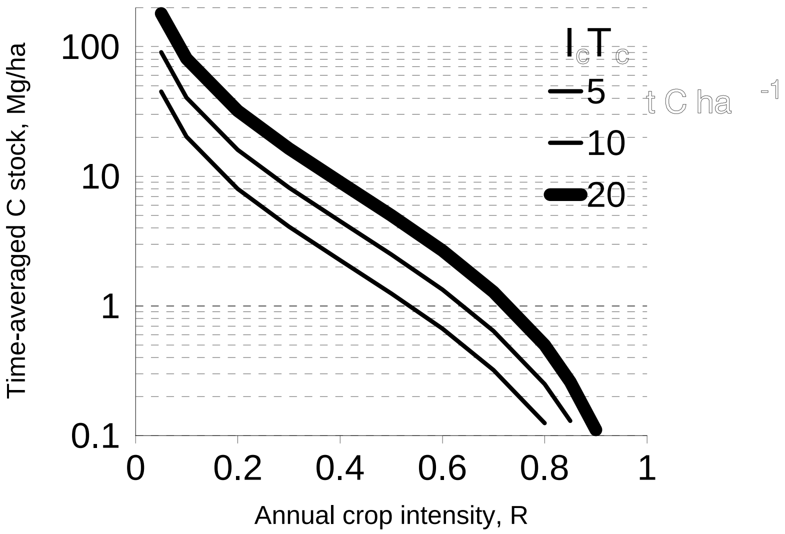


Figure II.2 *Time-averaged Carbon stock of shifting cultivation and fallow rotation systems, as a function of the land use intensity R = Tc/(Tc + Tf) where Tc is length of cropping period (yr), Tf = length of fallow regrowth period (yr) and Ic = annual C accumulation rate during fallow regrowth (Mg ha^{-1} yr^{-1})*

To estimate the time-averaged C stock of the range of land use systems evaluated as 'alternatives to slash and burn', we need the following information:

- Is it a rotational system where periodically whole fields are cleared of vegetation to start a new cycle, or is it managed under permanent vegetation cover?
- What is the length of a single rotation cycle?

- What is the rate of C sequestration per year during the various stages of the cycle (e.g. during periods where annual food crops are grown and during periods of fallow regrowth)?
- Does the C stock reach a maximum at which annual C sequestration levels off?

The land use systems chosen for evaluation all are rotational in nature, except for the community managed forest with extraction of non-timber forest products. Commercial logging (officially) consists of logging episodes and periods where the forest can recover. All other land use systems involve field clearing at the start of a new cycle, mostly using slash-and-burn techniques of land clearing. Some of the rubber agroforests may evolve into a stage of gap-level rejuvenation instead of field level clearing, but the form chosen for evaluation of profitability (chapter IV) is a rotational form. (We will come back to the issue of rotational versus permanent agroforests in chapter IV).

The main remaining uncertainty is the annual rate of C sequestration. The measurements of standing C stock in a range of land uses at different ages since land clearing by slash-and-burn can be used to estimate an average rate of C sequestration (Fig. II.3). In the figure three groups of land use are distinguished:

- logged-over forests; we have to make a rather arbitrary decision on the effective age of the natural forest and the line connecting the points of logged forest with natural forest may overestimate C sequestration if logging has done near-permanent damage to part of the system (such a logging ramps and trails, see chapter III),
- natural fallows (secondary forests), agroforests and more intensive tree-crop production systems, which apparently accumulate at a rate of about 2.5 Mg C ha-1 yr-1
- cassava/*Imperata* systems where there is a negligible rate of C accumulation with age, presumably because annual fires prevent the build up of C stocks in vegetation.

On the basis of these results time-averaged C stocks were assigned to the land use types chosen for evaluation (Table II.1).

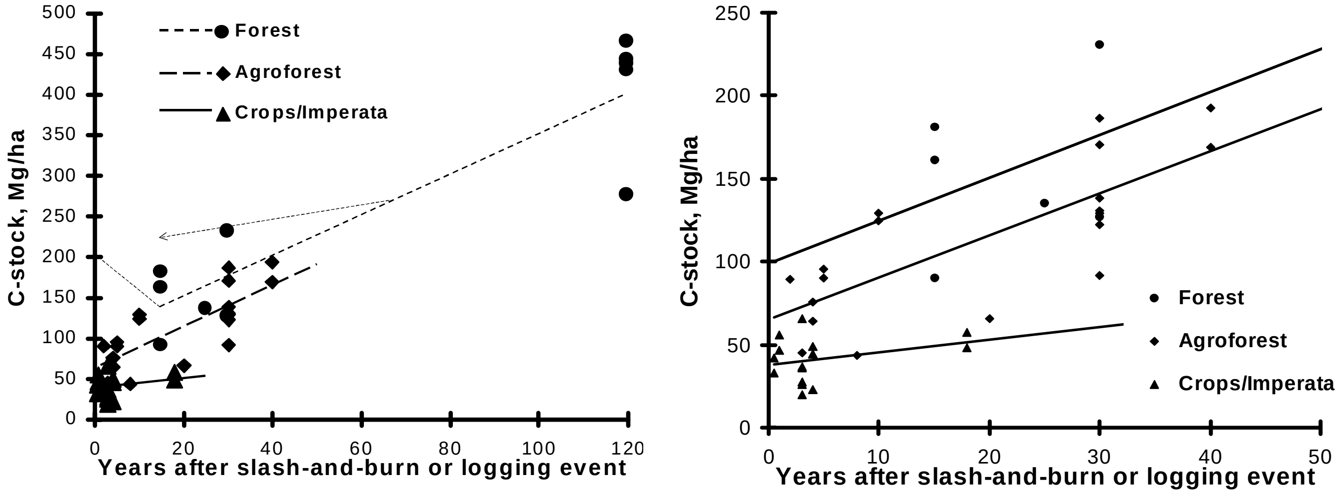


Fig. II.3 *Carbon stock in aboveground biomass, surface litter and top 30 cm of the soil, as a function of time since forest clearing (slash-and-burn) or logging (left: whole data set, right: excluding the natural forest plots)*

Table II.1 *Time-averaged carbon stocks for land uses of the lowland peneplain; three regression lines were used for the calculations (1 for forest, 2 for agroforest and tree-crop plantations, 3 for cassava-imperata)*

Land use system	Line	Maximum age (yr)	Time averaged C stock Mg ha^{-1}
Natural forest	1	120	254
Community-based fores management	1	60	176
Commercial logging	1	40	150
Rubber agroforests	2	40	116
Rubber agroforests with selected planting material	2	30	103
Rubber monoculture	2	25	97
Oil palm monoculture	2	20	91
Upland rice/ bush fallow rotation	2	7	74
Cassava/*Imperata* rotation	3	3	39

The values given here contain many assumptions. As part of the ASB-Phase 2 activities in Indonesia, efforts were made to use the Century model (Parton *et al*., 1987, 1994) for typical transitions from forest into other land use patterns. As the best data on such a time series were collected in the Lampung benchmark area for a forest-to-sugarcane conversion series (where isotope discrimination allows us to follow the fate of 'forest' versus 'cane' organic inputs, Hairiah *et al*., 1995), model efforts focussed on this series for model validation (Sitompul *et al*., 1996). Modifications were made to the core routines of the Century model to represent fractions similar to the measurable size-density fractions

(LUDOX method, Hairiah *et al.*, 1995). The results (Fig. II.4) show that good agreement between measured data and modelled estimates could indeed be obtained.

When the same model was used, however, for data of the KILLSOM/ADDSOM experiment at the BMSF station in the Lampung benchmark area, agreement between measured and modeled was less convincing (Fig. II.5); the experimental data contain a substantial scatter, indicating micro-variability not accounted for in the model. Simulations for *Peltophorum* inputs deviated more from measured points, possibly due to the effect of polyphenolic substances not yet accounted for in the Century model. Overall this experiment shows that none of the organic input treatments is able to maintain the soil organic matter level as it was at the start of the experiment, despite total inputs from litter of at least 8 Mg ha^{-1}. The main reason for this effect may be a lack of soil macrofauna incorporating litter into the soil -- nearly all inputs decompose at the soil surface and probably contribute little to soil C pools. The century model can be modified to include such effects of soil fauna, and this appears to be a priority area if a better prediction of land use effects on soil carbon pools is needed. Better predictions of soil carbon fractions, however, appear to be more relevant for 'sustainability' issues than they are for the total C balance. Changes in total carbon stocks are clearly dominated by changes in aboveground biomass and a better prediction of vegetation development is key to improved modeling of land use effects.

II.2 Greenhouse gas emissions

Measurements of the net flux of methane and nitrous oxide were made in a wide range of land use systems. Scaling up from point measurements to typical fluxes over the life span of a land use system (similar to the time-averaged C stock) is not yet possible, however. Day/night as well as seasonal rhythms have to be considered to derive annual flux data, which should be combined for the year of forest clearance and slash-and-burn, early re-growth etc.

Table II.2 summarizes the flux data obtained in the wet and dry season for the land uses of our current evaluation. Methane oxidation rates were higher in the dry than in the wet season. The low level of NH_4 and NO_3 in *Imperata* and cassava might have caused the low N_2O emission from those land-use systems. Data on N-mineralisation, therefore, have to be analyzed to explain the difference with nitrification or denitrification pathways. For the current analysis we explored the relationship between net methane flux and soil bulk density, and between nitrous oxide emission and soil mineral N concentration, both modified by water-filled pore space at the time of observation. Both relationships were weak, and may not form sufficient basis for extrapolation between measuring points. A further process-level analysis of causal factors is probably needed before GHG emissions can be linked to models such as the Century model.

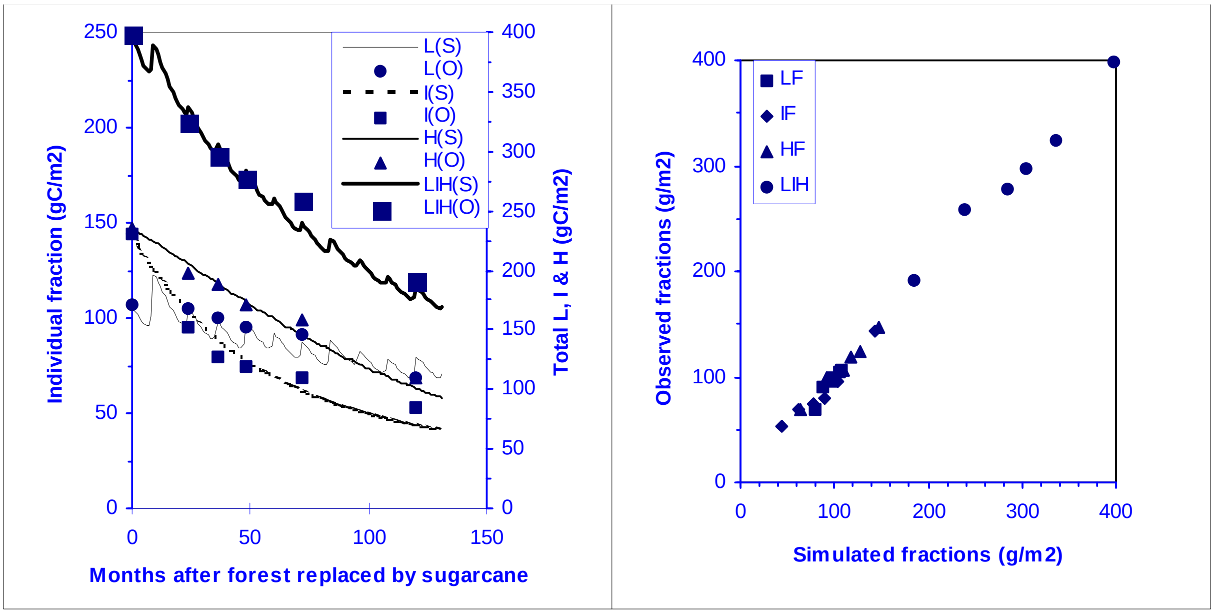


Figure II.4 *The dynamics of simulated (lines, S) and observed (points, O) for light (L), intermediate (I), heavy (H) and total macro-organic matter (LIH = L + I + H) fractions when lowland rainforest is converted to sugarcane (A), and the relationship between observed and simulated L, I, H & LIH fractions (B) within 0-20 cm depth under sugarcane. LIH = L + I + H*

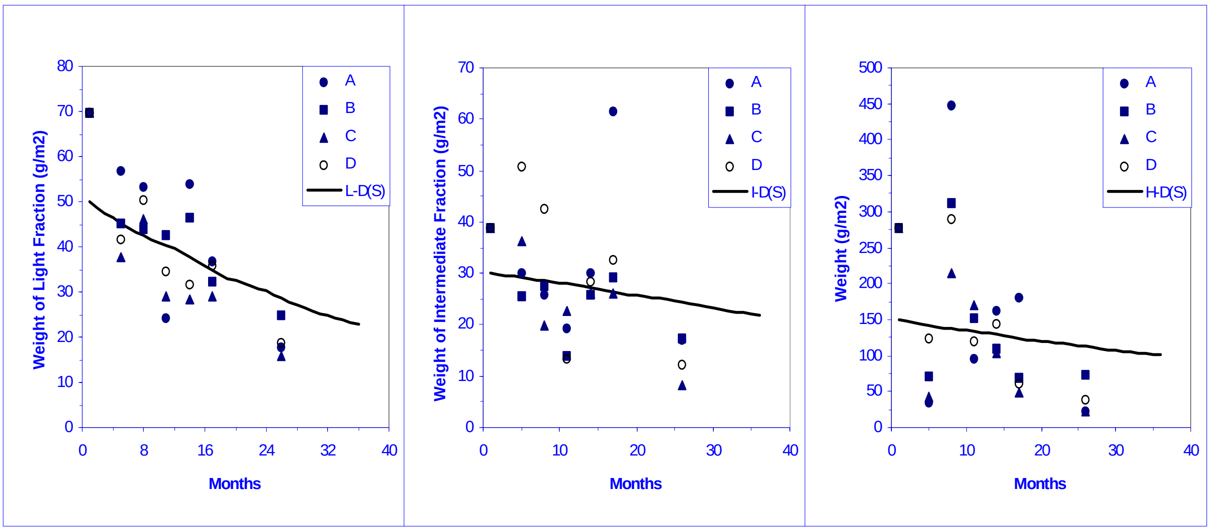


Figure II.5 *Modeled and measured fate of soil macro-organic matter fractions as part of a KILLSOM/ADDSOM experiment in Lampung (Hairiah et al., 1996), where Gliricidia litterfall is the main source of inputs; the overall decline is still a consequence of past conversion from forests and a lack of incorporation of organic inputs into the soil*

Data for methane oxidation and nitrous oxide emission can be compared on the basis of their 'net radiative forcing' (NRF) CO_2 equivalent values (26 and 206, respectively). It is obvious that removing above-ground carbon stock from forested land or tree-based system will have a greater effect on global warming than that caused by soil emissions. For the natural forest and rubber monoculture plots studied the overall effect on net radiative forcing is negative (this means less global warming, as more methane is oxidised than nitrous oxide emitted in NRF equivalents). For the other land uses nitrous oxide emissions will have a bigger impact on the greenhouse properties of the atmosphere than the methane oxidation.

The last two columns in Table II.2 make a tentative comparsion between the greenhouse gas fluxes of land uses per se, with the effects of land use conversions based on change in time-averaged carbon stock. When the difference in C stock is allocated to a 25 year time period, and the data are converted to units of mol C m^{-2} yr^{-1}, it becomes clear that changes in C stock will be one to two orders of magnitude larger than the emissions in the land uses on a stable basis. Obviously, the net climate effect for any land use when derived from lowland rainforest is strongly negative (for the first 25 years), while all land uses would have a substantial mitigating effect on climate change if they replace the *Imperata*/cassava cycle.

II.3 Belowground biodiversity

Data on belowground biodiversity indicators are summarized in Table II.3. For most parameters the differences between data collected in Jambi and those in Lampung were larger than those between different land uses within each of these benchmark areas. This is reflected in the probability values for the two 'main effects' (province and land use) in table II.3; for a number of parameters land use effects in Lampung differed from those in Jambi, reflected in a statistically significant interaction.

Table II.2 *Summary of net greenhouse gas emission effects from current land use (methane and nitrous oxide) and land use change (carbon, allocated to a 25 year period)*

Land use system	Time averaged C stock, Mg ha^{-1}	Mean seasonal net methane absorption, mg m^{-2} h^{-1}		Mean seasonal net N_2O emission, μg m^{-2} h^{-1}		Net radiative forcing (C equivalents) mol m^{-2} yr^{-1}		
		Wet	Dry	Wet	Dry	soil emis-sions	LU conversion (25 years) from forest	LU conversion (25 years) from *Imperata*
Natural forest	254	0.036	0.046	12.9	1.80	-0.03	0	n.a.
Community-based forest management	176	*	*	*	*	*	26	n.a.
Commercial logging	150	0.044	0.050	17.8	3.60	0.06	35	n.a.
Rubber agroforests	116	0.035	*	34.6	2.97	0.71	46	-26
Rubber agroforests with clonal material	103	*	0.029	*	3.06	0.61	50	-22
Rubber monoculture	97	0.009	0.060	6.1	0.43	-0.06	52	-20
Oil palm monoculture	91	*	*	*	*	*	54	-18
Upland rice/ bush fallow rotation	74	*	*	*	*	*	60	-12
Cassava/*Imperata* rotation	39	0.001	0.018	9.4	*	0.24	72	0

n.a.= not applicable
**= no data*

At first sight the effects of land use on belowground biodiversity appear to be much smaller than expected. Estimates of total population size for most microbial or soil macrofauna groups are remarkably similar, although there are indications of shifts between groups. For example, the *Imperata* grasslands have the highest densities of earthworms and mycorrhizal spores, while the forests have more ants and spiders in litter and soil samples (but not in the pitfall traps). The total number of soil macrofauna groups present in litter+soil samples was reduced in the Cassava+ *Imperata* samples, but for pitfall samples no difference was found and for mycorrhizal spore diversity the highest values were found for this land use type.

Table II.3 *Results of the surveys of indicators belowground biodiversity in five land uses of the lowland peneplain of Sumatra; the statistical model tested for differences between the two provinces (Lampung versus Jambi, confounded with a different sampling date (September versus November)), five land use categories (Forest, Agroforest, Rehabilitation (young tree-based systems), Cassava and Imperata, respectively) and their interaction. For data on soil fauna the model included a term for depth effects (surface litter and three soil layers), which is not reported here*

	Prob of F > value found			Means for land use types						
	Pro-vince	Land use	P * L	P	all	F	A	R	C	I
Total bacterial count (CFU g^{-1} of soil, log)	.0001	.057	.0003	L	3.34	3.48	3.41	4.03	2.49	3.32
				J	4.03	4.00	3.84	3.81	4.21	4.50
				J+L		3.80	3.65	3.94	3.18	3.71
Fungi (CFU g^{-1} of soil, log)	.0001	.0008	.0001	L	3.21	3.46	3.39	3.41	2.26	3.44
				J	4.28	3.31	4.10	5.05	5.40	5.11
				J+L		3.37	3.78	4.07	3.52	4.00
Respiration (mg CO2-C kg^{-1} day^{-1}, log)	.0001	.0001	.38	L	1.90	2.04	1.95	2.13	1.48	1.89
				J	2.65	2.83	2.70	2.56	2.33	2.54
				J+L		2.53	2.36	2.30	1.82	2.10
P-solubilizers (CFU, g^{-1} of soil, log)	.0001	.0323	.038	L	-1.49	-1.10	-1.80	-0.47	-1.46	-2.38
				J	.376	-.063	0.779	0.897	-.446	0.464
				J+L		-.528	-.510	0.076	-1.21	-1.43
Azotobacter (CFU, g^{-1} of soil, log)	.0001	.45	.0004	L	-.167	0.183	0.075	-.243	-1.060	0.036
				J	2.13	1.77	1.72	2.79	2.79	2.50
				J+L		1.17	0.98	1.28	0.59	0.91
Azospirillum (CFU, g^{-1} of soil, log)	.0001	.070	.33	L	0.70	1.19	0.417	0.819	0.645	0.416
				J	3.37	3.58	3.14	4.22	4.42	2.11
				J+L		2.22	2.18	1.67	2.53	1.02
Spores of mycorrhizal fungi (g^{-1} of soil, log)	.0001	.0001	.0001	L	5.15	4.97	4.80	5.18	5.89	4.96
				J	4.33	3.82	3.80	4.16	5.68	5.60
				J+L		4.25	4.24	4.80	5.81	5.17
Number of mycorrhizal fungal species	.0001	.0001	.0001	L	5.68	5.19	5.89	5.93	6.09	5.39
				J	4.72	4.07	4.08	4.39	5.93	6.89
				L+J		4.49	4.85	5.34	6.04	5.80
Active Soil Carbon indicator 1 (Microb population/C_{org})	.28	.59	.41	L	17	11	16	30	12	17
				J	21	15	24	18	29	26
				J+L		14	20	25	19	20
Active Soil Carbon indicator 2 (Microb population * C_{ref} / C_{org})	.15	.73	.33	L	43	27	41	82	27	41
				J	61	47	65	43	85	79
				J+L		39	55	66	50	54

PITFALL trappings of active surface fauna (number of individuals per pitfall during 2 days)

Ants (log)	.007	.15	.85	L	4.68	4.76	4.40	5.32	4.28	4.66
				J	5.48	5.56	4.71	6.35	5.41	6.06
				J+L		5.04	4.50	5.51	4.48	4.86
Spiders (log)	.002	.1793	.55	L	2.4	2.37	2.36	3.04	2.46	1.90
				J	3.05	3.02	2.56	3.61	3.26	3.31
				J+L		2.60	2.42	3.15	2.61	2.10
Beetles (log)	.0073	.0154	.77	L	2.54	3.64	1.87	2.98	2.14	2.20
				J	3.76	4.57	3.58	3.36	3.38	3.90
				J+L		3.97	3.39	3.05	3.36	2.30
Cockroaches (log)	.0023	.0021	.46	L	.35	-.03	-.33	.4	.97	.64
				J	.99	.73	.07	2.4	2.0	1.1
				J+L		.24	-.21	.76	1.16	.70
Crickets (log)	.0001	.0001	.57	L	1.93	1.02	.93	2.41	2.92	2.26
				J	3.16	2.71	2.24	3.36	4.47	4.63
				J+L		1.63	1.33	2.58	3.20	2.60
Number of groups per sample	.015	.313	.35	L	5.5	5.3	5.3	6.6	5.6	4.8
				J	6.7	6.6	7.0	6.0	8.0	5.5
				J+L		5.8	5.9	6.5	6.0	4.9

LITTER + SOIL macrofauna (the statistical model included a factor for depth not reported here), No. m^{-2}

Ants (log)	.73	.0020	.384	L	.26	.75	.39	.31	-.04	0
				J	.50	1.22	.20	.79	.31	-.24
				J+L		1.08	.26	.55	.16	-.12
Spiders (log)	.0001	.0025	.213	L	.25	.62	.79	.04	-.09	-.02
				J	-.32	-.14	-.33	-.29	-.51	-.44
				J+L		.09	.01	-.13	-.33	-.23
Earthworms (log)	.0023	.0064	.049	L	-.18	.15	-.36	-.26	-.55	.03
				J	.34	0	.23	.72	.33	.84
				J+L		.04	.06	.23	-.05	.44
Slugs (log)	.64	.176	.076	L	-.08	.17	.11	.17	0	0
				J	.14	.05	.07	.33	.42	0
				J+L		.08	.08	.25	.24	0
Other groups	.54	.040	.683	L	5.28	8.7	7.3	4.6	4.1	2.6
				J	4.01	5.7	4.8	5.4	1.3	1.3
				J+L		6.6	5.5	5.03	2.5	2.0
Number of groups per sample point	.0001	.0025	.223	L	3.33	4.3	4.0	3.3	2.4	2.9
				J	2.75	3.3	2.5	3.3	2.5	2.1
				J+L		3.5	3.0	3.3	***2.5***	***2.5***

In a further analysis of the data we only compared the *Imperata*/cassava land use (IC) with the three others (RAF). In that analysis we found a significant decrease in IC compared to RAF for respiration, P-solubilizers, woodlice (isopods) caught in pitfall traps and ats, spiders, cockroaches, crickets, 'other' and group diversity for the soil macrofauna. A statistically siginificant increase was found for mycorrhizal spore density and diversity and pitfall catches of cockroaches, slugs and crickets. For parameters such as earthworms an increase in *Imperata* was off-set by a decrease in cassava.

In the Lampung benchmark area detailed information was obtained on nematode genera (or families) in the five (ICRAF) land uses. Only for the plant-parasitic *Meloidogyne* nematodes did we find a significant ($p < .001$) effect of land use, with very high densities in the cassava fields, intermediate ones in the forested fields (RAF) and an absence in the *Imperata* fallow plots. For the other groups (*Rhabditida, Dorylaimida, Criconemoides, Tylenchus, Helicotylenchus, Rotylenchus, Monochus, Hoplolaimus, Scutelonema, Aphelenchus*) differences between replicate samples in the same land use were larger than those between land uses as a group, so the null-hypothesis of no land use effect was not rejected.

The number of rhizobia in the soil was estimated using a MPN method (Brockwell *et al.*, 1975) and three legumes *(Macroptilium atropurpureum, Pueraria phaseoloides* and *Glycine soja)* as host plants. Siratro-nodulating bacteria were found in only one location of forest, and mature agroforest, all three locations of young agroforest, two locations of cassava and two location of *Imperata* grasslands, while kudzu-nodulating bacteria were found in one location of forest, one location of mature agroforest, two locations of young agroforest, none of cassava and *Imperata* grasslands. There were no wild soybean-nodulating bacteria found in any locations in Lampung. In Jambi siratro-nodulating bacteria were found in two of the four locations of forest, one of the five locations of mature agroforest, one of the two locations of young agroforest, none of the two locations of cassava, and one of two locations of *Imperata* grassland. Kudzu-nodulating bacteria were found in two of the four locations of forest, more of the five locations of mature agroforest, one of the two locations of young agroforest, none in cassava and *Imperata* grasslands. Similarly, wild soybean-nodulating bacteria were not found in any locations in Jambi. The results thus indicate that in several locations land use systems are lacking suitable host legumes . Importantly, there were no indications of a relationship between occurrence of symbiotic N2-fixing bacteria and land use system. The occurrence of symbiotic N2-fixing bacteria seems to be influenced by the presence of suitable host legumes in the respective land use systems.

It may be that our conclusion of relatively small effects of land use on soil fauna is colored by the type of parameters measured. It is possible that greater differences would appear if more sensitive parameters were collected, e.g. specific groups of spiders and ants rather than the groups as a whole. Some evidence on much stronger response to land use change was collected as part of the intensive biodiversity survey in Jambi, where termite data were collected and sorted by trophic group (wood versus soil feeders). These (un-replicated) samples showed large differences between forest and agroforests on one hand and the cassava/*Imperata* plots in the other hand (Swift 1998).

II.4 Aboveground biodiversity

As part of the integrated survey of land use systems in the peneplains, aboveground biodiversity was assessed in terms of the richness of species and plant functional types ('modi') in standard-sized sample plots. In the data analysis a single vector 'V index' may be defined which gives a clear differentiation between *Imperata* grasslands as one extreme and natural forest as the other. The vector is composed of a large number of the plot-level measurements (Fig. II.6).

The V index classifies monospecific tree plantations with their associated 'weeds' as halfway on the scale between natural forest and *Imperata* grasslands, close to the vegetation of a logging ramp as part of logged forests. Old rubber agroforests are intermediate between logged and natural parts of natural forest, confirming earlier data on species richness (De Foresta and Michon, 1997). The V-index is based on a number of parameters, including basal area of trees, plant species richness and number of unique combinations (modi) of plant functional attributes (PFA). PFA diversity of rubber agroforests can equal that of natural forests, but the number of botanical plant species per modus is less. The data suggest that the ratio of botanical species and modi may be an informative single indicator of aboveground biodiversity of forests and forest-derived land covers. As may be expected, a good correlation exists between aboveground C stock and such indices of aboveground (plant) biodiversity (Fig. II.7).

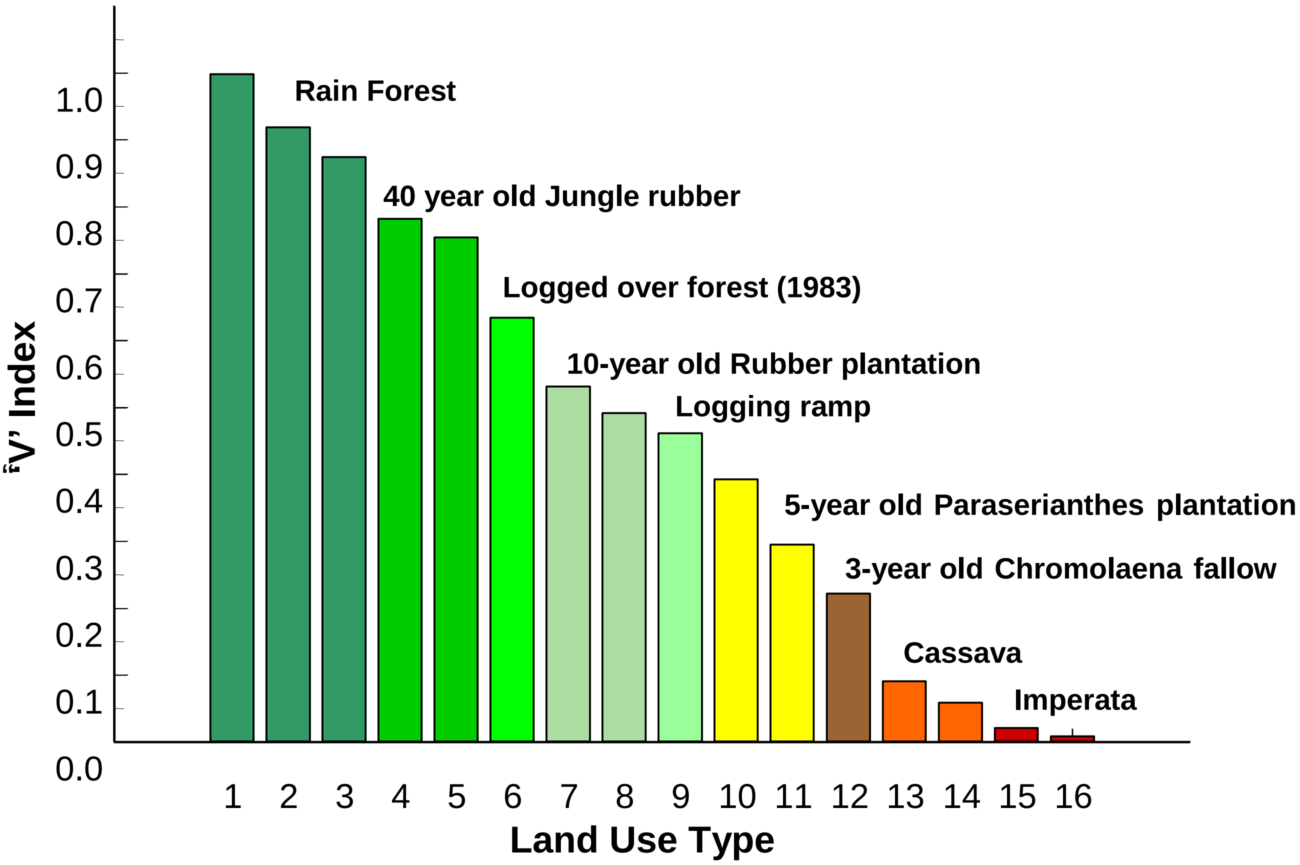


Figure II.6 *Overall classification of vegetation structure and plant biodiversity ('V' index) for intensive sampling points in Jambi; the V index is the most-discriminating single axis in multidimensional parameter space, which groups 'similar' plots*

II.5 Landscape level assessments

Some first steps were made towards landscape level diversity assessments, including diversity among different sample points in the same land use class. The basic question may be phrased as: are all forest sites the same ('if you've seen one forest you've seen them all') or do they contain more internal variation then human-derived land covers, with the *Imperata*/ cassava system as extreme.

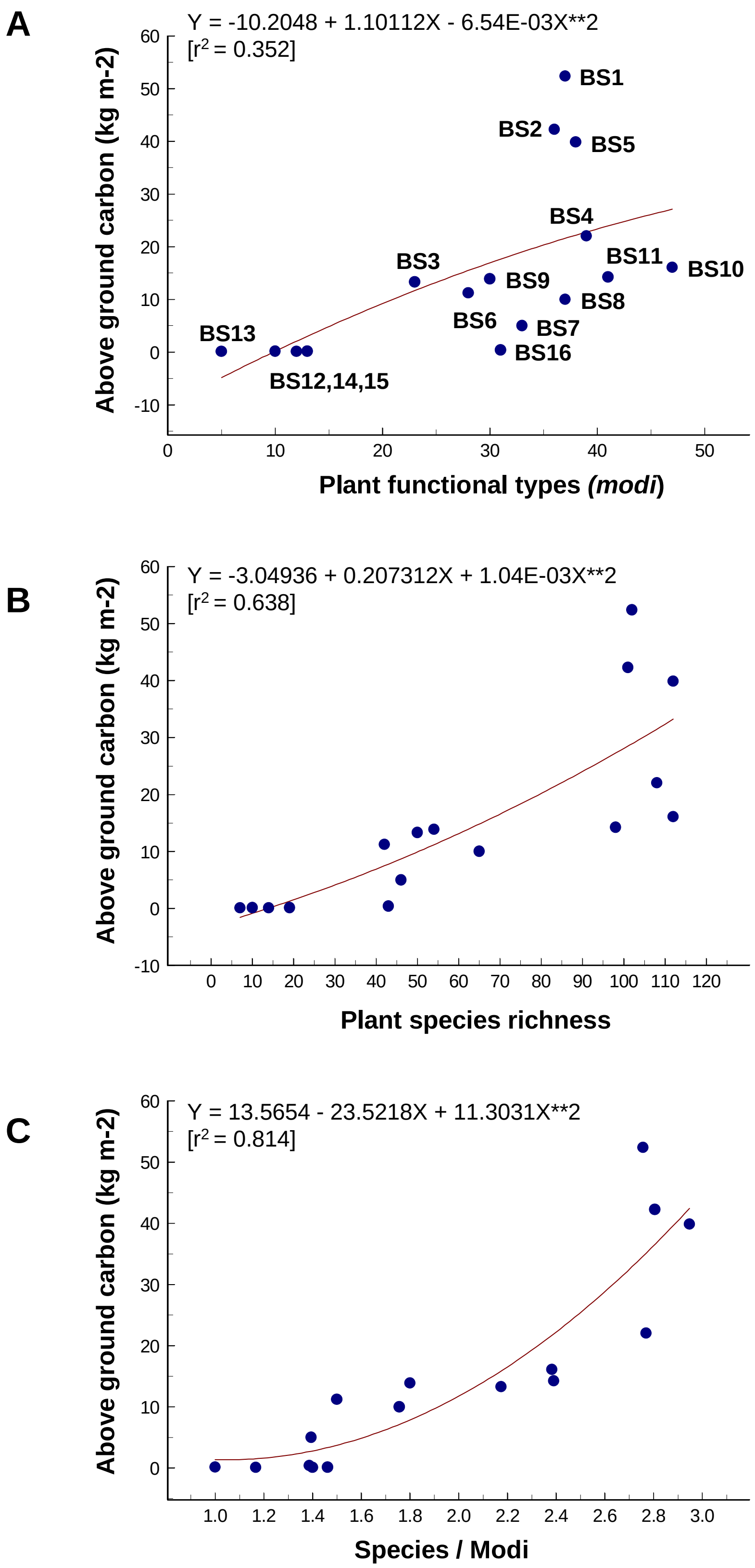


Figure II.7 *Comparative relationships between above-ground carbon, plant functional type richness, species richness and species / modi ratios along a gradient of land use types, Jambi, Lowland Sumatra*

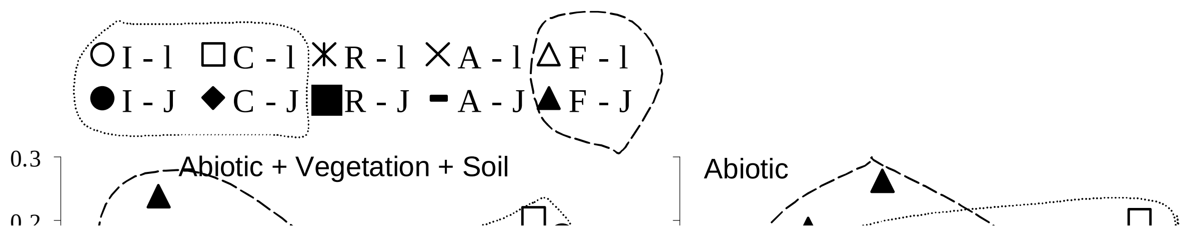


Figure II.8 *Ordination (showing the two first principal components) of sample points for all parameters in the integrated survey (abiotic + vegetation + soil) or different subsets of these parameters; the lines indicate the domains for forest sample points as natural background and Imperata + cassava as extremes of human modification, I= Imperata, C=Cassava, R= Rehabilitation (young AF system), A= Agroforest, F= Forest, L= Lampung (open symbols), J= Jambi (closed symbols)*

Figure II.8 presents the 31 points for the integrated survey, using different parts of the total data set for defining similarity among sample points. If only the abiotic soil parameters are considered, the area spanned by the forest points more or less coincides with that of the cassava/*Imperata* system, indicating that basic soil characteristics are probably little changed by forest conversion (upper right in Fig. II.8). The Lampung points (open symbols) fall in a different class than the Jambi points (closed symbols), and this dichotomy is conserved for all other parts of the data set. If the soil biological parameters are added to the abiotic soil descriptors (see lower right quadrant), the *Imperata*/cassava points stand a bit further out from the forest ones, but there are no simple tests of the statistical significance of such a difference. When the vegetation parameters are combined with abiotic soil descriptors (lower left), the cassava/*Imperata* points for Lampung are clearly outside the forest points, indicating that this conversion may have increased landscape level diversity. When all parameters are considered (upper left), distances are less pronounced.

The view that part of the 'savanization' (formation of grasslands) of forests can be seen as an increase of landscape level diversity is supported by analyses of large mammals in a landscape historical context. Boomgaard (1997) argued that large mammal populations initially benefited from human presence in forest landscapes.

The transformation of forests into agroforests may initially have added little to landscape level diversity, in the sense that all parameter combinations found in such agroforests are within the domain of natural forests. During this transformation, these agroforests have become a major reservoir for forest flora and fauna in the current landscape where natural forest has become scarce (Jambi) or near absent (Lampung). Current data indicate that old rubber agroforests indeed contain a substantial part of forest diversity. However, more detailed research on fern diversity (H. Beukema, research in progress) shows that the between-plot variation in species composition of natural forests is substantially larger than that for rubber agroforests, even if plot-level diversity is approximately the same. Translating the current plot-level assessments to landscape level statements about global environmental impacts is thus not a trivial exercise, which will need further attention in future assessments.

III. Sustainability indicators for land uses following forest conversion

A set of plot (field) level criteria and indicators was developed to evaluate the sustainability of a range of land use systems which can follow forest conversion (Weise 1998). Sustainability is a complex concept, as there are many reasons why certain land use activities can not be sustained. The original list developed for the ASB project (Van Noordwijk *et al.*, 1998) included criteria at field scale as well as 'downstream' and 'down wind' environmental effects of certain land use types. Effects of these externalities on broader notions of sustainability are beyond the scope of this phase of research, which is confined to field level sustainability criteria. The main issue then is whether or not farming activities degrade their resource base to a level that impairs future productive use of the land. Three major categories of threats to continued farming are considered:

- A. not maintaining soil of sufficient structure and biological activity,
- B. not balancing the budget of nutrient exports and imports,
- C. letting pest, weed and disease problems reach unmanageable proportions.

Any of these categories can become such a constraint to continued farming that land may have to be (temporarily) abandoned, therefore the most serious category of problems determines the overall sustainability.

For each of the criteria a number of indicators were developed which can be measured relatively easily, often using data already collected as part of the integrated survey of biodiversity, C stocks and greenhouse gas emissions. These measurements were made for specific land cover types (the FARCI (or ICRAF) series: forest (F), mature agroforest (A), young tree-based systems (R(egrowth)), long-term cassava cropping (C) and temporarily abandoned *Imperata* grassland (I)), in the Jambi as well as Lampung benchmark area. For the current purpose 'land use systems' have to be reconstructed from these measurements, as for example agroforests as a land use have an early as well as a mature phase. All measurements were made in the previously specified benchmark areas, and they thus contain the confounding effects of land use history and current management practices typical for the various actors. For example, continued production of food crops (cassava) is restricted to former transmigration settlements that were cleared from previous forest cover by bulldozer. Current levels of soil compaction may date back to this event regardless of the current land use, but this still forms part of a broader 'syndrome' of land use decisions.

No agricultural land use can consistently harvests produce without putting management efforts into maintenance of the system, so all judgements of sustainability depend on a specified management regime and farmer efforts to overcome obstacles. For each indicator a tentative threshold was developed, which allows a final judgement in three categories:

0 (RED) = Problems may get beyond the means of farmers to resolve

0.5 (AMBER) = Additional effort will be needed to address these issues, which may affect the profitability of the land use system, but may otherwise be within the farmer's management options

1 (GREEN) = No major problems beyond what normal farm management can deal with.

Before we discuss these indicators a certain ambiguity in the sustainability concept must be mentioned: the final criterion is the possibility to continue farming on a given piece of land, keeping all threats at manageable levels. Continued farming, however, may depend on the ability to change and develop a farm in new directions. Whereas certain land use practices, such as cultivation of very efficient nutrient scavengers such as cassava, may meet the criterion of persistence for a period of say 20 years, this practice is likely to reduce the number of future options, because the soil depletion it induced will require substantial re-investment in soil nutrient stocks before other crops can be grown. The current criteria refer to the field-level land uses per se, as these are measurable while a full land use transition matrix that can only be assessed by other means. We will come back to this in the final section of this chapter.

III.1 Soil structure and biological activity

The following indicators were used:

A1. **Soil compaction** as evident from soil bulk density (dry weight per unit volume) in the topsoil,

A2. **Soil carbon saturation**: organic carbon (Corg) content relative to that for forest soils of the same texture and pH**.** This criterion is based on a reference soil C level, Cref, which is estimated from regression analysis of a large soil data set for Sumatra (Van Noordwijk *et al.*, 1997):

$$Cref = \exp(1.333 + 0.00994*Clay\% + 0.00699*Silt\% - 0.156*pH\text{-}KCl)$$

A3. **Active Soil Carbon** (ASC):

The globally proposed indicator based on microbial biomas relative to soil C could not be used because microbial biomass was not measured in a standardized way. Six other parameters are presented here, however:

- dry weight of light plus intermediate fraction for the LUDOX size-density fractionation procedure (Hairiah *et al.*, 1995),
- mineral ammonium and nitrate content of the topsoil during measurements,
- population count of total bacteria (colony forming units), relative to the Corg content (as suggested for the ASC indicator), and relative to the C saturation
- soil respiration (during lab incubation)

All six parameters can be judged against the values obtained for natural forest sites

A4. **Soil Exposure** (SE):

Number of months of low (< 75%) soil cover / length of system cycle in months

Available primary data for Lampung and Jambi are summarized in Tables III.1 and III.2. Bulk density data in Tables III.1 and III.2 refer to slightly different sampling depths, but indicate a clear difference between undisturbed forests and land under a cassava/*Imperata* cycle, with intermediate degrees of compaction under agroforests and other tree-based production system. Serious localized soil compaction was clear in logged-over forest where tracks and logging ramps were compacted beyond easy recovery. It is easy to compact a soil, but in systems without soil tillage it can take a long time before the soil recovers. Soil compaction can have an impact on water infiltration, root growth and greenhouse gas emissions, but probably stayed below critical levels in all cases observed. For a number of land use systems the overall rating is thus 0.5 (see table III.3).

The carbon saturation data show that no land use systems fully maintain the soil organic matter levels in the top soil of a natural forest (once corrected for soil texture and pH of the site; many values are above 1.0 as the equation for Cref was based on data for the top 10-15 cm of forest soils), but serious declines were only found for the cassava/ *Imperata* land use type, with the lowest values measured in cassava fields. Reductions of soil organic matter content to this range is evidence of substantial depletion of organic nutrient stocks in the soil and may affect soil physical properties as well as nutrient buffering against leaching. As with soil compaction, problems can be created much faster than they can be solved. For the A2 indicator only the cassava/*Imperata* cycle gets a warning flag (0.5 score). As mentioned before for soil compaction, the low current value of C saturation may have been partly due to reclamation history as well as current land use (bulldozer land clearing can remove part of the topsoil out of the field boundaries), but frequent fires, low organic inputs through cassava litterfall and frequent soil tillage can account for the low values found.

Table III.1 *Measured soil fertility indicators for the integrated biodiversity and GHG emission survey in Lampung (L) and Jambi (J) ASB benchmark area (September - November 1996)*

Land cover type (number of observations)	Bulk density 2-7 cm, g cm^{-3}	Corg/ Cref	Light + interm. fraction, g kg^{-1}	Ammo nium	Nitra- te	Bact. pop/ Corg	Bact. pop. * Cref/ Corg	Soil resp. mg CO_2 C kg^{-1} day^{-1}
Lampung	1.27	0.84	2.25	23	11	17	43	7.0
Jambi	1.09	1.05	3.86	14	12	21	61	15.3
Group 1	L	0 – 5	L	L	L + J	L	L	L
Forest (3)	1.17	1.54	3.22	40	18	12	27	7.9
Agroforest (4)	1.18	**1.16**	2.48	28	13	16	41	7.2
Regrowing trees (3)	**1.32**	**1.12**	2.60	**11**	**8**	30	82	8.6
Cassava (3)	**1.34**	***0.71***	**1.12**	**16**	**10**	12	27	**4.6**
Imperata (4)	**1.41**	**1.02**	**1.88**	**16**	**6**	17	41	**6.7**
Group 2	J	5 – 15	J	J		J	J	J
Forest (4)	0.91	0.97	7.18	18		15	47	17.9
Agroforest (5)	1.01	0.82	**3.07**	18		24	65	16.2
Regrowing trees (2)	**1.22**	**0.74**	**2.46**	**8**		18	43	13.1
Cassava (2)	**1.17**	***0.55***	**3.11**	**11**		30	85	10.6
Imperata (2)	**1.28**	**0.72**	**3.44**	14		26	79	14.0
Fprob LUT	<0.001	0.009	0.006	<0.001	0.011	NS	NS	?
LUT*Prov	<0.001	NS	0.021		NS	NS	NS	0.026
LUT*Depth	-	0.021	-	-	-	-	-	-
SED (interaction)	0.08	0.22	1.26	4..1	3.5	10		2.8

The various indicators of soil biological activity in Tables III.1 and III.2 may give a partially conflicting signal: the mineral N supply at the time of measurement was higher in the forest and mature agroforests than in other land uses, indicating that N supply from mineralization may have exceeded current N demand from the vegetation around the time of measurement (end of dry season); these same land uses had a relatively high respiration rate, but when estimates of total microbial population size are scaled by soil organic matter content or by C saturation, the 'active fraction' of the total soil organic matter pool in forests appears to have been lowest. On the basis of this evidence (and other data in the soil biodiversity survey) we conclude that there is no lack of active soil biota in any of the land uses, and *Imperata* grasslands are not 'depleted' ecosystems from a soil biological perspective, even though their soil organic capital has been reduced.

Table III.2 *Additional soil data from intensive biodiversity survey in Jambi (November 1997); data refer to duplicate samples per land cover type*

Land cover	Bulk density (0 - 5 cm) mean $g\ cm^{-3}$	Bulk density (0 - 5 cm) Coeff. variab.	Corg/Cref 0 - 5 cm depth	Ground cover ($kg\ m^{-2}$) Dead wood	Ground cover ($kg\ m^{-2}$) Litter	Ground cover ($kg\ m^{-2}$) Green biomass.	Land Use
Natural forest	0.68	0.224	1.37	12.73	1.33	0.07	Natural forest NTFP extraction
Logged-over Forest	0.77	**0.342**	1.20	13.40	1.18	0.02	Commercial logging
(Logging ramp)	**1.20**	0.181					
5 year old Timber Plantation	0.69	0.119	1.23	7.76	0.77	0.03	
40 year old Rubber AF	1.01	0.131	1.38	7.75	1.41	0.17	Rubber agroforests
10 year old Rubber Plantation	0.73	0.148	0.99	10.0	0.73	0.10	Rubber monoculture
							Oil palm monoculture
Chromolaena fallow	0.77	0.103	1.16	0	0.56	0.34	Upland rice/ bush fallow rotation
Cassava	**1.19**	0.069	**0.58**	0	**0.10**	0.20	Cassava/*Imperata*
Imperata	**1.23**	0.117	0.81	0	**0.05**	0.25	rotation

The indicator of soil cover (A4) requires inferences over the lifespan of the system rather than point measurements. The data in Table III.2 show that the nature of soil cover can shift from dead wood and leaf litter in forests to covers dominated by green biomass. Bare soil is rarely exposed in the landscapes of the peneplains. In all land use systems with a slash-and-burn land clearing event, soil may be exposed for about 6 months per cycle (or 2% of the time for a rubber system with a 25 year cycle). The only land use system where soil exposure may be an issue is the cassava/*Imperata* cycle where soil is exposed during the first 3 months of a cassava crop (unless heavily weed-infested or intercropped with crops such as rice, which is not possible at reduced soil fertility), and for about 1 month per year in all cases when the *Imperata* fallow is burned. Combined, this may lead to about 10% of the time with incomplete soil cover, when the soil is vulnerable to the direct impact of rain and sun.

Table III.3 *Sustainability rating of land use systems for Criterion A (maintenance of soil structure and biological activity); 1 = no major problems, 0.5 = problems within farmer management range, 0 = problems beyond what farmers can solve*

Land use system	A1 Compaction	A2 Carbon saturation	A3 Active soil C_{org}	A4 Soil exposure	Overall rating A	Comments on main issue which need attention
Natural forest	1	1	1	1	1	-
Community-based forest management	1	1	1	1	1	-
Commercial logging	0.5	1	1	1	0.5	Soil compaction in ramps and trails
Rubber agroforests	0.5	1	1	1	0.5	Soil compaction?
Rubber agroforests with clonal planting material	0.5	1	1	1	0.5	Soil compaction?
Rubber monoculture	0.5	1	1	1	0.5	Soil compaction?
Oil palm monoculture	0.5	1	1	1	0.5	Soil compaction?
Upland rice/ bush fallow rotation	1	1	1	1	1	-
Cassava/*Imperata* rotation	0.5	0.5	1	0.5	0.5	Soil compaction, low Corg, lack of soil cover

III.2 Nutrient balance

Three indicators were developed to judge whether the nutrient balance is (or could potentially be) maintained in a cropping system

B1. **Net Nutrient Export (NNE)** or nutrients contained in all harvested products minus those in fertilizer inputs for N, P, and K, in kg ha^{-1} $year^{-1}$. High net exports indicate the likelihood of depletion, high net surpluses, on the other hand, may indicate excessive fertilizer use and risks of pollution of ground- and surface water. Nutrient imports include fertilizers and N fixation through legumes in the system (none in the land uses considered here). For the net nutrient export, fertilizer inputs are taken at their nutrient value (Table III.4).

B2. **Nutrient Depletion Time Range (NDTR)** If nutrient stocks in soil and vegetation are large relative to net nutrient exports, nutrient offtake can be part of a wise natural resource management strategy; if exports are large relative to stocks, one can expect that yields will decline in the near future, unless nutrient inputs will be increased. Two types of estimates were used for nutrient stocks in the system: total nutrient content of soil *plus* vegetation and the directly available pool. Neither is directly satisfactory, as measures of the available nutrient pool necessarily use rather arbitrary fractions and there is considerable variation between plants in effectiveness of accessing 'non-available' nutrient sources. As nutrient stocks depend on the soil and vegetation cover, one can not directly assign an NDTR value to a land use system in the peneplains of Sumatra; the soils closer to rivers with a higher clay and silt content will have larger stocks than the sandier soils of the rest of the lowland peneplain. The values (Table III.5) only indicate an order of magnitude.

Table III.4 *Net Nutrient Export (NNE) based on partial nutrient budgets for different land uses (LU's}, based on yield and input data from farm profitability studies (Chapter IV)*

			OUT = harvest, kg ha^{-1} cumulative for 25 yr			IN = fertilizer, kg ha^{-1} cumulative for 25 year			In – Out kg ha^{-1} year^{--11}		
LU	Pro-ducts	Yield Mg ha^{-1}	N	P	K	N	P	K	N	P	K
NTFP harvesting	Various		0.02	0.002	0.03	0	0	0	0	0	0
Logging	Wood	13	63	6	38	0	0	0	-2.5	-0.2	-1.5
Rubber .AF	Rice	0.8	9	28	75						
	Rubber	11.8	78	96	428						
	total		87	124	502	0	0	0	-3	-5	-20
Rubber AF, improved	rice	0.8	9	28	75						
	rubber	28.6	189	234	1036						
	total		198	261	1111	74	50	0	-5	-8	-44
Rubber.monoculture.	rice	0.8	9	28	75						
	rubber	10.3	68	84	373						
	total		77	112	448	149	100	0	3	0	-18
Oil palm	palm oil	268	777	427	1656	2039	980	1794	50	22	6
Sh.Cult.long	rice	6	71	207	559	0	0	0	-3	-8	-22
Sh.Cult.short	rice	4	47	138	373	0	0	0	-2	-6	-15
Cassava	tuber	242	678	244	955	504	160	368	-7	-3	-23

1. Nutrient concentrations kg Mg^{-1}	N	P	K
Palm oil (bunch)	2.9	0.55	3.9
Rubber (DRC)	6.6	1.2	4.4
Cassava	2.8	0.36	3.9
Rice	11.8	2.9	2.7

NB Oil palm estimates based on removal of bunches without return of mill effluent; if fruits are sold instead of bunches, NPK exports will be lower

2. Fertilizer use kg ha^{-1}cycle^{-1} LUS	Urea	TSP	KCl
Rubber .agroforest	0	0	0
Rubber agroforests (int.)	165	250	0
Rubber monoculture	330	500	0
Oil palm	4530	4900	3900
Sh.Cult.long	0	0	0
Sh.Cult.short	0	0	0
Cassava	1120	800	800

Table III.5 *Nutrient Depletion Time Range.(NDTR) for the net nutrient exports of Table III.4 and an '**available**' nutrient stock of 800, 200 and 300 kg ha^{-1} of N, P and K, respectively, in vegetation, organic and directly accessible mineral forms in soil in a typical lowland rain forest of Sumatra's peneplains, and for a **total** nutrient stock (including less accessible pools in the soil) of 8000, 1200 and 3000 kg ha^{-1} respectively. NDTR has the unit time and indicates when nutrient stocks would be zero under a linear extrapolation of current trends. Negative net exports (inputs > exports) lead to negative NDTR values.*

	Av.Stock/(Out-In), (year)			Tot.Stock/(Out-In), (year)		
	N	P	K	N	P	K
NTFP harvesting	>10 000	>10 000	>10 000	>10 000	>10 000	>10 000
Logging	317	833	197	3175	5000	1974
Rubber AF	229	40	15	2290	242	149
Rubber AF clones	161	24	7	1614	142	68
Rubber monoculture	-281	424	17	-2814	2545	168
Oil palm plantation	-16	-9	-55	-159	-54	-545
Sh.Cult. long cycle	283	24	13	2825	145	134
Sh.Cult. short cycle	424	36	20	4237	218	201
Cassava	115	60	13	1152	358	128

Table III.5 shows that the substantial differences between the land use systems in net nutrient exports (Table III.4) are reflected in very different depletion trajectories. The nutrient where the most rapid depletion may occur is potassium (K). If only the directly available pool is considered, depletion within a 25-year time frame may occur for the rubber systems and shifting cultivation as well as cassava production. If total stocks are considered (at least part of non 'available' K can be accessed by plants), the time frame to depletion becomes several decades at least. For N no problems are to be expected for the land uses described here according to this calculation. However, our calculations do not include nutrient losses other than in harvested products and substantial N losses will occur during slash-and-burn clearing of forest lands, as well as by leaching during subsequent periods of low N demand by the vegetation relative to the N supply from mineralization. A more refined estimate would have to include the full spectrum of processes incorporated in the Century model (Palm *et al.*, 1998) and goes beyond the current sustainability assessment.

The nutrient balance calculations were based on the technical specifications used for the profitability assessments in part IV. For the cassava/*Imperata* cycle, a moderate use of fertilizer was assumed, below replacement level, but at least mitigating nutrient depletion. Many farmers in the benchmark area appear to use no fertilizer at all in this system, however.

For such no-input versions the nutrient balance is clearly negative. A clear trade-off may exist for this land use type between sustainability and profitability.

B3. The **Relative Nutrient Replacement Value (RNRV)** relates the export of nutrients in harvested products to the costs of replacing them into the agro-ecosystem in the form of chemical fertilizer. This assessment is based on the harvested products rather than the full production system, but refinements could be made in as far as nutrient recoveries depend on the system context. In the calculations for Table III.6 (long term) nutrient recovery of 25, 20 and 30% has been assumed for N, P and K, respectively, while N fixing trees (petai (*Parkia)* and jengkol (*Pithecelobium*), included in the Non timber forest products (NTFP) scenario) are assumed to derive two thirds of their N from the atmosphere.

Table III.6 *Relative nutrient replacement value for main products of various land use systems (Rupiah prices before July 1997); modified and extended from Van Noordwijk et al. (1997)*

	Nutrient removal, g/kg product			Nutrient replacement value Rp/kg	Farmgate value of product, Rp/kg	Relative nutrient replacement value (RNRV)
	N	P	K			
NTFP - rotan	2	0.2	1	10	20000	< 0.001
NTFP - petai/jengkol	5	0.5	5	24	500	0.05
NTFP - durian	3	0.3	6	28	1000	0.03
NTFP - others						< 0.001
Timber	2.5	0.25	1.5	13	108	**0.12**
Rubber (latex)	6.3	1.2	4.4	42	2000	0.02
Oil palm (bunches)	2.9	0.55	3.9	25	60	***0.41***
Rice	11.8	2.9	2.7	70	400	**0.17**
Cassava	2.8	0.36	3.9	22	50	***0.44***

The Nutrient replacement value is obtained as the sum of nutrient contents and replacement costs per nutrient for N, P and K (neglecting other nutrients):

Replacement price per nutrient exported, Rp/g	2.3	12	2.9
Fertilizer price, Rp/kg	260	480	400
Nutrient fraction of fertilizer	0.45	0.2	0.46
Nutrient recovery by the crop	0.25	0.2	0.3

Most RNRV values are below 10% and this indicates that nutrient replenishment would be within reach of farmers if, when and where actual nutrient responses of the crop make fertilizer use necessary. For rice the value is around 15% and this indicates a range were details of fertilizer use (and the various assumptions on efficiency made here) will be important for farmers' decisions on fertilizer use. For oil palm and cassava the RNRV values are around 45%, indicating that fertilizer costs would be a major part of the farm budget if farmers would have to balance the nutrient budgets (when the 'free lunch' of living off the initial stocks is over). The low RNRV values for both products are caused by their low farmgate price per kg product. For oil palm, marketing of fruits instead of bunches could considerably reduce the nutrient exports and, hence, the RNRV. For cassava only a shift in farmgate prices of the product and/or of fertilizers could make fertilizer use more attractive.

The overall judgement for criterion B thus highlights the difficulties in maintaining balanced budgets for cassava at current prices (and based on estimated technical coefficients and recoveries), and indicates a number of concerns for upland rice rotations, oil palm production and the proposed intensified rubber at reduced fertilizer input management. Where the overall evaluation indicates values in the critical range, a more detailed assessment is needed for different soils, management practices etc.

III.3 Crop protection from weeds, pests and diseases

For criterion C two indicators have been proposed, both based on 'expert opinion' rather than direct measurements:

C1. **Potential for Weed Problems**:

Weed problems becoming a major constraint in the system, unless addressed by additional labour and/or technical input

C2. **Potential for Pest or Disease Problems**:

Pest or disease problems becoming a major constraint in the system, unless addressed by additional labour and/or technical input

Weed problems are mostly related to *Imperata*, which is hard to control without herbicides (too expensive for smallholder food production) or ploughing (Van Noordwijk *et al.*, 1997). Damage by pigs and monkeys to new planting material can be a serious obstacle when clonal (more expensive) planting material is used, whereas the existing system tolerates substantial tree losses by planting at high densities at low costs per seedling. The natural regrowth of rubber agroforests is probably less problematic as a 'weed' than the grass or fern vegetation which develops under attempts at 'weed control'.

***Table III.7** Indicators of current and potential nutrient balance; NDTR = nutrient depletion time range; RNRV = relative nutrient replacement value; 1 = no major problems, 0.5 = problems within farmer management range, 0 = problems beyond what farmers can solve*

Land use system	B1 Net export	B2 NDTR	B3 RNRV	Overall Rating B	Comments on main issue
Natural forest	1	1.0	1	1	
Community-based forest management	1	1.0	1	1	
Commercial logging	1	1	1	1	
Rubber agroforests	1	1	1	1	
Rubber agroforests with selected planting material	0.5	0.5	1	0.5	Output increased at low input?; K supply needs attention
Rubber monoculture	1	1	1	1	
Oil palm monoculture	1	1	0.5	0.5	Assumed fertilizer rates may be too high; RNRV rating supposes fruits sold rather than bunches
Upland rice/ bush fallow rotation	1	0.5	0.5	0.5	Fertilizer use required for intensification
Cassava/*Imperata* rotation	0.5	0.5	0	0	Nutrient balance can not be attained at current prices; K in short supply?

***Table III.8** Indicators of problems with crop protection from weeds, pests and diseases;1 = no major problems, 0.5 = problems within farmer management range, 0 = problems beyond what farmers can solve*

Land use system	C1 Weeds	C2. Pests & diseases	Comments on main issue
Natural forest	1	1	no problems
Community-based forest management	1	1	
Commercial logging	1	1	
Rubber agroforests	1	1	
Rubber agroforests with selected planting material	1	0.5	pigs & monkeys at replanting; fungal diseases when sensitive clones are used
Rubber monoculture	0.5	0.5	fungal diseases, pigs and monkeys at replanting; ferns as ground cover may be problematic
Oil palm monoculture	1	1	
Upland rice/ bush fallow rotation	1	0.5	vertebrate and insect pests are a constraint
Cassava/*Imperata* rotation	0.5	1	*Imperata* fallows are a weed problem unless farmers have draught power available

III.4 Synthesis of sustainability indicators

When all indicators are combined (Table III.9) we derive the following assessment:

- most land use systems considered have one or more aspects which need attention, but most of these stay within the range of solvable problems at farm level,

-the cassava/*Imperata* cycle has a number of issues associated with it and one of them (maintaining a nutrient balance) is so serious that it can probably not be resolved at the farm level within the current constraints.

III.5 Land use change matrix

Sustainability as defined above indicates the degree of reproducibility of a land use system: does it maintain the conditions required for its own continuation? In the real world, however, it is unlikely that land uses will remain unchanged over more than one (or a few) human generations, and it may thus be interesting to evaluate which options are kept open with a given land use system (Table III.10).

Natural forest can be used as starting point for all land use types, but in a strict sense can only originate from forests; community-managed forests, some logging techniques and extensive rubber agroforests can lead to a return of a vegetation close to natural forests. On the other side of the spectrum, the cassava/ *Imperata* cycle can be started after any land use system, but forms a 'dead end', as it can not maintain its own productivity and it takes substantial efforts and expense (nutrient replenishment and *Imperata* control) to return to other (more profitable ands sustainable) land use types. The various tree-crop systems appear to be freely convertible into each other, but extensive rubber agroforests will change in character once the seedbank of original natural vegetation is depleted and the site is out of reach of seed dispersal. Table III.10 strengthens the conclusion that the cassava/*Imperata* system is the most problematic of the land use systems considered here.

Table III.9 *Overall assessment of sustainability of various land use systems for the peneplain of Sumatra (compare tables III.3, III.7 and III.8)*

Land use system	A1	A2	A3	A4	B1	B2	B3	C 1	C2	**Over-all**	Main issues[1]
Natural forest	1	1	1	1	1	1	1	1	1	**1**	
Community-based forest management	1	1	1	1	1	1	1	1	1	**1**	
Commercial logging	0.5	1	1	1	1	1	1	1	1	**0.5**	C
Rubber agroforests	0.5	1	1	1	1	1	1	1	1	**0.5**	C
Rubber agroforests with selected planting material	0.5	1	1	1	0.5	0.5	1	1	0.5	**0.5**	C, K, W,P
Rubber monoculture	0.5	1	1	1	1	1	1	0. 5	0.5	**0.5**	C,W,P
Oil palm monoculture	0.5	1	1	1	1	1	0.5	1	1	**0.5**	C, Fert
Upland rice/ bush fallow rotation	1	1	1	1	1	0.5	0.5	1	0.5	**0.5**	Fert, P
Cassava/*Imperata* rotation	0.5	0.5	1	0.5	0.5	0.5	0	0. 5	1	**0**	C, Fert, W

1. C = soil compaction; K = potassium balance; Fert = price of fertilizer; W = weeds; P = pests and diseases

Table III.10 *Table of land use transformations that are feasible in a 20-50 year period; crosses indicate where transitions from one land use system to another are possible*

Land use system	1	2	3	4	5	6	7	8	9	Comment
1. Natural forest	X	X	X	X	X	X	X	X	X	Universal starting point
2. Community-based forest management	?	X	X	X	X	X	X	X	X	
3. Commercial logging	?	X	X	X	X	X	X	X	X	
4. Rubber agroforests	?	X	?	X	X	X	X	X	X	
5. Rubber agroforests with clonal planting material		?	?	X	X	X	X	X	X	
6. Rubber monoculture					X	X	X	X	X	
7. Oil palm monoculture					X	X	X	X	X	
8. Upland rice/ bush fallow rotation		X		X	X	X	X	X	X	
9. Cassava/*Imperata* rotation					?	?	?		?	Self incompatible, a 'dead end'

IV. *Local and national concerns: criteria and indicators*

Alternative systems and technologies must be profitable and socially acceptable for smallholders; if not they have little prospect for adoption (hence impact). Part IV reports the empirical results of application in Indonesia of the methodological innovations of the ASB global working group on socioeconomic and policy issues (documented in Vosti *et al*. 1998). The GEF project did not provide funds for empirical research on these essential topics, which affect adoptability of land use alternatives by smallholders and also are the basis for assessing tradeoffs (if any) between national policy objectives and global environmental benefits. Thus, funding had to be sought from other sources – and was secured from the Asian Development Bank (ADB) and the Ford Foundation supplemented by additional funds from DANIDA, the Government of Japan, and others. The process of seeking additional funding delayed work on this key component of the research, which could not begin until funding was secured in mid-1997.

Assessment Criteria. Empirical results for Indonesia for four sets of indicators – profitability, labor requirements, cash flow constraints, and household food security – will be presented in this part of the report. From among these, a sub-set of indicators will be selected for two of the sets of assessment criteria presented in Part I:

- Criteria for **smallholders' socioeconomic concerns**: production incentives, labor constraints, and household food security.
- Criteria for **policymakers' objectives**: growth and aspects of equity and stability

This part of the report will conclude with sections on tradeoffs and complementarities among smallholders' concerns and policymakers' objectives and on 'scaling up' the assessment from plots to landscapes and watersheds. Criteria for **institutional barriers to adoption**, which are concerns to both smallholders and policymakers, will be considered in Part V.

IV.1 Profitability indicators

Since many of the land use alternatives in Sumatra involve perennials, the appropriate measure of **profitability** is the **net present value** (NPV, present discounted value) of revenues less costs of tradable inputs (fertilizer, fuel, etc) and of domestic factors of production (land, labor, management) over the full 25 year period considered in the analysis. Because it can account for input and factor costs as well as outputs and can handle time by discounting future values, this measure of total factor productivity is superior to partial measures of productivity (e.g., yield or output per unit labor).

The **policy analysis matrix** (PAM) technique provided the framework for estimating profitability indicators as well as the indicators of labor requirements and cash flow constraints discussed below. The 'PAM' is a matrix of information about agricultural and natural resource policies and factor market imperfections that is created by comparing multi-year land use system budgets calculated at private and social prices (Monke and Pearson 1989 is the basic reference). **Private prices** are the prices that households and firms actually face, so private profitability – the NPV at private prices **--** is a measure of ***production incentives***. **Social profitability**, calculated at economic (shadow) prices, removes the impact of policy distortions and market imperfections on incentives for adoption and investment. Thus **social profitability** —the NPV at social prices **--** is an indicator of ***potential profitability*** (or comparative advantage). **Divergences**, the difference between private profitability and social profitability, are indicators of distortions, arising either from policy or from market imperfections and failures. The structure of the PAM is described in Table IV.1, which is taken from Monke and Pearson (1989, p. 19).

As pointed out by our colleague, Arild Angelsen, the list of potential corrections to arrive at social prices is quite long. The adjustments to derive social prices in these analyses focus mainly on policy distortions arising from trade restrictions. As discussed below, we also used a lower real discount rate (15% instead of 20%) to capture a rough approximation of the impact of capital market imperfections on the private cost of capital. We have used the same wage rate in both sets of calculations, implicitly assuming that there are no imperfections in the market for unskilled labor. While this is not completely true, it also seems that these imperfections do not have a significant effect in the unskilled labor market (see discussion of labor markets in Section V.4 below). The main omission here is that prices are not adjusted to reflect costs and benefits of environmental externalities arising from these production activities, such as smoke, ecological changes, and loss of watershed functions. These adjustments, which probably would be significant and which are necessary for the complete analysis, are not possible at this time because of lack of data. Filling this gap is a priority for future research, as discussed below in Section IV.5.

These studies focus on primary production in agriculture and forestry. To get the complete economic picture, especially regarding comparative advantage and growth potential, it would be necessary to extend these analyses ‘downstream’ to include the private and social profitability of processing activities, especially for timber, rubber, cassava, and palm oil. Each of these studies of processing activities (described in Appendix E) would be a major undertaking in its own right and was not feasible during Phase II work in Indonesia.

Table IV.1 Policy Analysis Matrix

	Revenues	Costs: Tradable inputs	Costs: Domestic factors	Profits
Private prices	A	B	C	D[1]
Social prices	E	F	G	H[2]
Effects of divergences and efficient policy	I[3]	J[4]	K[5]	L[6]

[1] Private profits, D, equal A minus B minus C.
[2] Social profits, H, equal E minus F minus G.
[3] Output transfers, I, equal A minus E.
[4] Input transfers, J, equal B minus F.
[5] Factor transfers, K, equal C minus G.
[6] Net transfers, L, equal D minus H; they also equal I minus J minus K.

Ratio Indicators for Comparison of Unlike Outputs

Private cost ratio (PCR): C/(A – B)
Domestic resource cost ratio (DRC): G/(E – F)
Nominal protection coefficient (NPC)
 on tradable outputs (NPCO): A/E
 on tradable inputs (NPCI): B/F
Effective protection coefficient (EPC): (A – B)/(E – F)
Profitability coefficient (PC): (A – B – C)/(E – F – G) or D/H
Subsidy ratio to producers (SRP): L/E or (D – H)/E

Source: Taken from Monke and Pearson 1989, Table II.1, page 19.

To assure comparability across land use systems (and across ASB sites in Indonesia and Thailand), a regional short course on application of the PAM approach to natural resource management and policy analysis was be held in Chiang Mai, Thailand, 1-13 June 1997. Through participation in lectures and computer-based exercises, teams developed a common methodology for analysis of land use systems. The course, which was funded by ADB, involved eleven participants from Indonesia (see Annex D) plus eight from Thailand. The Indonesian teams trained in the course then undertook studies of six Sumatran land use systems selected for study in ASB Phase II. Five of these six studies were sub-contracted to Indonesian national partners listed in Table IV.2. The sixth, on transmigration systems, was completed by an ICRAF researcher (see Budidarsono 1998). Fortunately, except for the study of industrial timber, preliminary results of these ongoing socioeconomic assessments are available to be included in this report.

__Table IV.2__ ADB-Funded Grants for Socioeconomic Research in Indonesia

Research Topic	Researchers	Institution
1. Does shifting cultivation really cause deforestation? Economic analysis of shifting cultivation and five-year bush fallow in Lampung Province	- Bustanul Arifin - Agus Hudoyo	Department of Agricultural Economics and Rural Sociology, University of Lampung
2. Economic analysis of land use system for large scale plantations of oil palm and industrial timber estates	- Retno Maryani - Setiasih Irawanti	Forest Products and Forestry Socio-Economics Research and Development Centre, Ministry of Forestry
3. Economic analysis of large scale logging	- Machfudh - Wesman Endom	Forest Products and Forestry Socio-Economics Research and Development Centre, Ministry of Forestry
4. Analysis of the economic efficiency and comparative advantage of the Sumatran small-holder rubber using 'PAM' method	- Prajogo U. Hadi - Gelar Setya Budhi	Center for Agro Socio-Economic Research, Agency for Agricultural Research and Development, Department of Agriculture
5. Economic analysis of NTFP extraction in Rantau-pandan, Province of Jambi	- Arif Aliadi - Wibowo A. Djatmiko	The Indonesian Tropical Institute (LATIN)

Operational definitions for the six land use types were given at the end of Chapter I.

1. Community-based forest management,
2. Large-scale commercial logging
3. Smallholder rubber, including both rubber agroforests and rubber monoculture.
4. Large-scale plantations of oil palm and industrial timber estates
5. Upland rice with bush fallow
6. Transmigration systems, focusing on cassava and *Imperata cylindrica* (*alang-alang*)

See Tables I.2, I.3, and I.4 for additional specifications of these systems. Annex E contains the PAMs for the various scenarios and more information on each of the studies.

All of these studies use the macroeconomic parameters tabulated below because the data were collected in July 1997, when the exchange rate was about Rp 2400 / US dollar. By most assessments of economic fundamentals (e.g., purchasing power parity), the Indonesian Rupiah was not greatly overvalued at that time. The consensus was that the overvaluation of the Rupiah relative to the dollar may have been 10-15% in June 1997. Some expert analysts even expected the Rupiah to appreciate if it were floated in 1997 (Mc Leod 1997). To almost everyone's surprise, the collapse of the Thai Baht in July 1997 spread to the Rupiah (among others). By January 1998, the Rupiah had fallen to over Rp 17,000 per US dollar. After a recovery below Rp 10,000, it had fallen again to over Rp 14,000 per dollar in June 1998. The reasons why Indonesia's currency fell the furthest and has stayed down the longest rest with profound problems in its banks and other financial institutions compounded by the worst social instability and political uncertainty in 30 years.

The impact on land use incentives resulting from this monetary, social, and political crisis will be examined in Part VI. Although the causes of the regional financial crisis are not yet fully understood, they do not reflect fundamentals of the productive sectors of Indonesia's economy. **By any *economic* measure, the Indonesian Rupiah was extremely undervalued in mid-1998 as a result of the financial, social and political turmoil.** (Under these conditions, people demand a huge premium to hold Indonesian currency.) **To assess land use alternatives over the longer term, the macroeconomic parameters of July 1997 are a better guide than those that have prevailed during the crisis.**

Macroeconomic parameters for PAMs	**July 1997**
Exchange rate	Rp 2400 / US$ 1
Wage rate in Sumatra	Rp 4000 / day
Real interest rates (net of inflation):	
Private:	20 % per year
Social:	15 % per year

Real interest rates – that is interest rates net of inflation -- are the discount factors used to value future cash flows in current terms. As in most developing countries, capital markets in Indonesia are fraught with imperfections – some of which have been manifested in the financial crisis. Private interest rates (at least for smallholders, if not for large corporations that could secure subsidized credit) have been very high in real terms. In July 1997, *formal* sector lending rates were almost 30% pa and inflation was under 10% pa. Thus the private interest rate of 20% used in these analyses is a lower bound for the actual cost of capital for smallholders. The real social interest rate is less than the private rate and 10% is probably too low. So, somewhat arbitrarily, a rate of 15% has been used for the real social cost of capital, which is both the interest rate and the discount rate for calculating NPV at social prices. This difference between private and social interest rates is the main cause of divergences between calculations at private and social prices for many of the land use alternatives. The analyses are quite sensitive to the choice of discount rates, which unfortunately involves considerable uncertainty. Particularly for the private cost of capital, the subjective discount rate may be much higher (or lower) than the 20% real rate used here. Interest rates in the informal sector often exceed 100% per year. Stein Holden estimated that the average subjective discount rate

(rate of time preference) among transmigrants in Riau exceeded 90% (Arild Angelsen *pers comm).* On the other hand, as Angelsen has pointed out, 'desire to claim or secure land rights may modify the effect of high discount rates.'

An activity with NPV less than zero is 'unprofitable' by definition. This does not necessarily mean that there are no positive cash flows. Instead, it means that it would be more profitable to do other things with the land, labor and capital than to devote them to this activity. **If land is scarce, the NPV estimates measure returns to land** because they are the 'surplus' remaining after accounting for costs of labor (including imputed value of family labor), capital (through discounting), and purchased inputs.[1] (To the extent that management is a scarce factor, it also would be included in the residual.) We also present a measure of **returns to labor, the wage rate that sets the NPV equal to zero**. This calculation converts the 'surplus' to a wage after accounting for purchased inputs and discounting for the cost of capital; no surplus is attributed to land. This measure of returns to labor is valid when land is abundant and labor is scarce. Returns that exceed the wage, Rp 4000 per day, mean the activity will be attractive to family members compared to off-farm work or would justify hiring labor.

Although local land abundance with household labor scarcity has prevailed historically and certainly continues in the ASB sites in Brazil and Cameroon, this fundamental relationship seems to be shifting in Sumatra. Nevertheless, it still is reasonable to believe that local land abundance and household labor scarcity continue in the forest margins, at least from the point of view of smallholder households in central Sumatra. This is supported by the result that returns to labor for rubber agroforests, the predominant smallholder land use, are almost identical to the wage rate (Table IV.3). This implies that no 'rent' accrues to land under the dominant system and is consistent with land abundance (since the 'rent,' its opportunity cost, is near zero).

- For these reasons, and to facilitate cross-site comparisons, **returns to labor valued at private prices was selected as the indicator of profitability for smallholders' production incentives.** Private prices are used in this indicator to reflect actual incentives smallholders faced under policies in effect in mid-1997.

At the same time, local and national policymakers increasingly are making public policy decisions under conditions of land scarcity and labor abundance. Land certainly is a constraint that should be considered by policymakers in choices regarding development of large-scale estates versus smallholders and there are other reasons to believe these development strategies are mutually exclusive (Tomich *et al* 1995).

- **Returns to land valued at social prices will be used as the indicator for potential profitability from policymakers' perspective.** Social prices are used to indicate potential value added from this alternative if policy distortions and market imperfections were removed. This impact on value added is directly linked to policymakers' growth objectives.

[1] In some figures, we will use an alternative measure called the **internal rate of return** (IRR), which is the discount rate that brings the NPV to zero. The IRR is technically inferior to NPV for assessment of mutually-exclusive alternatives (Gittinger 1982), but using it makes the same point with greater clarity.

Table IV.3 Profitability Matrix, July 1997

Land Use System	RETURNS TO LAND			RETURNS TO LABOR	
				Wage to set NPV to Zero	
	NPV Private Prices	NPV Social Prices	Divergences	Private Prices	Social Prices
	Rupiah 000 / ha	Rupiah 000 / ha	Rupiah 000 / ha	Rp / person-day	Rp / person-day
Community - based forest management	8.0 to 16	9.4 to 18	(1.5) to (2.5)	11,000 to 12,000	11,000
Commercial Logging	(804) to (131)	(32) to 2,102	(2,233) to (773)	(17,349) to 2,008	7,,917 to 31,400
Rubber agroforest (seedlings)	1.6	73	71	4,000	4,100
Rubber agroforest (clones)	*(95) to 2,202*	*234 to 3,623*	*(330 to (1,420)*	*3,900 to 6,900*	*4,200 to 7,700*
Rubber monoculture	(167)	*(993)*	*(826)*	*3,683*	*2,600*
Oil palm monoculture	275	1,480	*(1,204)*	5,797	9,981
Upland rice/bush fallow rotation	(220) to (76)	(180) to 53	(37) to (130)	2,700 to 3,300	3,000 to 4,500
Monoculture cassava/*Imperata cylindrica*	(71) to 360	(315) to 389	135 to 243	3,895 to 4,515	4,085 to 4,455

Estimates of returns to land and returns to labor, each evaluated at private and at social prices, are presented in Table IV.3. The upland rice / bush fallow rotation stands out as being unprofitable, either in terms of potential profitability (returns to land at social prices) or smallholder production incentives (returns to labor at private prices). For the upland rice / bush fallow system, the higher (less negative) returns are for the fallow of ten years or more, which is no longer feasible. The lower (or more negative) numbers in the range correspond to short fallow shifting cultivation. These results are consistent with the disappearance of shifting cultivation in most of Sumatra's peneplains and piedmont. Sustainable forms of continuous foodcrop production may be *technically* feasible in Sumatra's peneplains, but often are not financially attractive because they require too much labor and too many purchased inputs. For this report, we have focused on cassava, which may be among the most profitable of the continuous foodcrop alternatives for the peneplains. The most profitable cassava system studied was an extensive fallow system without any fertilizer applications. Profitability at private prices was estimated at over Rp 545,000 per ha (see Appendix E). However, this example is not included in Table IV.3 because, as noted in Part III, these systems mine nutrients, exhausting the soil and reducing the range of future land use options. Two cassava systems that use fertilizer are included in Table IV.3, one with fertilizer applications from the first year and one with fertilizer beginning in the seventh year after forest clearing. Application of fertilizer from the first year after clearing (30 kg N; 60 kg P; and 60 kg K per year) is not profitable privately (negative Rp 71,000 per ha) or socially (negative Rp 315,000 per ha). These treatments and the agronomic results are taken from experiments conducted at the Biological Maintenance of Soil Fertility (BMSF) research project at the ASB benchmark area in Lampung. However, an intermediate approach (also reported in Table IV.3) with fertilizer applications beginning in year seven (50 kg N; 50 kg P) does produce relatively attractive returns at both private prices (Rp 360,000 per ha) and social prices (Rp 224,000 per ha). However, the longer-run sustainability of this system requires further study. Note that, because of chemical fertilizer price subsidies that were still in effect in mid-1997, cassava is one of the few cases where estimated 'divergences' are positive, indicating that policy increases private profitability.

Returns to labor are highest for community-based forest management (extraction of NTFPs), but these high returns are dependent on some mechanism to exclude outsiders. Thus, this system plays an important role for existing communities that can regulate access to forest lands. If, on the other hand, communities could not regulate access to their forests, one would expect the returns to labor from extraction of forest products to decline toward the wage rate. However, even under 'open access' one would still expect returns to labor to exceed the wage rate by some margin equal to a risk premium. The risks involved include possibility of failure to find products to extract and also the risk (and associated costs) of detection by officials, since many of these activities are prohibited.

The relatively low returns to land – only slightly above rubber agroforests – suggest that NTFP extraction is not a feasible alternative for large numbers of people, because there is not enough land for everyone to practice this extensive livelihood strategy. This results must be interpreted with some care, however, for three reasons. First, these extractive activities are highly site-specific. It may be that the study site is not representative. Only additional studies can resolve this. Second, as often is the case, at least part of this community forest is on State Land and it is not clear how this problem of tenure insecurity might bias these results. On one hand, long run profitability may be overstated because of unsustainable harvesting (viz., songbirds and rattan). On the other hand, if the community or individual members had secure property rights, this might induce them to invest and to manage resources to increase productivity over time. Finally, as already noted, it was not possible to put a value on timber extraction, but it is likely that this is significant. We hope to be able to conduct a study of the economics of smallholder timber extraction in the future.

The results for commercial logging appear paradoxical, but this is because of policies that produce the biggest divergences for any of these land uses. First, the sustainable logging regulations – if they really are followed – reduce profitability, mainly by slowing timber extraction. Second, high export taxes (effectively an export ban) for logs and sawn timber depressed the domestic prices of logs from 50-70% below comparable world prices. (Timber export taxes were to be reduced to 30% by the end of 1998.) However, timber companies could get around both of these problems. First, as mentioned above, many companies circumvent regulations on timber extraction. Second, these typically are vertically-integrated firms producing products like plywood for the export market.

Therefore, the best indicator of profitability of these activities for logging companies is the figure of just over Rp 2 million per ha, valued at social prices that reflect world prices of forestry products. When comparable estimates are available for industrial timber plantations, it seems likely that these will be more profitable than logging.

By all accounts, illegal logging is common, which seems inconsistent with these results of negative returns to logging at private prices. However, the major cost item for logging concessions -- establishing and maintaining logging roads -- is not incurred by illegal loggers. If one can get access to timber without having to invest in infrastructure (and at the same time circumventing various fees), logging can be very profitable.

One could argue that the estimated NPV of logging activities of over Rp 2.1 million per ha (about US$ 875) in mid-1997 should be added to the social profitability for *all* the other activities and to private profitability, at least for large-scale estates that often can market timber felled as a by-product of land clearing. Recall that natural forest cover is the starting point underlying these calculations (and all the other estimates in this report). Thus all the forest-derived land uses (rubber, oil palm, cassava, and even upland rice) started out with felling of forest timber. And, as already noted, there is substantial (but as yet unquantified) timber felling in conjunction with NTFP extraction. Thus, in many cases it would be appropriate to add the value of the harvested wood to the profitability of each activity overall. This modification is debatable for private profitability of smallholder systems, however, because most of the felled timber is burned instead of marketed. Yet, this simply may be a result of trade restrictions that make it artificially difficult for smallholders to sell timber legally (Section VII.2). The estimate of timber values was not added to other land uses in the tables presented in the report, however, because the one-off value of timber extracted as a by-product of land clearing often exceeds the value of the derived land use. **Thus, although it is technically correct to do so, adding the value of timber – which admittedly is subject to considerable uncertainty – would simply obscure differences in profitability among the derived land uses. This problem in presentation is linked to a problem in conservation: if regulations can be circumvented – as often is the case -- forest conversion is privately profitable simply for the value of timber regardless of the subsequent land use. Of course, for the social profitability calculations, timber values would have to be balanced against losses of ecological and other environmental functions of natural forests.**

Oil palm is widely viewed as the most profitable alternative for Sumatra's peneplains and Indonesia's oil palm producers have the lowest unit costs in the world. Thus, it is no surprise that large-scale oil palm monoculture is among the most profitable alternatives, either in terms of returns to land valued at social prices or in terms of returns to labor valued at private prices. The later measure is of limited relevance, however, because the official wages for plantation workers are well below these estimates of returns to labor. But, much as they had earlier in Malaysia (Barlow 1986), plots of 2-5 ha of oil palm planted by independent smallholders began to appear in Sumatra beginning in the 1980s. These merit study for their possibility to combine high potential profitability from a national perspective with attractive returns to smallholders' labor. For the time being, however, Government development strategies discriminate against the emergence of independent smallholder oil palm producers. For example, some provinces will not license palm oil mills unless the enterprise also has its own oil palm plantation or associated smallholders in nucleus estate/smallholder (NES) schemes. This is intended to prevent NES participants from selling their produce outside the project (as happened in the case of rubber) in order to avoid repayment of loans. But not licensing independent mills in an effort to prevent free trade in fresh oil palm fruit also retards development of the market for independent smallholder oil palm producers.

The three contrasting rubber systems produce a wide range of results. First, as already noted, it is encouraging that returns to labor at private prices are virtually identical to the market wage for rubber agroforests planted with seedlings. Although these smallholders are the lowest cost producers of natural rubber in the world (Barlow *et al.*, 1994), returns to land at social prices are not much above upland rice with a long bush fallow rotation and are well below oil palm monoculture.

Perhaps the most striking result in Table IV.3 are the returns to land at social prices for rubber agroforests planted with PB 260 clones, which rival large-scale oil palm monoculture. This system also produces attractive returns to labor at private prices. ***These data must be treated with caution – which is why they are in italics – since they are based on projections from farmer-managed trials and have not been verified through broader experience by smallholders***. The top of the range of profitability estimates might actually be attained by 10-25 % of smallholders (E Penot *pers comm.*) However, the lower figure in the range represents an expert's best guess about a 'worst case' scenario for yields in this system for the bottom quartile. The big question is where the middle of the profitability distribution would be for this system – and that can only be answered through farmers' experience. But these results support the idea that potential profitability of rubber agroforests planted with clonal material (and other smallholder agroforests planted with appropriate, higher-yielding germplasm) may be comparable to large-scale oil palm plantation monoculture, at least as long as wages are low.

The profitability estimates for smallholder rubber monoculture planted with GT 1 clonal seedlings provide a cautionary tale to balance the encouraging projections for rubber agroforests planted with PB 260 clones. These monoculture plots were part of a government-sponsored rubber replanting project that was undertaken with high expectations. But the disappointing yields that were obtained because of institutional shortcomings involving supply of planting material, technical information, and credit – these will be taken up in Part V -- could not offset the high costs of that project's approach. Instead of the high-cost approach in this case of rubber monoculture, the strategy to introduce clones into smallholders' agroforests seeks a moderate increase in yields at minimal incremental costs. Yet the costly lessons of earlier failures in smallholder rubber development should be borne in mind (Tomich 1991), including difficulty in supplying clonal planting material. The sites studied, for example, were designed to be planted with clones but were actually planted with clonal seedlings because of this problem.

IV.2 Labor requirements indicators

Table IV.4 presents three different indicators of labor requirements. First is total person-days required to establish a system, where 'establishment' refers to the period before positive cash flows begin. The two systems with highest potential profitability in the previous section – smallholder rubber agroforests planted with clones and large-scale oil palm—both have very high labor requirements for this phase. However, recall that each system also had high returns to labor. Thus, problems in the labor market or credit market that will be discussed in Part V could impose a serious barrier to adoption, but returns to labor itself is not a problem here.

- More generally, **returns to labor valued at private prices**, which was selected above as an indicator of smallholders' production incentives, **also is a good indicator for smallholders' concerns with labor constraints if combined with assessments of institutional barriers in markets for labor and capital**.

The two other indicators of labor requirements in Table IV.4 are closely related, labor requirements for the operational phase (defined as the period after positive cash flow begins) and total labor. Both measures are averaged over time and the units are person-days per hectare per year.

- **From the perspective of policymakers concerned with employment generation, total time-averaged labor requirements is a good indicator that is related to equity and stability criteria.** Note, however, that while labor-intensive alternatives should be attractive for policymakers who are concerned with job creation, these alternatives will only be attractive to households if they provide attractive returns to labor, the indicator discussed above.

For the rubber and oil palm systems that were evaluated, total time-averaged labor requirements are similar, ranging between 100 and 150 person-days per ha pa. Harvesting labor is the biggest component in these systems. Because of lack of pronounced seasonality in much of Sumatra, harvesting of rubber and oil palm can go on roughly 10 months a year. The two extractive activities – community based forest management and commercial logging – fall at the opposite extreme. Neither of these extractive activities nor the upland rice / bush fallow rotations can provide many employment opportunities compared to treecrop-based alternatives.

Table IV.4 Labor requirements matrix, July 1997
(total labor inputs for establishment and averages over time for operations and total labor)

Land Use System	Establishment phase (Person-days/ha)	Operation phase (Person-days/ha/yr)	Total Labor (Person-days/ha/yr)
Community - based forest management	na	0.2 - 0.4	0.2 - 0.4
Commercial Logging	15 to 100	17 to 41	31
Rubber agroforest (seedling)	271	157	111
Rubber agroforest (clones)	*444*	*74*	*150*
Rubber monoculture	*344*	*166*	*133*
Oil palm monoculture	532	83	108
Upland rice / bush fallow rotation	na	15 to 25	15 to 25
Monoculture cassava / *Imperata cylindrica*	na	98 to 104	98 to 104

IV.3 Cash flow constraints indicators

Because perennials are so important among the Sumatran alternatives, our analysis of cash flow constraints focused on multi-year (rather than seasonal) cash flow constraints in order to assess whether the investments required by these systems are barriers to adoption by smallholders. Table IV.5 takes two perspectives on multi-year cash flow constraints: years to positive cash flow and the NPV of establishment costs, which we define as costs prior to positive cash flow. The imputed value of family labor is included in these establishment costs because these labor inputs presumably represent foregone earnings in other activities even if they do not require cash outlay.

By either measure, community-based forest management is the only profitable system without any multi-year cash flow constraints. For the other systems, years to positive cash flow range from 2 years for logging and cassava to 6-10 years for smallholder rubber and 10 years for large-scale oil palm. Time is not a constraint by itself, as evidenced by almost 3 million ha of rubber agroforests that have been planted by smallholders without any formal credit. The NPV of establishment costs at private prices, which is derived directly from the PAM cash flows, probably is the best indicator of cash flow constraints for smallholders. In interpreting these estimates, keep in mind that the existing rubber agroforests are evidence that the Rp 1.3 million required to establish them has not been an insurmountable barrier for smallholders. These estimates suggest that replacing seedlings with higher-yielding clones in rubber agroforests more than doubles investment costs to roughly Rp 2.6 – 2.9 million per ha. Since there is no long-term institutional credit for smallholders in Sumatra, whether these investment requirements are barriers to adoption depends in large part on the divisibility of the activity (i.e., is it possible to plant a bit at a time?).

At Rp 8 million per ha, investment costs for large-scale oil palm plantations are the highest of all. Investments of this magnitude would be difficult for many smallholders. But capital costs for large-scale plantations may be inflated for at least two reasons. First, large-scale oil palm plantations formerly received heavily subsidized credit from the Government, which would tend to make them artificially capital intensive. Second, there may have been a tendency among respondents to overstate investment costs in order to mask the profitability of these investments. Even more than rubber, adapting high-yielding oil palm systems as alternatives for smallholders will require research to develop options that are less capital intensive.

Table IV.5 Cash flow constraint matrix, July 1997

Land Use System	Years to positive Cash flow Private prices (Years)	NPV of Establishment cost Private prices (Rupiah / ha)	Years to positive Cash flow Social Prices (Years)	NPV of Establishment cost Social Prices (Rupiah / ha)
Community - based forest management	na	na	na	na
Commercial Logging	2	820,669 to 869,199	2	716,917 to 764,238
Rubber agroforest (seedlings)	10	1,305,536	10	1,477,735
Rubber agroforest (clones)	*6 to 7*	*2,593,458 to 2,862,422*	*6 to 7*	*2,950,338 to 3,303,338*
Rubber monoculture	*10*	*2,085,257*	*10*	*2,192,584*
Oil palm monoculture	10	8,041,847	9	8,182,015
Upland rice/bush fallow rotation	never	na	never	na
Cassava / *Imperata cylindrica*	2	na	2	na

IV.4 Household food security indicators

Food nutrient content measures, as in Table IV.6, can be seriously misleading because food security derives from the ability to obtain food, including purchases, and not just capacity to grow it. An unsustainable, low-productivity shifting cultivation system that is suffering decreasing yields because of nutrient depletion and increasing variability in yields because of pest problems may be a riskier basis for securing household food supply than a rubber plot that reliably produces a steady stream of output that can readily be marketed in exchange for rice that trades at a stabilized price.

To accommodate land use alternatives that do not involve foodcrops, our food security indicator is based on Sen's (1982) concept of risk of food entitlement failure, which encompasses trade-based and production-based entitlements to food as well as security of property rights over productive assets (inheritance and transfer entitlements). Moreover, one of the key dimensions of this analysis is the 'path' of food entitlement – is it derived from consumption of one's own food production, exchange of one's own production for food, or working for wages to buy food? These 'paths' determine the measure of risk of entitlement failure. If the path is production of one's own food, **one simple indicator of production risk is the coefficient of variation of yields**.[2] If the path is exchange for food, terms of trade risk must be considered in addition to production risk. **A simple indicator of terms of trade risk is the coefficient of variation of the ratio of revenue (price of output times yield) to the price of the staple food, which for Sumatra is rice.** This can also be viewed as the coefficient of variation of purchasing power in terms of rice. (Note that if one's product is rice, the prices cancel out and all that is left is the coefficient of variation of yields, our indicator of production risk.) Finally, if the path is wage labor, risk of entitlement failure is a function of the employer's financial situation, which is only partly related to production or terms of trade risk. These simple measures do not adapt easily to multiple output systems, such as extraction of non-timber forest products. Although many of these commodities may be important to households' food and nutritional security, data for food security indicators are not available for NTFPs. Calculations in Table IV.6 indicate that production risk for rubber agroforests may be less than the upland rice/bush fallow rotation. Terms of trade risk for rubber is twice its production risk, as measured by its coefficient of variation. Although these measures suggest upland rice/bush fallow is less 'risky' than rubber, the superior production incentives for rubber agroforests are the reason why they have displaced upland rice over the past century.

IV.5 The 'missing middle': scaling up from plots to landscapes

Work is needed to expand the assessments of sustainability from plot-level agronomic issues to include environmental externalities at the landscape level and watershed functions. In addition to the two existing study areas in Lampung, the ASB-Indonesia Consortium is planning to have a serious look at the issues of watershed degradation and rehabilitation in the foothill/ mountain zone of Lampung . This is a zone of major conflicts between migrants who are attracted by the fertility of the soils (allowing for coffee production), but who come into conflict with forestry officials who try to maintain this zone as 'protection forest'. This site, together with Mae Chaem in Northern Thailand and Manupali in Mindanao, the Philippines, are the 3 areas that will be the focal points for our regional program's research on policies and technologies to address environmental externalities at the landscape level.

The policy-driven agenda will require new biophysical insights into landscape-level processes of soil and water conservation, as current plot-level insights can not be easily scaled up (Figure IV.1). The Sumber Jaya area, halfway between Krui and the North Lampung ASB benchmark area seems eminently suitable to take up this challenge (see Map 3). In order to complete the landscape transect, it is necessary to expand from the present focus on the peneplains and piedmont agroecological zones in order to include the montane zone and coastal swamps.

[2] The coefficient of variation is the standard deviation in a series divided by the mean of the series. It is a relative measure that expresses variation as a proportion of the average level.

Table IV.6 Household Food Security Matrix

Land Use System	Nutritional Value of Food Produced by the System			Food Entitlement via: Own Production, Exchange, or Wages		Risk of Food Entitlement Failure		
				Establishment	Operation	Production Risk		Terms of Trade Risk
	Calories: avg kcal /ha/yr	Protein: Avg. kg /ha/yr	Micro-nutrients			Food	Non-food	
Community-based forest management	?	?	Important	n.a.	Own prod'n & exchange	?	?	?
Commercial logging	Nil	Nil	Nil	Wages	Wages	n.a.	n.a.	n.a.
Rubber agroforests	118	2.2	?	Own prod'n	Exchange	n.a.	0.13	0.26
Oil palm	19,800	Nil	Nil	Wages	Wages	n.a.	n.a.	n.a.
Upland rice / bush fallow rotation	441 - 490	8.3 - 9.2	Nil ?	n.a.	Own prod'n	0.18	n.a.	n.a.
Monoculture cassava degrading to *Imperata cylindrica*	9,900	13.6	Nil	n.a.	Own prod'n & exchange	0.06	n.a.	0.22

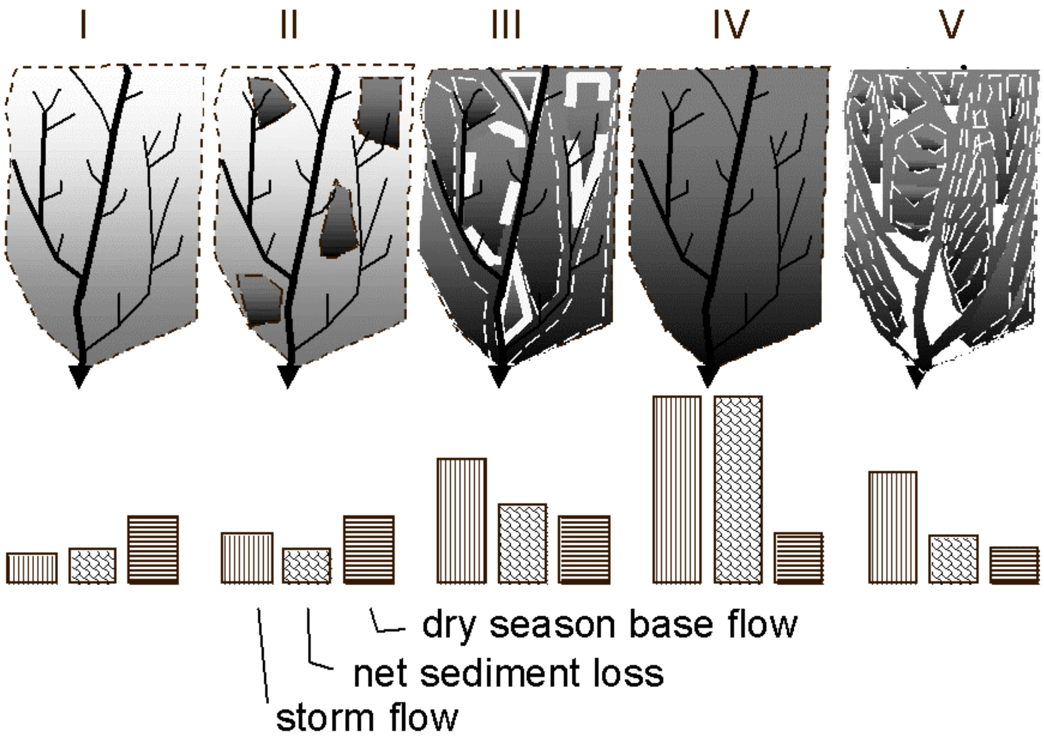


Figure IV.1 *Schematic development of the landscape in a sub-watershed and its effects on storm flow, net sediment loss and dry-season base flow: I. original forest cover, II. patches of forest opened for shifting cultivation, III. intensification of land use has brought most land into cultivation, except for riverain borders and hedges along paths, IV. reclamation of all 'wastelands' has removed all filter strips causing a disproportional rise in net sediment loss, V. restored agroforestry landscape with permanently vegetated contour strips and riparian woodlands (Van Noordwijk et al., 1998)*

Managing smoke. As will be discussed Part VI, banning burning has not worked. What policy options and policy instruments presently exist to manage the recurrent regional problem of too much smoke in the wrong place at the wrong time? What data would be useful in designing and implementing a strategy to manage burning in order to address the smoke problem? What are the consequences of land clearing without the use of fire? What is the role of remote sensing data? Of studies of local institutions? What other types of data or research would be useful to policymakers? If those data were available, how could they be used? (And, given the inaction to date, under what circumstances would they be used?)

Changing roles of biodiversity in the landscape. Much discussion of biodiversity conservation focuses on existence values – i.e., preventing extinctions. Landscape ecology currently emphasizes managing corridors and bufferzones to improve opportunities for dispersal and recolonization. Much less attention has been given to local functional values of biodiversity in the landscape (belowground as well as above), ranging from the tangible (but not yet well quantified) roles of biodiversity in sustainability and resilience of production systems to less tangible esthetic and spiritual roles of biodiversity for local people who experience its pluses (and minuses) daily. Which among these—and other roles—are felt to be most important at the local and national level? To what extent is it feasible to go beyond plot-level measures of richness and to scale-up to the landscape level? Are there important functions that are unquantifiable? If so, how can these be incorporated in the debate? More broadly, how can diverse societies identify these functional roles of biodiversity and assess tradeoffs with other public policy objectives?

Loss of watershed functions. National concern for forest conservation and reforestation often focuses on the loss of the watershed functions of natural forests. While some land uses may be as good as natural forest in this regard, land uses differ significantly in their ability to supply these watershed functions. Loss of watershed functions can be a combination of:

A. on-site loss of land productivity as a result of erosion,
B. off-site concerns about water quantity, including annual water yield, peak (storm) flow, dry season base flow, and groundwater recharge or depletion,
C. off-site concerns about water quality, including siltation of reservoirs and environmental damage from runoff of pesticides, fertilizers, or animal wastes.

Research on this topic will seek to quantify erosion from natural processes, agriculture or other activities (such as road construction) and to assess the impacts (positive as well as negative) of resulting sedimentation and to assess how land use change affects risks of floods and seasonal water shortages.

IV.6 Tradeoffs and complementarities between smallholders' concerns and policymakers' objectives

- **Policymakers' concerns with potential profitability and smallholders' concerns with production incentives and household food security**. If they *really* are more profitable than smallholder alternatives, all the large-scale systems involve tradeoffs with smallholder production incentives and household food security, since such projects often displace local smallholders with little or no compensation. (In the case of large-scale logging, there also is a tradeoff with employment creation.)

- **The potential profitability of some tree-based alternatives for smallholders (viz., rubber agroforests planted with clones) appears to be comparable to large-scale estates and logging.** However, this requires further verification through additional studies of smallholder rubber and other alternatives, such as smallholder timber and smallholder oil palm. **This result holds promise for complementarity between policymakers' concerns with potential profitability and smallholders' production incentives. It also suggests that policy concerns with equity and mounting concerns about social and political instability can be addressed through a smallholder-based development strategy without a significant reduction in economic growth.**

- **If they can be adapted for smallholders, the treecrop-based systems offer attractive production incentives.** Since labor markets appear to work well, labor should not be a serious constraint to adoption. Thus, **smallholder treecrop systems also offer complementarity with employment creation objectives.**

- Potential impacts on household food security depend crucially on government policy regarding rice marketing**. If the government can sustain its commitment to rice price stabilization, households' production of treecrops for sale should not jeopardize their food security**. However, it remains to be seen whether rice price policies can be sustained.

Other potential constraints to adoption by smallholders will be examined in Part V.

V. Output 3.1. Linking global environmental benefits to sustainable land use alternatives

This part of the report concerns **Project Output 3.1**, *recommendations that link global environmental benefits to land use practices by (a) assembling and prioritizing alternatives to slash-and-burn in terms of sustainable agriculture and (b) analyzing environmental impacts and collating these analyses with data on agricultural productivity and sustainability of current and alternative land use.* If alternatives to slash-and-burn were to have hope for significant impact in Indonesia (or any of the countries involved in ASB), the scope of the research project had to expand beyond climate change and biodiversity reported in Part II. This 'linking' goal of the project, which necessarily involves assessments of tradeoffs (and complementarities) among impacts spanning the plot, household, landscape, watershed, and national level--as well as global environmental phenomena—could not be achieved meaningfully without assessment of the sustainability and adoptability of the alternatives reported in Parts III and IV.

V.1 ASB-Indonesia matrix

This ASB matrix approach was developed as a tool to link global benefits with sustainable alternatives that are adoptable by farmers (Vosti *et al* 1998; Tomich *et al*, 1998). The ASB-Indonesia matrix links environmental, agronomic, policy, socioeconomic, and institutional indicators and was developed in collaboration with scientists from other ASB sites. These criteria and selection of specific indicators were discussed in detail in Parts I-IV:

Indicators of global environmental impacts:

- Carbon sequestration, measured as time averaged carbon
- Biodiversity, using the aboveground species richness for vascular plants

Agronomic sustainability:

- Summary indicator and specific qualitative indicators for pests and diseases

National policymakers' concerns:

- Potential profitability (comparative advantage), measured as the net present value of returns to land assessed at social prices
- Equity and stability, measured in part by employment opportunities. Indicators of adoptability presented below also are relevant to poverty alleviation objectives derived from concerns about equity and stability.

Smallholders' socioeconomic concerns and adoptability of land use alternatives

- Production incentives (financial profitability) received by smallholders, measured as returns to labor valued at private prices.

- Household food security, where one of the most important considerations is the pathway for obtaining food: own production, exchange, or wage labor.

- Qualitative indicators of problems in markets that may create barriers to adoptability. Problems in input supply, output, labor, and capital markets are indicated respectively by an ‘I’, ‘O’, ‘L’, or ‘K’. Uppercase letters indicate serious constraints; referred to as ‘red lights’ below. Lowercase letters indicate potential constriants; called ‘yellow lights’ below.

- Qualitative indicators of other institutional problems that also have the potential to create barriers to adoptability. The specific problems and issues considered below were access to non-market information (indicated by an ‘N’), regulatory issues (‘R’), local environmental issues (‘E’), insecure property rights (‘P’), equity biases (‘B’), and need for social cooperation (‘C’). Again, uppercase denotes a ‘red light’ and lowercase is a ‘yellow light’.

Now that this array of indicators has been assembled in Table V.1, it is possible to examine tradeoffs and complementarities across the various criteria.

V.2 Relationships among global benefits, sustainability, and local/national objectives

Because of the multiple criteria regarding production and environmental services of forests, ‘deforestation’ must be viewed as a multidimensional phenomenon. Sometimes this policy problem may simplify to a few key dimensions (tradeoffs). Conversion of natural forest has the major effect on the supply of forest functions, but the subsequent land uses also matter a great deal for agronomic sustainability and the supply of global environmental benefits. Table V.1 presents very preliminary estimates of the orders of magnitude of these differences for 7 systems that represent the major land uses in Sumatra’s peneplains, the low-elevation, undulating areas of poor soils that comprise the island’s largest agroecological zone.

All the tree-based systems (smallholder agroforests and monoculture as well as large-scale plantation monoculture) in Table V.1 are agronomically sustainable. On the other hand, shortening of fallow rotations from 10 years or more to less than 5 years with rising land scarcity is undermining sustainability of shifting cultivation, which has been disappearing anyway as population pressure increases in Sumatra (van Noordwijk *et al.* 1995a) And continuous cultivation of cassava does not appear sustainable on this land because of depletion of nutrients and of soil organic matter. On these soils, marginal revenues from fertilizer applications to cassava do not cover fertilizer costs at current prices, which are near the world market price for most nutrients except nitrogen, which has been subsidized in Indonesia. (Subsequently, fertilizer subsidies were lifted.)

Table V.1 ASB Matrix for the Forest Margins of Sumatra

Land use		Global environment		Agronomic sustainability		National policymakers' concerns		Adoptability by smallholders			
Description	Scale of operation / evaluation	Carbon sequestration	Biodiversity	Plot-level production sustainability		Potential profitability	Employment	Production incentives	Household food security	Institutional & policy issues	
		Time averaged (Mg/ha)	Plant species/ standard plot	Overall rating	Main sustain-ability issues (1)	Returns to land (Rp 000 / ha) at social prices	Time averaged labor input (days/ha/yr)	Returns to Labor (Rp / day) at private prices	Food entitle-ment via:	Market imper-fections (2)	Other institutional problems (3)
Natural forest	25 ha fragment / 1 ha	**254**	**120**	**1**		**0**	**0**	**0**	**n.a.**		
Community-based forest management	35,000 ha common forest / 1 ha	**176**	**100**	**1**		**9.4 to 18**	**0.2 to 0.4**	**11,000 to 12,000**	**own prodn & exchange**	**o**	**N, R, P, C**
Commercial logging	35,000 ha concession / 1 ha	**150**	**90**	**0.5**	**C**	**(32) to 2,102**	**31**	**(17,349) to 2,008**	**wages**	**O, K**	**N, R, E, P, B, C**
Rubber agroforest	1-5 ha plots / 1 ha	**116**	**90**	**0.5**	C	**73**	**111**	**4,000**	**exchange**		**P, b, c**
Rubber agroforest w/ clonal planting material	*1-5 ha plots / 1 ha*	*103*	*60*	*0.5*	*C,K,W,P*	*234 to 3,622*	*150*	*3,900 to 6,900*	*exchange*	*I, k*	*N, P, b, c*
Rubber monoculture	*1-5 ha plots / 1 ha*	*97*	*25*	*0.5*	*C,W,P*	*(993)*	*133*	*3,683*	*exchange*	*I, k*	*N, P, b, c*
Oil palm monoculture	35,000 ha estate / 1 ha	**91**	**25**	**0.5**	C,Fert	**1,480**	**108**	**5,797**	**wages**	**I, o, K**	**N, R, e, P, B, c**
Upland rice / bush fallow rotation	1-2 ha plots / 1 ha	**74**	**45**	**0.5**	Fert,P	**(180) to 53**	**15 to 25**	**2,700 to 3,300**	**own production**		**n, P, c**
Continuous cassava degrading to *Imperata*	1-2 ha plots within settlement project / 1 ha	**39**	**15**	**0**	C,Fert,W	**(315) to 603**	**98 to 104**	**3,895 to 4,515**	**own prod'n & exchange**	**o, K**	**n, E, p, c**

Notes for Table V.1
(1) Plot-level production sustainability: C = soil compaction; K = potassium balance; Fert = cost P = pest or disease problem
(2) Market imperfections: I = input market problem; O = output market problem; L = labor market problem; K = capital market problem
(3) Other institutional problems: N = non-market information problem; R = regulatory problem; E = local environmental problem; B = equity biases (gender or distributional); C = social cooperation required
For market imperfections and other institutional problems: upper case letters indicate more serious problems

C sequestration depends largely on cycle length (frequency of clear felling for rejuvenation). Where treecrop systems can be rejuvenated without clear felling, a substantial increase in C stock may be possible. Moreover, there do not appear to be big differences among forest extraction and the other tree-based systems regarding carbon stocks and greenhouse gases. Thus, as far as agronomic sustainability and climate change objectives are concerned, tree-based systems dominate among the alternatives.

Raising productivity of rubber agroforests, which span millions of ha, offers a promising pathway in Sumatra. There appears to be great potential for raising profitability of these systems though adaptation of existing higher-yielding clones within existing smallholder systems, which would also enhance household food security and expand employment opportunities. It may be possible to combine these potential benefits from the perspective of smallholders and national policymakers with significant biodiversity conservation because the mix of planted species is augmented by natural regeneration of forest species (Michon and de Foresta; van Noordwijk *et al*. 1995b). Indeed, these agroforests may approximate a number of forest functions, thereby providing the technical foundation for sustainable community-based forest and watershed management. But it must be emphasized that agroforests are ***not*** perfect substitutes for biodiversity conservation in natural forests. Indeed conversion of natural forests to agroforests involves a significant reduction in species richness. For assessments of higher plants made along 100 m line transects in Sumatra, over 350 species were found in primary forests while the number dropped to about 250 species for rubber agroforests. However, the richness remaining in agroforests still is much higher than the 5 or so species of higher plants found in rubber monoculture (Michon and de Foresta).

As discussed in Part IV, a key unresolved question is whether the potential for development of smallholder rubber agroforests can compete with the (private and social) profitability of large-scale alternatives, including oil palm plantations, industrial timber estates and logging concessions. These are viewed as 'best bets' for economic development by many policymakers and donors, in large part because of conventional wisdom of economies of scale in plantation development. **If** it turns out that large-scale development alternatives are more profitable—recall from Part IV that this is not a foregone conclusion—an important tradeoff between global environmental benefits and national development objectives will have to be faced. This is because there is an important tradeoff with biodiversity conservation for large-scale plantation monocultures such as oil palm.

Even if further analysis shows that the large-scale schemes hold no advantages in terms of private and social profitability compared to smallholder schemes (see Part IV), a potential tradeoff between profitability and biodiversity conservation remains to be addressed concerning smallholder systems (van Noordwijk *et al.,*. 1995b). Farmer management aimed at increasing productivity of systems often decreases biodiversity. Whether or not this apparent trade-off between productivity and biodiversity is inescapable is the subject of debate--and further research. Very little is known about the shape of the family of curves describing the trade-off function, or even whether a trade-off always exists (Figure V.1). If the relationship is convex to the origin, even modest productivity gains cause great loss of biodiversity. If the relationship is concave, biodiversity loss is relatively slow for initial increases in productivity. In this case, raising productivity to an intermediate level may involve a modest trade-off in terms of biodiversity loss. Thus, two of the most important research questions regarding the selection of 'best bets' in Sumatra are: what is the shape of this family of curves? and what factors influence the biodiversity of these complex, multistrata systems as productivity of their components increases? So while there may be a tradeoff between potential profitability and aboveground biodiversity in tree-based production systems, this requires further verification.

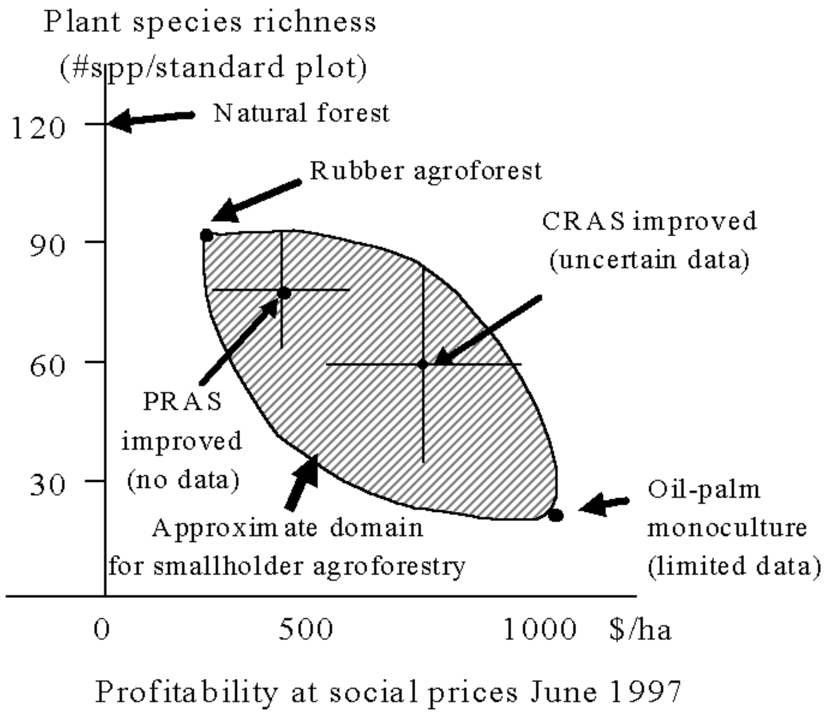


Figure V.1 *Potential profitability versus biodiversity for new technology*

V.3 Potential for development of technological options

A wider range of tree-based 'best bet' alternatives for smallholders should be examined regarding their environmental, agronomic, and economic impacts and feasibility of adoption. The priorities listed in Table V.2 were identified by scientists active in the ASB-Indonesia Research Consortium at a national meeting held in Bogor on 6 May 1998.

Table V.2 Priorities for further studies of Sumatran land uses

'Meta' land use	**Corresponding land use in Sumatra**	**Type / scale of operation**	**Landscape mosaic context**	Remarks
Candidates for new studies in the Peneplains				
Simple treecrop systems	**Smallholder oil palm monoculture**	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape mosaic	Identified as a priority at May ASB-Indonesia meeting: need for study in Jambi and Lampung?
	Smallholder timber monoculture	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape mosaic	Identified as a priority at May ASB-Indonesia meeting: need for study in Jambi and Lampung?
Candidates for new studies in the Piedmont				
Multistrata agroforestry systems	**Robusta coffee under shade**	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape mosaic	Linked to watershed work in Lampung – high priority as part of 'scaling up' efforts.
	Damar agroforests (rice-pepper-coffee-fruit-damar)	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape mosaic	Lots of data on this system are available.
Simple treecrop systems	**Robusta coffee monoculture**	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape mosaic	As noted above, linked to watershed work in Lampung – high priority as part of 'scaling up' efforts.
	Cinnamon monoculture	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape mosaic	Most of the data needed are available from a recent dissertation.

Smallholder rubber production continues to be the most important source of income in most of the lowland peneplain of Sumatra and W. Kalimantan. The current economic crisis has benefitted rubber farmers as their rupiah income has increased more than inflation, despite the decrease of world rubber prices when denominated in dollar terms. Yet, to remain an attractive option, rubber productivity (per unit labor and per unit land) will have to increase. We are exploring the potential to incorporate higher yielding clonal rubber into smallholder rubber gardens, building on farmers' current knowledge and decision-making skills. Past efforts have been geared toward part of the target group only, and may have insufficiently addressed the concerns and constraints of small scale farmers.

Our experiments have shown that selected high-yielding clones can be successfully established in smallholder systems at substantially reduced management intensity, compared to the monocultural plantations for which they were originally selected. Weeding intensities of 1-3 times per year are sufficient for good rubber growth, and this need only be done within the rows of rubber trees. We find that fertilizer application can usually be reduced or eliminated. The main constraint to rubber establishment appears to be pig and monkey damage, which can be controlled by fences, bamboo shafts around individual trees, or regular guarding of the plots. The bamboo shaft technique, a common practice in one of the study villages, but not known in others, appears to be effective against pig damage.

Rotational Agroforestry Systems ('RAS') consist of an establishment phase, during which food crops can be interplanted with young trees and a phase in which the trees dominate, before the cycle starts all over, by a (field-level) clearing (often by slash-and-burn) to prepare the land for a next cycle. The harvested fraction of total biomass differs widely from near zero in classical fallow systems to over 50% when most wood is harvested and only branches and ‘slash’ are left in the field. A wide range of RAS system has been developed in various parts of the world, ranging from crop-(improved) fallow rotations, where annual food crops provide the main value to systems where trees such as rubber make the 'fallow' by far the most important phase for continuous revenue generation or where the final harvest of an established wood-lot dominates, as in 'taungya' systems. Where the annual food crops dominate, system improvement will often tend to shorten the cycle, by choosing fallows which restore soil fertility faster. Where the trees (formerly thought of as 'fallow') provide the main value, the systems may evolve toward longer cycles. But all RAS systems have in common that the rotation has a clear end point at which the farmer decides to fell the trees and re-plant (when the expected gains of doing so are higher than the expected gains of waiting). This means that slow-growing trees have little chance to mature, unless they are very profitable. Some forms of RAS such as rubber agroforestry systems can allow the regeneration of part of the natural forest vegetation, but only for those species that reproduce within the maximum age of the stand.

In contrast to these rotational systems, we may distinguish a class of **Permanent Agroforest Systems ('PAS')**, where rejuvenation takes place at a patch level of one or a few trees, without slash-and-burn land clearing. The system approaches the character of a permanent, forest-like vegetation, even if it started in the same way as a RAS. Prime examples of PAS are Damar agroforests of Krui West Lampung (Sumatra) and mixed fruit tree gardens ('Tembawang') of Kalimantan and Sumatra. Part of the rubber agroforests has evolved in this direction, where gap replanting leads to mixed-age vegetation. Slow-growing elements can be retained in such a system to reach maturity, as decisions are made on a tree rather than forest basis. Environmental values, such as biodiversity conservation and C stocks, which tend to increase with age, can be substantially higher in PAS than in RAS, while environmental problems associated with the slash-and-burn methods used in starting a new cycle in RAS are absent in PAS.

Does this mean that Permanent Agroforest Systems are a 'better bet' than Rotational Agroforestry Systems within the frame of the 'Alternatives to Slash and Burn' project where environmental values are considered as well as profitability? For the time-averaged C stock we may expect an increase of about 30 Mg C ha^{-1} as the average age goes up from 15 – 20 years for a 30-40 year cycle, to 30 for a 60 year's life span of individual trees. Net GHG emissions are likely to be reduced as the agroforest soil can probably maintain a loose topsoil structure and phases with excess mineral N and thus N_2O emissions can be reduced by managing the regeneration process. No problems are to be expected with the sustainability criteria used in our evaluation, so the profitability and institutional issues may be the main concerns. Returns to labor may be reasonable, if a comparison is made with NTFP collection and rubber agroforestry, but the returns to land will probably be less than the maximum in Table IV.3. There also are institutional concerns: PAS systems that mimic natural forests have been mistaken for natural forests and classified accordingly by state forestry officials, denying access to the farmers (or their children) who planted and managed the trees.

PAS normally occur in a mosaic with land uses that allow food crop production on a rotational or permanent basis, such as in paddy rice fields. Full reliance on the market as a way of ensuring local food security has not generally been attractive, even for PAS systems which generate a constant flow of revenue such as the Damar agroforests. Agroforest managers can spread risks by maintaining a broad portfolio activities, which may yield or earn good prices in different years. The opportunities of benefiting from genetic selection in tree planting material may be no less than in RAS, provided the planting material suits the more competitive environment of an established stand, with less opportunities for the farmer to manage above- and belowground growth conditions to meet the needs of a young individual tree.

All tree-crop based production systems evaluated during the second phase of the ASB project in Indonesia are Rotational Agroforestry Systems. Yet, information on the scope of rubber agroforests evolving towards PAS has gradually accumulated. Sandy Williams (*pers comm*.) documented farmers' experiences with gap replanting in Jambi and found evidence of active relocation of rubber seedlings to make use of relatively open places in existing rubber gardens and selective cutting of non-rubber trees to facilitate rubber sapling establishment. Since damage by pigs and monkeys is a major risk to young rubber planted after field-level slash-and-burn, farmers experimented with planting young rubber among partially-cleared fields. This may reduce the risk of predation, but at the same time does not allow the farmers to take further measures such as fencing. Franz Gatzweiler (*pers comm.*) working in West Kalimantan found that rubber agroforestry systems can gradually evolve into mixed fruit/timber PAS ('tembawang') by interplanting and allowing natural regeneration to take place.

To complement current data, a further analysis of PAS management of rubber agroforests is needed. Two options for management should get attention:
- rubber regeneration by gap planting, and
- enrichment of rubber gardens with fruit and timber species.

Best bets for rehabilitating degraded lands

The options for farmers who are trapped in the cassava/*Imperata* cycle are reduced in comparison with those in the forest margin. The soil has been depleted of those forms of organic matter that can feed crops of young trees by mineralization. However, the soil is not depleted of soil organisms, including micro-symbionts such as mycorrhiza and N fixing microbes. Development of tree-based production systems can be hindered by the landscape context of such plots, with a large chance of fires raging through plots where individual farmers would plant trees. The soil seedbank is nearly exhausted and there is a limited array of tree species that can reach the plot and start the process of succession towards forests – most trees will have to be introduced by the farmer. In what may seem a hopeless situation for any individual, it may be more attractive to abandon the land, look for employment in the city, or open new land where the forest margin is still accessible.

The situation in the North Lampung ASB benchmark area illustrates these hardships, aggravated by the long dry season of 1997 and its effects on the trees that had been planted (against the odds). A long drought and intense fires were followed by a locust plague during the next growing season, devastating rice, maize and sugarcane crops. Opportunities for off-farm employment meanwhile were reduced as the sugarcane plantation in the neighbourhood barely survived. The local (illegal) sawmill (which transformed the last trees left in the landscape into construction wood and provided local employment), closed down as timber supply was depleted and the building boom in Jakarta collapsed.

Are there any bets which are still worth making for farmers in such circumstances? Our rather abstract analysis of 'best bets' may need a reality check. Cassava prices have increased after the drought and cassava production is gaining in popularity – despite our judgement that this is not sustainable. Intensive food crop production is biophysically possible, but requires substantial investments beyond the means of local farmers. Oil palm and rubber are feasible, although for both tree crops the length of the dry season is near the limit. The long dry season of 1997 may have caused a 40% decline in oil palm yields in this area (with effects on fruit production for about a year after the drought), while rubber yields in plantations were only reduced by 10 % (S. Budiman, *pers comm.*). Farmers in the benchmark area still see smallholder oil palm production as an attractive option and are willing to work hard to clear *Imperata*- infested plots. They reckon they can clean only ¼ ha per year. This type of oil palm production differs substantially from the 'nucleus estate – smallholder scheme' on which most government projects are built. It definitely deserves a further study of its prospects, opportunities and constraints. Rubber agroforestry may be the other main opportunity for farmers in the area, managed as pure stands or mixed with timber trees or fruit trees (*Paraserianthes* is popular but did not perform well in the long dry season of 1997, except for the wetest places in the landscape). A wider array of trees is needed to diversify production for these circumstances. Initial farmer surveys have shown interest in a number of local trees (including *Alstonia* or 'pulai') as well as introduced species. Markets for locally-produced wood may be well enough developed, as there is hardly any wood coming from forest remnants. There are some remnants of mixed fruit tree agroforests, as well as early stages of such a system, based on local fruit trees that have undergone little selection and 'domestication'. Marketing of such fruits is not well developed, but road access may be good enough. Outside the ASB benchmark area many farmers have planted rubber already, often intercropped with cassava. The cassava – rubber combination is considered risky in the rubber literature as it entails a risk of root diseases shared in the *Euphorbiaceae* family to which both belong. Farmers may not be aware of these risks, or simply feel that they have no choice, as direct income is needed while waiting for rubber to become productive.

Would this type of tree-crop based intensification of land use be relevant to interest groups aside from the farmers directly involved? The answer to this question has a local/direct part and an indirect one, based on migration as an option for people in the benchmark area. (This depends whether improved opportunities in areas such as the benchmark area reduce the pressure on the forest margins). Direct consequences for biodiversity conservation of a tree-based intensification in the degraded lands are likely to be small, but a change from a land use with a time-averaged C stock of 40 Mg ha^{-1} to one of 100 Mg ha^{-1} could be significant. Net GHG emissions may increase during such rehabilitation, as the availability of mineral N will have to increase, but excess N fertilization (standard practice in intensively managed oil palm plantations) may be less likely to occur under smallholder management.

V.4 Potential for adoption of existing land use alternatives

The ASB-Consortium will marshal its research results in order to inform key planners and policymakers about the potential environmental, social, *and* economic benefits of a smallholder-based development strategy as an alternative to large-scale plantation monoculture. But, as already mentioned, there are some important institutional questions that must be addressed to enable widespread adoption of profitable alternatives by smallholders. Table V.3 on market institutions and Table V.4 on other institutional issues are summaries of a more elaborate assessment of institutional requirements following Vosti *et al.* (1998). Although it does not capture all the nuances of these complex institutional issues, the following notation was developed to 'flag' the most serious **institutional barriers to adoption by smallholders** for further detailed analysis:

⊕ indicates **no constraint**, interpreted as a 'green light' to go ahead with development

♦ indicates a **possible constraint**, a 'yellow light' meaning proceed but with caution

• flags a **serious constraint**, a 'red light' that jeopardizes prospects for adoption of the alternative by smallholders

Market institutions

Input supply markets. Planting material supply markets are the greatest barrier to adoption of profitable alternatives by smallholders – indicated by 'red lights' for clonal rubber and for oil palm. For example, farmers have little access to improved rubber planting material. The Treecrops Advisory Service, which is virtually the sole provider of rubber budwood, has focused its efforts on supplying planting materials to project participants in the past and largely has ignored the much larger number of non-participants (Tomich 1991). Except in a few areas of Sumatra, the private nursery industry has only begun to develop. For public and private sources alike, there are serious problems of reliability regarding quality of planting material, which is difficult to assess until several years after planting. Current delivery pathways for improved planting material (and the information needed to use it) seem inadequate, but direct government intervention to supply germplasm may be neither feasible nor desirable. For example, subsidizing germplasm would hamper development of a private nursery industry.

Table V.3
Institutional capacity vis-a-vis system-specific institutional needs
--A market checklist

Land Use	Input Supply Markets	Output Markets	Labor Markets	Capital Markets
Community forest		♦	⊕	⊕
Commercial logging	⊕	•	⊕	♦
Rubber agroforest (seedlings)	⊕	⊕	⊕	⊕
Rubber agroforest (clones)	•	⊕	⊕	♦
Rubber monoculture	•	⊕	⊕	♦
Oil palm monoculture	•	♦	⊕	•
Upland rice / bush fallow rotation			⊕	⊕
Continuous cassava degrading to *Imperata cylindrica*	⊕	♦	⊕	♦

blank = n.a, ⊕ = no constraint, ♦ = possible constraint, • = constraint

Output markets. Government restrictions on marketing and international trade are the greatest barriers to development of smallholder timber-based alternatives and also hinder community-based forest management. Beginning in 1998, government has agreed to begin deregulation of timber exports, to abolish joint-marketing associations (that functioned as cartels), and to end export quotas and numerous other restrictive marketing arrangements. Although export taxes still are high, private firms now should be free to trade timber as they wish. In Part VII, detailed attention is given to export taxes on timber from agroforestry species, which currently are set at 30%.

Previous restrictive marketing practices damaged most timber companies' marketing capacity by inhibiting development of marketing networks that could respond to buyers' needs. The situation is particularly bad for rattan, since the export ban on raw rattan destroyed overseas markets or induced importers to seek alternate supplies. There also is concern that old 'rent seeking' practices (like the plywood and clove cartels) will re-emerge under new guises. These risks are increased by lack of market information on these commodities. The lack of information probably is worst for non-timber forest products, especially those occupying narrow market niches.

Oil palm also has been subject to export taxes (set at 60% through the end of 1998) and at times export bans (Tomich and Mawardi 1995) that seriously depress farmgate prices. For oil palm and cassava there also are some concerns about development of local markets that can link smallholders with processors. However, these seem to be emerging.

Local markets for natural rubber have functioned for a century or more. Although there are some imperfections affecting quality – viz., difficulty of assessing dry rubber content -- these markets transmit world price changes to the farmgate rapidly and marketing margins reflect transport and other costs. Natural rubber markets have been subject to few distortions from national policy, but at times the international buffer stock has depressed prices.

Table V.4
Institutional capacity vis-a-vis system-specific institutional needs
--A checklist for other institutional issues

Land Use	Non-Market Information	Regulatory Issues	Local Environ -mental Impact	Property Rights	Equity Biases	Social Cooperation
Community forest	•	•	⊕	•	⊕	•
Commercial logging	•	•	•	•	•	•
Rubber agroforest (seedlings)	⊕	⊕	⊕	•	♦	♦
Rubber agroforest (clones)	•	⊕	⊕	•	♦	♦
Rubber monoculture	•	⊕	⊕	•	♦	♦
Oil palm monoculture	•	♦	♦	•	•	♦
Upland rice / bush fallow rotation	♦	⊕	⊕	•	⊕	♦
Continuous cassava degrading to *Imperata cylindrica*	♦	⊕	•	♦	⊕	♦

blank = n.a., ⊕ = no constraint, ♦ = possible constraint, • = constraint

Labor markets. Although the complete analysis also included skilled labor requirements, the summary analysis presented here focuses on unskilled labor. Instead of hiring permanent skilled workers, smallholders may be more likely to develop certain technical skills themselves. So the relevant barrier is the acquisition of technical information (considered in Table V.4) rather than the market for skilled labor.   Although labor markets in Sumatra fall short of the theoretical 'ideal' of economics textbooks, recent empirical studies linked to ASB (Suyanto *et al.*, 1998a and 1998b) indicate that labor markets work reasonably well. All alternatives get 'green lights' regarding unskilled labor markets. It is worth noting that casual markets for skilled labor (e.g., chainsaw operators) also are emerging.

Capital markets. Capital market problems are second only to planting material supply as a barrier to adoption resulting from market imperfections. As already noted, there is no long-term institutional credit available in rural Sumatra. Household savings, which financed investments in existing smallholder agroforestry systems like rubber agroforests, are often underestimated. In rural Indonesia, farmers are able to receive considerable credit from informal sources (relatives, moneylenders). However, current economic hardships – especially rising food prices -- may be straining these resources. Capital market imperfections (lack of credit and interest rates well above the social price of capital) may constraint smallholders' nutrient purchases for cassava production, use of clonal rubber planting material, and certainly are a barrier to smallholder oil palm. Whether or not smallholder timber extraction is constrained by capital market imperfections depends in part on development of contract markets for chainsaw services and log transport.

Other institutional issues

Non-market information. Information acquired from research (e.g., new technologies) comes primarily from the Government and existing research facilities are inadequate to meet research needs of the diverse productions conditions of these land uses. This constriant is particularly severe for alternatives, such as NTFPs and smallholder timber, that are not high priorities for Government, especially compared to rice, the staple food. This bottleneck on technical information is a concern for all systems, except rubber agroforests using seedlings where indigenous knowledge is well developed.

Regulatory issues. As discussed above under output markets, policies that restrict access to markets are a particular concern for timber and non-timber forest products and for oil palm. This is compounded for timber and NTFPs by policies that attempt to restrict access to State Forest Land, even if it has been used by local people for generations (see property rights below). Thus, especially for timber and NTFPs – but to a lesser extent for oil palm – success in these alternatives requires considerable investment of time (and often money) to 'work the system' under current policies.

Local environmental issues. Based on available data, production of most of these systems earns a 'green light.' (However, there may be water and air quality concerns arising from the processing of rubber, oil palm, and cassava.) The exceptions are large-scale logging and continuous cassava cultivation, which are susceptible to erosion. As we emphasized at the end of Part IV, further work is needed to assess the environmental impacts, including air quality, landscape biodiversity, and watershed functions, of expansion of particular alternatives.

Property rights. This is a highly-charged political issue that draws a 'red light' for all systems except continuous production of foodcrops on a transmigration site; even here there can be problems of tenure conflicts with indigenous groups that pre-date the settlement. In most cases, tenure status of lands at the forest margins (and the products derived from those lands) needs to be clarified between the government and local communities. The damar agroforests in Krui exemplify this situation. Although developed and managed by smallholders for over a century, this land recently was classed as State Forest Land. As discussed in Part VII, a breakthrough came in this particular case with the former Minister of Forestry's decision to declare the damar agroforest as a 'Special Use Zone' (*Kawasan dengan Tujuan Istimewa; KdTI*) recognizing farmers’ rights to manage these agroforests and enjoy the benefits derived from them (See section VII.1). It is hoped that this approach can develop into a prototype for addressing this serious institutional problem.

Equity biases. The primary concern is that potential economies of scale will lead to concentration of land under commercial logging, for which scale economies have been documented elsewhere, and for oil palm, where scale economies probably are not intrinsic but may result from current development policy. Despite the conventional wisdom, the prevailing faith in economies of scale in production of so-called ‘plantation’ commodities receives little (if any) support from agricultural economics (Hayami; Tomich, Kilby and Johnston). This is, nevertheless, an empirical question that requires further investigation in the next phase of ASB research. Unlike production, marketing and processing of primary products often are characterized by increasing returns to scale. This is the case for three of the most important land use alternatives--rubber, pulp, and oil palm--in Sumatra. The natural rubber industry in Southeast Asia provides an excellent example of the efficiency with which markets can integrate low-cost production by smallholders with processing in factories that achieve economies of scale; similar marketing arrangements should work for pulp. Oil palm conventionally has been viewed as an estate crop in Southeast Asia (but not in Africa) because of its perishability. Even in this case, however, oil palm production on independent plots as small as one ha began to emerge in Sumatra in the 1980s. Outgrower schemes, contract farming, and other institutional arrangements all can help reduce transactions costs in linking efficient smallholder producers with efficient large-scale processors.

There also is some cause for concern regarding gender bias since recent studies have shown that tree planting induces a shift from matrilineal inheritance to partilineal inheritance for some categories of trees in some areas of Sumatra (Suyanto *et al.*, 1998b). Ongoing studies led by the International Food Policy Research Institute (IFPRI) should add to our understanding of potential gender biases.

Social cooperation. The main need for social cooperation concerns the two forest extraction alternatives, community based extraction of NTFPs and logging. In each case, sustainability of the land use is in doubt if communities cannot manage a system to restrict access to their common property resources.   Indigenous communities with their customary laws intact appear to have this capacity (see discussion of ‘KdTI’ in Part VII); recent settlers may not.   Collective action also is required for fire and pest control, and may be an emerging constraint in many agricultural systems.

VI. Output 3.2. Development of policy & institutional options

This part of the report concerns **Project Output 3.2**, *development of policy interventions to facilitate the adoption of recommended land uses by (a) reviewing and analyzing policy options and recent institutional experiences relevant to the alternative land uses, (b) facilitating community participation schemes in selected pilot areas, and (c) organizing national workshops and consultations with relevant stakeholders and policymakers for policy and institutional reforms necessary for adoption of recommended land use alternatives.*

VI.1 Analysis of policy and institutional options

Many of the forces driving deforestation and natural resource degradation arise at the regional or 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 best-bet alternatives at the field-level. Profitability is a necessary condition for adoption of 'best bets' by smallholders, but is *not* sufficient by itself as a means to slow deforestation. Indeed, precisely because these alternative land uses are *profitable,* the 'best-bets' could have the perverse effect of accelerating deforestation by attracting new migrants to the forest margins. But the relative profitability of forest conversion by smallholders it not determined solely by production technology; it also is tied to institutions and the legal framework that establishes, monitors and enforces boundaries of public land as well as private property rights; to policies regarding public investment in infrastructure and social services; and to macroeconomic policy instruments (exchange rates, monetary and fiscal policies). The institutional and policy environment that is necessary and sufficient for 'best bet' alternatives to reduce poverty *and* deforestation is not well understood yet--and is a top priority of ongoing ASB research. However, it is a sure bet that deforestation will accelerate if profitable innovations for rainfed land uses are introduced where there is open access to forests and within an economy-wide context of rapid population growth and stagnant opportunities elsewhere in agriculture, industry and services.

The key hypothesis underlying the ASB research project in Indonesia can be summarized as: *Intensifying land use as an alternative to slash-and-burn can reduce deforestation and reduce poverty.* Under which conditions is intensification a reasonable approach; under which ones is it not? At least three necessary conditions for validity of the intensification hypothesis were identified in ASB Phase I (van Noordwijk *et al.,* 1995) and some of their interrelationships are depicted schematically in Figure VI.1.

1. At the *plot level*, intensification technologies must be environmentally and agronomically sound, socially acceptable, and financially profitable for smallholders.
2. At the *community level*, there must be effective monitoring and enforcement of property rights.
3. At the provincial and national level, attention must be given to reducing the broader forces that drive deforestation.

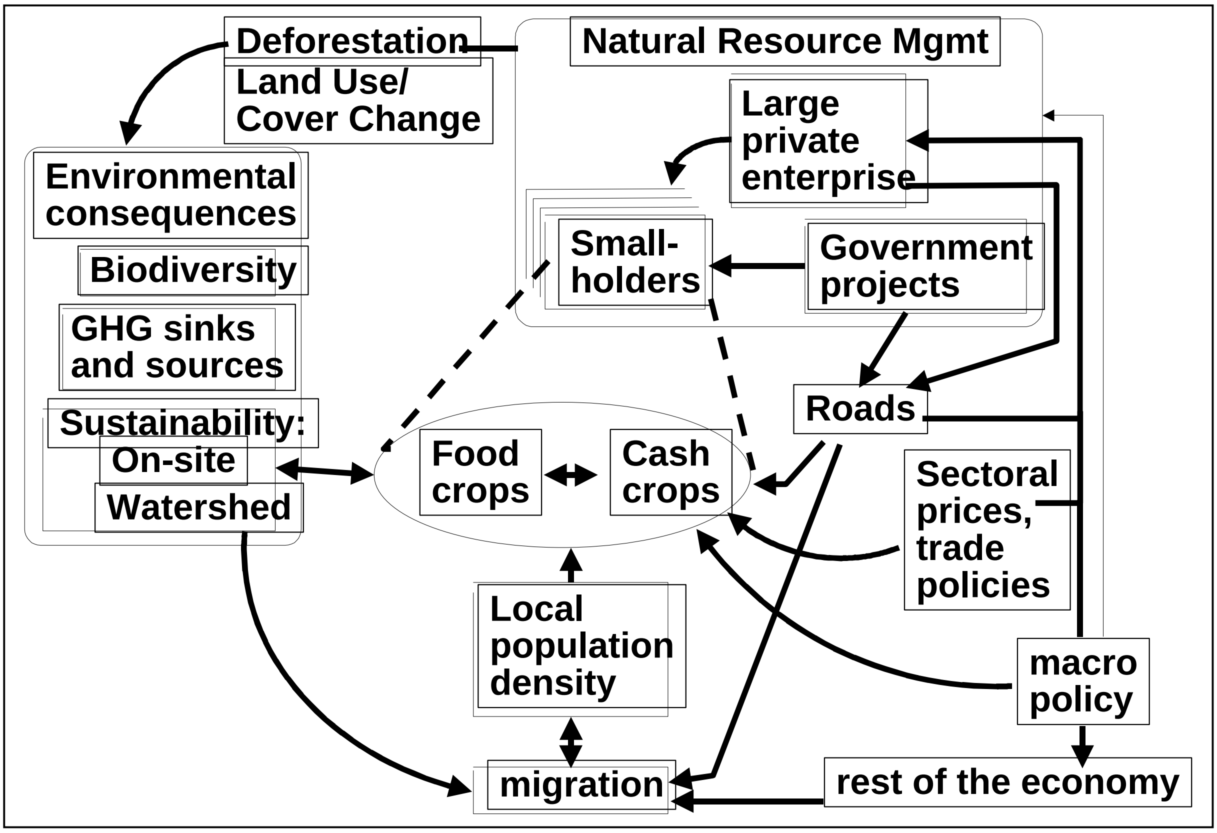


Figure VI.1 *Forces Driving Deforestation*

The first five parts of this report have focused on empirical measurement of relationships at the plot level. But property rights and tenure institutions, public investment in roads, trade policies, and macroeconomic shocks all affect households' livelihood options and, thereby, reduce (or intensify) forces that push migrants to forest margins; this policy and institutional ‘environment’ also has a powerful effect on the natural resource management decisions made by people at the forest margins. Each of these forms a component of ongoing research and is discussed below.

The overall programme—which is chiefly funded by the Asian Development Bank and the Ford Foundation--is designed to determine whether intensification of agroforestry production in specific upland settings can help Indonesia and other Southeast Asian countries and donor agencies balance environmental objectives with economic development and poverty reduction. These issues for policy and institutional research are nested as in Figure VI.2: each topic corresponds to a necessary condition for the intensification hypothesis; none is sufficient alone.

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Figure VI.2 Research Framework: *Decision Tree for Smallholder Agroforestry Systems for Upland Resource Management*

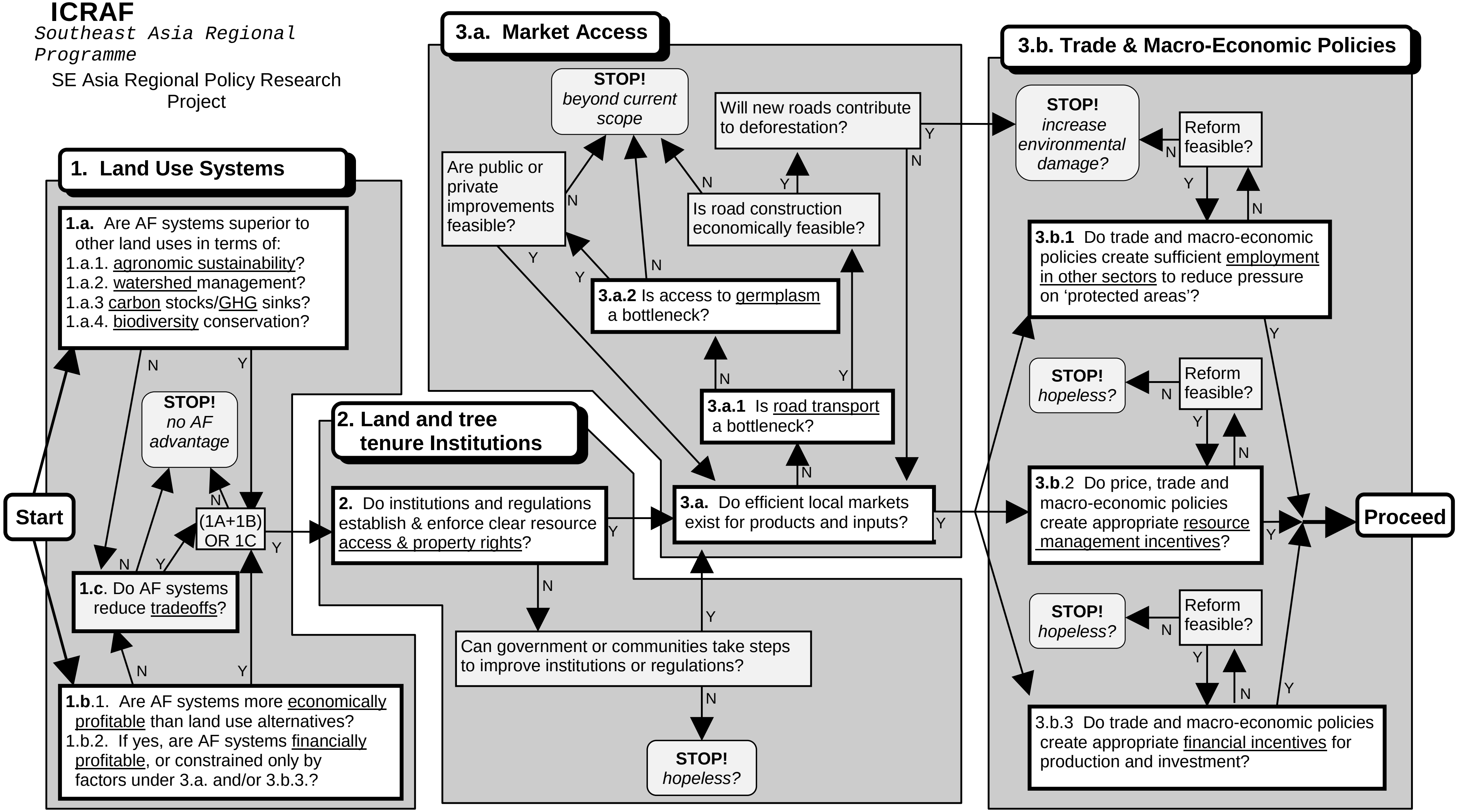


Figure VI.3 ICRAF Southeast Asia Regional Policy Research Agenda

Component	Scale	Main Policy Questions	Clients	Policy Instruments	Research Methods	*Collaborators*	Sites
Analysis of Land Use Systems	Plot	Are productivity increases feasible and profitable? If so, are they agronomically sustainable? And how are changes in technology and land use likely to affect the supply of global public goods?	Smallholders; NARS; ministries of agriculture, forestry, environment and finance; donor agencies.	Public investments in research and extension. Trade and price policies.	Application of the policy analysis matrix to analysis of private and social profitability, policy distortions, & market imperfections. Rapid assessment tools for agronomic sustainability & biodiversity. Measurement of C stocks & GHG emissions.	ASB Consortia in Indonesia and Thailand; including CASER, FORDA, LATIN, Lampung University and EU Project in Indonesia; Chiang Mai University and the Royal Forest Department in Thailand; TSBF, CIFOR.	Jambi and Lampung Provinces on the island of Sumatra in Indonesia. Northern Thailand, focusing on the Mae Chaem watershed with supplemental sites in Mae Taeng and elsewhere as needs are identified in consultation with research partners.
Analysis of Land Use Systems	Watershed / Landscape	How do changes in patterns of land use affect the supply of watershed functions? Specifically, what are the effects of land cover change on: (1) sedimentation of reservoirs, (2) flooding, and (3) seasonal water shortages?	Local communities, local government, NGOs, ministries of agriculture, forestry, environment, and public works; donor agencies.	Land use planning through local participation. Watershed classification. Public investment in infrastructure & other sectoral programmes. Resettlement policies.	Tools to be developed for rapid assessment of watershed functions. Spatial models of watershed functions.	ASB Consortia in Indonesia, Thailand, & the Philippines; incl. FORDA in Indonesia, Chiang Mai, Kasetsart, and Mae Jo Universities, Royal Forest Dept, Dept of Land Development, Royal Project Foundation, & ANU in Thailand, & UPLB in the Philippines.	Upper Tulang Bawang watershed in Lampung Province, Sumatra. Mae Chaem watershed in Northern Thailand. Manupali watershed on Mindanao in the Philippines.
Land & Tree Tenure: Indigenous Institutions	Household / Community	How do indigenous institutions adapt to population pressure? Do indigenous institutions establish and enforce clear resource access and property rights? How do these institutions affect resource management decisions?	Local communities, local government, NARS; NGOs; ministries of internal affairs, agriculture, and forestry; donor agencies.	Institutional endowments (customary, local government, NGO).	Econometric models.	IFPRI and Jambi University.	Various communities in the buffer zone of Kerinci Seblat National Park in Sumatra.
Land & Tree Tenure: Options for Institutional Reform	Community	Do existing institutions and regulations establish and enforce clear resource access and property rights? What can communities and government do to improve institutions and regulations in order to better meet social, economic, and environmental objectives?	Same as above.	Institutional reform. Land allocation policy. Sectoral programmes.	Process-oriented research on institutional reform.	LATIN, WATALA, ORSTOM, Univ. of Indonesia, Dept of Forestry and CIFOR in Indonesia. Chiang Mai University, Care-Thailand and Royal Forest Dept. in Thailand. Philippine collaborators to be identified.	Krui, Lampung Province, in the buffer zone of Bukit Barisan Selatan Nat'l Park and other communities to be selected in Indonesia. Buffer zone of Mt. Kitanglad Nat'l Park, Manupali watershed in Mindanao. Mae Chaem watershed in N. Thailand, including buffer zone of Doi Inthanon Nat'l Park.
National Policies: Market Access & Infrastructure	Provincial	How do decisions about location of road construction and other large government projects affect land use change? (Bottlenecks in access to improved germplasm may be studied later.)	Ministries of public works, resettlement, planning, forestry & agriculture; donor agencies.	Infrastructure investment. Land allocation & resettlement policies.	GIS-based spatial econometric models.	World Bank Policy Research Dept; UNESCO; BIOTROP in Indonesia; Chiang Mai University & Royal Forest Dept. in Thailand.	Sumatra with possibility of extension to Kalimantan in Indonesia. Mae Chaem watershed in N. Thailand.
National Policies: Macroeconomic & Trade Policies	National	How do macroeconomic & trade policies affect land use change? Do macroeconomic & trade polices create sufficient employment in other sectors to reduce pressure on land & forest resources?	Ministries of planning, finance, forestry, and agriculture; donor agencies.	Macroeconomic & trade policies.	CGE model with distinct regional components for labor flow between Java & Sumatra and detailed land use activities for lowland Sumatra.	IFPRI (in leading role) and CASER in Indonesia. School of Environment, University of Brighton	Java-Sumatra labor market interactions and their links with land use change in lowland Sumatra.

Synthesis of these results is intended to yield policy lessons relevant for the region. A **participatory, client-driven approach** is intended to enhance prospects for impact on institutional development and policy reform. ASB research priorities are driven by the needs of two broad groups of clients: smallholders living at the forest margins and policymakers who influence the range of choices available to these smallholders. Just as participatory methods are used in ASB research to understand smallholders' objectives and constraints, consultation with policymakers also is a hallmark of this client-driven approach to policy research. The focus of consultation is to obtain crucial insights from policymakers about their perceptions of problems, opportunities, and constraints, including institutional mechanisms for policy implementation, in order to guide the iterative process of research to identify and develop feasible policy options.

VI.2 Property rights and community participation in natural resource management

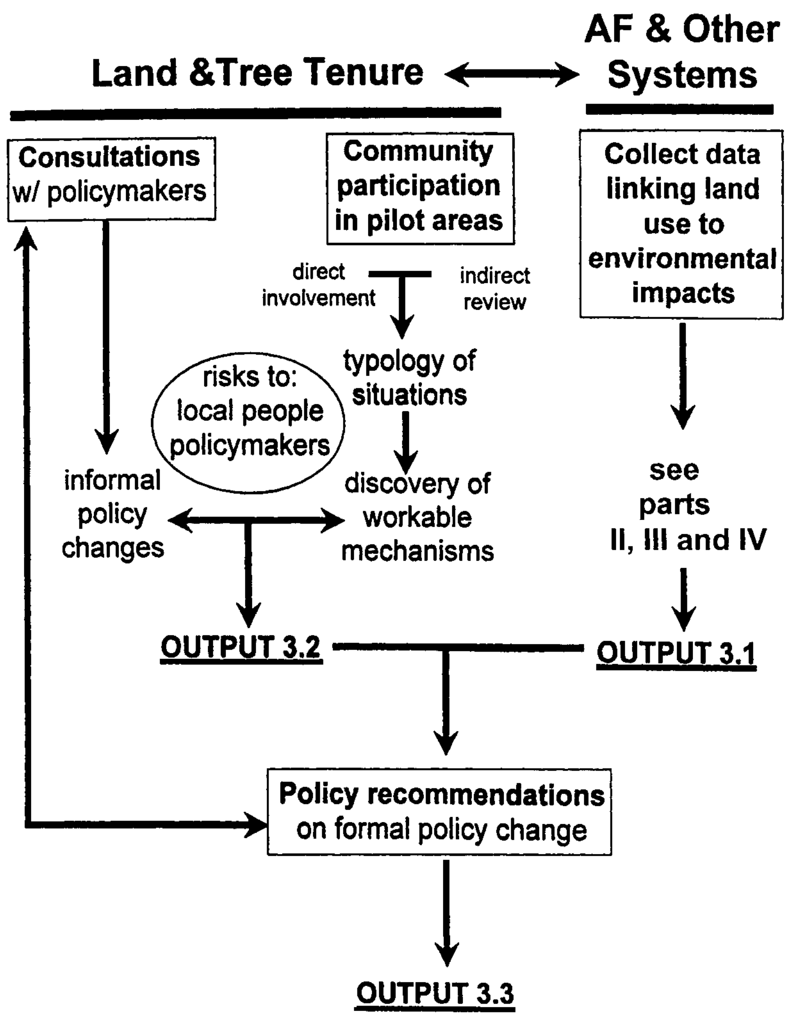
Land and tree tenure institutions -- both formal and informal -- affect resource access and property rights, and are a major determinant of incentives (and disincentives) for sustainable resource management. But do existing formal and informal institutions and the regulatory framework create incentives 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 better support improved functioning of these institutions?

Existing resource access controls typically are inadequate to address the realities of poverty and land pressure in Indonesia and more generally in Southeast Asia. The result often has been increasing conflict among communities and between rural populations and the institutions of the state charged with managing forests. However, exceptional windows of opportunity currently exist in the region for institutional innovations aimed at authentic people's participation in forest resource management. (A new decree for community-based resource management in Indonesia is discussed in Part VII.)

While clearer property rights may be necessary to establish better incentives for natural resource management, they may not be sufficient to secure sufficient environmental benefits. For example, community management of buffer zones of protected areas may be a more effective means of monitoring and enforcing restrictions on forest encroachment by spontaneous migrants ('forest squatters') and illicit logging, but little is known about tradeoffs and complementarities among multiple goals in the implementation of such programmes. Another working hypothesis is that devolution of management of production forests (including logging) and/or watershed land use to local communities could improve natural resource management compared to the *status quo ante*. But devolution of control by itself may not create sufficient incentives for local communities to supply some forest services, including abatement of externalities felt at the regional level (flooding, siltation, smoke that impedes aviation) and global public goods (carbon sequestration and biodiversity conservation). Workable institutional mechanisms that can clarify, monitor, and enforce responsibilities as well as rights are needed to address such complex natural resource policy issues.

Figure VI.4 was developed collaboratively during a regional planning workshop in 1996 to depict the interactions between the measurements of environmental, agronomic, and socioeconomic indicators described in Parts II-IV and which contribute to Output 3.1 of this project combined with pilot projects at the community level (described in Part VII) and ongoing consultations with policymakers. As stressed above, the measurements are necessary to quantify tradeoffs between various objectives. The process-oriented work is necessary to discover institutional options that have good prospects to meet the objectives of policymakers and of local people—which, in turn, contributes to Output 3.2 of this project. Both parallel streams of activity – empirical measurements and process-oriented research – are necessary and complementary efforts in providing a sound basis for recommendations for policy change. These recommendations comprise the 'deliverables' of Output 3.3, discussed in Part VII.

Figure VI.4 *Linking land use analysis to community participation in resource management*



VI.3 National policies and forces driving land use change

The return of severe financial instability in Indonesia--after three decades of steady growth--combined with new global and regional trade agreements may lead to significant dislocations of people and economic activity. Priorities for research on national policies affecting deforestation may be grouped in two sets of policy instruments that influence incentives for forest conversion: policies that affect market access and links between trade and macroeconomic policies and migration pressure.

Market access. Market access affects opportunities for land use by smallholders and large-scale operators and for local entrepreneurs, including those engaging in activities linked economically to forestry and agriculture (nurseries and seed producers, processors, traders and transport companies). Do efficient local markets exist for products and inputs? Investigations focus on two elements of market access – the road system and germplasm supply – but also will endeavor to identify other important market imperfections that may warrant further investigation.

The road system has powerful effects on people's access to resources and marketing links that condition land use choices in the uplands. Is transport infrastructure (especially the road network) sufficient for marketing agroforestry products? If transport is a bottleneck, how will road construction change land use? Obviously, it matters where roads are built; but ICRAF researchers work with colleagues from the World Bank, BIOTROP, and other collaborators to learn more about how interactions of road location and other factors (markets, property rights, sectoral policies, biophysical characteristics) affect land use choice in an effort to understand what determines whether a road project will be a boon for regional development or an environmental catastrophe.

Research on the dynamics of land use change in Jambi Province seeks to answer the policy question: where is smallholder 'encroachment' on logged-over forest most likely to be a problem? This spatial econometric analysis of land use change focuses on the peneplain and piedmont agroecological zones. A geographic information system (GIS) containing maps of rivers, main roads, land use units (topographic and edaphic features), and land cover for the early 1980s and the early 1990s was sampled with a one km grid, which generated 9477 observations. A multivariate econometric model with a binary dependent variable (a probit) was used to control for site-specific biophysical features (fixed effects) and to estimate the effect of distance to rivers and main (asphalted) roads on the probability that logged forest would be converted to rubber agroforests and other land uses by smallholders. The data indicate that there was substantial smallholder 'encroachment' on logged natural forests in Jambi between the early 1980s and the early 1990s. The prototype model correctly predicts about 85% of conversion of logged forests by smallholders and about 78% of the cases where logged forest was not yet converted.[1] Site-specific biophysical features are highly significant, indicating that smallholders are selective in their choices of sites for conversion. Smallholder conversion of logged forest is significantly more likely within 10 km of main roads, which is consistent with a process driven by market opportunities for profitable treecrops. However, the results of this prototype model must be interpreted with great care. The period under study witnessed three big sources of change in Jambi: the all-weather Trans Sumatra Highway was completed, transmigration settlement projects expanded greatly, and large areas of the province were logged. Factors that affected which areas had been logged by the early 1980s (and which had not) may also affect the validity of our interpretation of these estimates. More work is needed to attempt to control for this possible selection bias. If these preliminary results hold up to further statistical refinements, this analysis can help set priorities for action within a two-pronged strategy combining community participation in management of some forest lands with improved monitoring and enforcement of access restrictions in other areas.

Trade and macroeconomic policies. Trade and macroeconomic policies affect households' livelihood options and, thereby, reduce (or intensify) forces that push migrants to forest margins; these policies also affect resource management decisions once they get there. Similarly, for subsistence-oriented communities who have long resided in remote forest areas, policies can affect opportunities for them to become more integrated into national economies, which could alter local land use patterns (and their sustainability) or shift labor away from agriculture or forestry into other sectors of the economy. Yet despite the dramatic change that trade and macroeconomic policies have already brought to Southeast Asia, the current shocks sweeping the region, and further important changes that will be forthcoming under global and regional trade agreements, the effects of these powerful policy instruments on rural land use patterns and incentives for forest conversion seldom have been analyzed. Are current trade and macroeconomic policies compatible with sustainable natural resource management by households? If not, what are the policy reform options? Are expanding employment opportunities in other sectors likely to take pressure off protected forest areas? If not, is forest conservation hopeless?

Research on these questions in Indonesia (and a twin study conducted for ASB in Brazil) is led by colleagues at IFPRI (the International Food Policy Research Institute) in collaboration with CASER (the Centre for Agro-Socio-Economic Research) and ICRAF Southeast Asia and is funded primarily by DANIDA. This study, entitled ‘Macroeconomic Policy, Labor Migration, and Land Use in Sumatra,’ is intended to answer a timely policy question: what are the impacts of structural adjustment programs (e.g., exchange rate devaluation, trade policy liberalization) on land use change

[1] The preliminary results presented in this paragraph are subject to revision and are not for citation or quotation. The findings, interpretations, and conclusions expressed in this paragraph are entirely those of the researchers. They do not necessarily represent the views of the World Bank, its Executive Directors, or the countries they represent.

and deforestation? This research activity incorporates links between macroeconomic policies and the level of wages, which in turn affect migration and, ultimately, land use change. These issues will be analyzed using a regional Computable General Equilibrium (CGE) model. This approach is particularly appropriate when analyzing interactions between agriculture and industry, links between macro and microeconomics, and the impacts of changes in policy and world markets on production, employment, and income distribution. The prototype model comprises over 20 sectors, with particularly rich detail for agriculture. The database for the model is a regional social accounting matrix (SAM), which provides a consistent framework for analysis. The regional product accounts in the SAM capture the flows of goods and services and the regional income accounts depict income distribution among seven different types of households. Data on production technology are derived mainly from prior studies supplemented by the ongoing ASB research on major production systems in Sumatra reported in Part IV.

VI.4 Ongoing policy analyses and the monetary crisis

Beginning in August 1997 and continuing until now, Indonesia has suffered the greatest real exchange rate depreciation of any country in the past 50 years (IMF staff, pers comm). The ongoing monetary crisis in Indonesia creates both a need for the types of research described above as well as an opportunity to analyze how macroeconomic shocks affect land use change, environmental services, poverty, and household food security.

The policy analysis matrix (PAM) technique described in Part IV provides a flexible tool for examining the effects of Indonesia's monetary crisis on production incentives. Because these are simple, spreadsheet-based models, it is possible to revise basic macroeconomic parameters to reflect current changes in exchange rates and inflation. The results presented in Table VI.1 reflect the change from an exchange rate of Rp 4000 per US dollar in July 1997 to a real exchange rate of approximately Rp 7,700 in June 1998. This 'real' exchange rate is calculated by deflating the nominal exchange rate of Rp 11,550 per US dollar that prevailed early in June 1998 by the 50% inflation since July 1997. These partial equilibrium models provide only first-order approximations of shifting incentives resulting from Indonesia's financial collapse. However the data used in these calculations also will be employed in the CGE models mentioned above, which are able to capture effects on real wages and various other macroeconomic feedbacks.

Prior to the monetary crisis that began in Indonesia in August 1997, unsustainable shifting cultivation was not financially profitable in much of Sumatra. This appears to have changed since the collapse of the Indonesian currency over the past 12 months, which may reverse the long-term decline in shifting cultivation. Also because of the currency collapse, profitability of many tree-based systems has increased substantially, which boosts incentives for forest conversion by smallholders and large-scale operators alike (see Table VI.I).

Table VI.1 Sensitivity of PAM studies to macroeconomic parameters

Land Use	Rupiah 000's / ha		US $ / ha	
	July -- 1997	***June -- 1998***	***July -- 1997***	***June -- 1998***
Community - based forest management	9.4 - 18	38 - 75	3.9 - 7.7	5.0 - 9.7
Commercial Logging	(32) - 2,102	317 - 7,422	(13) - 876	41 - 964
Rubber agroforest (seedlings)	73	6,743	30	741
Rubber agroforest (clones)	*234 - 3,622*	*12,544 - 24,340*	*98 - 1,509*	*1,629 - 3,161*
Rubber monoculture	*(993)*	*5,114*	*(414)*	*664*
Oil palm monoculture	1,479	2,104	617	273
Upland rice / bush fallow rotation	(180) - 53	1,200	(75) - (22)	150
Monoculture cassava / *imperata cylindrica*	(314) - 224	3,536 - 4,038	(131) - 93	405 - 501

VI.5 Smoke as a symptom of underlying policy and institutional problems[2]

In 1994 large amounts of smoke, caused by fires in Sumatra and Kalimantan and aggravated by El Niño, resulted in poor visibility and air pollution for the neighbouring countries of Singapore and Malaysia and caused severe health problems for people in the entire region. In 1997 history repeated itself, and this time the consequences were even more serious and more widespread than they were 3 years ago. One effect of El Niño is an air temperature inversion over Southeast Asia, which traps smoke that otherwise would escape into the upper atmosphere.

Who is responsible for the fires in Sumatra, Kalimantan and elsewhere in Indonesia?

We must be cautious in attributing blame for the haze that shrouded the region. It has been customary to put all the blame on smallholders. But now, thanks to satellite images posted on the Internet, it is clear that big companies have important roles in the problem too. At least 3 types of fires contributed to the smoke that, together with the drought and atmospheric conditions brought on by El Niño, created the regional problem:

- ***fires used as a tool to clear land;***
- ***fires that accidentally got out of control; and***
- ***fires started deliberately as a weapon in social conflict.***

No one knows how many of the fires were started to clear land or to serve as a weapon and how many were accidental. Nor can anyone now say with certainty how much smoke is the result of smallholders' actions versus the actions of large companies. However, numerous eyewitness reports are consistent with official assessments based on remote sensing and site visits: that land clearing by large companies apparently played a major role in the problem.

Fire as a tool. Slash-and-burn is a technique for land clearing and conversion to other purposes. It also describes an extensive system of agriculture that leaves land fallow after a few years of crop growing and opens up new land for planting. Slash-and-burn is the preferred method of land clearing in Indonesia—for smallholders and large companies alike—because it is cheap and easy. In addition, fire eliminates field debris, decreases regrowth of weeds, reduces pest and disease problems, adds fertilizer in the form of ash and loosens the soil to make planting easier. In some ways it is preferable to other land-clearing methods. For example, bulldozers cause soil compaction, erosion and sedimentation.

Slash-and-burn as a land-use system worked well for smallholders for centuries because communities regulated the use of fires. However, when used as a technique to convert entire forests to rubber or palm oil plantations, the amounts of smoke those fires produce can be excessive. That is the

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[2] This section on smoke draws heavily on Tomich *et al.* 1998 in *Agroforestry Today*. An earlier version of this material appeared as an ASB Update produced by the ASB-Indonesia Consortium and ICRAF's Southeast Asian Regional Research Programme.

problem this year, as it was in 1994—too much smoke in the wrong place at the wrong time. The objective then, is to reduce smoke emissions in critical years and during times of the year when smoke disperses slowly because of atmospheric conditions. Development policies for conversion of 'forestlands' are linked to the smoke problems Indonesia faced this year. 'Forestlands' are designated as state-owned lands, and they represent about 3/4 of the Indonesian land area. The many licenses granted each year to private companies for planting fast-growing timber species on forestland or oil palm on private land (that is, 'converted' state forestland) acts as a multiplying factor for fires. Because planters use fire to clear their fields and prepare them for planting, the 1997 fires should not have been totally unexpected. In this respect, smoke is an inevitable—if unintended—product of planned conversion.

Fire that accidentally spreads. Many local communities in Indonesia have created their own effective systems of fines and other penalties that are imposed on people who mismanage fire and cause damage to their neighbors' property. Until recently, no mechanisms have existed to punish incompetence or negligence in the use of fire by large companies. A monitoring and enforcement system also could be developed to detect and punish blatant misuse of fire by large companies.

Fire as a weapon . Millions of people live in the forestland areas but because they have no security of tenure, they can be evicted at any time to make way for development projects. Large companies have been known to burn land to drive out smallholders. Smallholders have been known to burn trees established by large companies to retaliate for perceived injustices. At the heart of this problem are conflicts over land, resulting from unclear and insecure property rights and land allocation policies that take too little account of established—albeit informal—local claims. Aside from contributing to social conflict, 'land grabs' by large companies that displace local people also undermine incentives at the community level to prevent, report and fight fires. If land allocation policies concentrate holdings while destroying incentives for on-the-spot fire prevention and management by the local people, there is a great risk that the present situation will be repeated.

It is important to note that part of the land granted to companies is not 'empty' forestland but land that has been occupied by farmers—often for centuries. These farmers have developed their own systems of land use, which they have to give up when the company takes over. Some companies try to accommodate farmers' needs but others don't, which leads to conflict. In these conflicts, fire is a powerful weapon for both planters and farmers.

These changes in land use disturb pre-existing social systems. They erode traditional techniques and social rules for fire control and increase social inequities and the perception of these inequities in rural areas. When lands are converted into estates, some smallholders may find jobs on the estates; some may be allowed to retain control of a piece of the land through the 'nucleus estate' scheme; some may move to other forestlands; and others will be forced to move to crowded urban centres, becoming part of the already large group of urban poor. Seen from these perspectives, it is reasonable to conclude that the risks of fires can only increase in the coming years unless social and policy issues are addressed along with the technical causes of fire and smoke. This needs to be carried out at 2 levels: by understanding how present policies affect smallholders and by recognizing the wider consequences of all policies related to land allocation and land conversion, from both an ecological and a social perspective.

Options for managing fires and smoke. Banning fires as a land clearing tool has been the focus of efforts to respond to the crisis but it is not the only option for managing smoke emissions. Potential alternatives include measures to:

- promote land clearing techniques that do not produce smoke
- reduce land clearing or burning during El Niño years or at other critical times
- decrease the amount of timber that is burned

Option 1: Ban use of fire for land clearing. Banning fires has not been effective. Bans on burning didn't work in 1994, the last time smoke was a regional problem, they didn't work this year, and they won't work as long as fire is the cheapest way to clear land. Until a workable mix of regulations, incentives, and sanctions is in place for the big companies involved, there is a risk that the brunt of enforcement may fall on a few unlucky smallholders. This would simply add to the burdens the drought already imposes on the rural poor, without much prospect of an overall effect on the smoke problem now or in the future. (The exception may be to ban fires on peat swamps, which can smolder underground for months and produce much more smoke per unit area than do fires that occur on upland soils.)
Option 2: *Develop alternatives to unsustainable forms of slash-and-burn agriculture*. In contrast to bans on burning, Indonesia's partnership with a number of international organizations in the global ASB Programme to develop viable alternatives that diminish (if not eliminate) smallholders' need for burning is an approach that can reduce smoke and poverty, but has received scant media attention. Agroforests are a good examples of viable alternatives that are good for people's livelihoods, good for the economy and good for the environment.
Option 3: Clear land without burning. There are a number of land clearing techniques that do not produce smoke. These include biological methods to accelerate decomposition and various mechanical techniques that chip or shred biomass, either for mulching on-site or for transport off-site for disposal or sale. All of these 'no-burn' techniques are less effective and more expensive than burning. Research may be able to reduce the economic and technical costs of some environmentally benign techniques such as mulching. If subsidies for adoption of these techniques are administratively feasible, such payments may be an efficient means to reduce smoke emissions. To determine whether subsidies for adoption of no-burn techniques are appropriate, the social and economic costs of smoke must be compared with the costs of alternatives.
Option 4: Burn when it does less harm. It is not feasible to regulate burning by the many smallholders

who clear plots of a hectare or so. But government permits regulate land clearing by large companies. So, one option is to allow less clearing in El Niño years, which can be predicted. Another option is to require burning permits for large companies and to enforce sanctions on those that burn without permits or burn more than specified in their permits. Selective restrictions have been used elsewhere to prohibit burning when smoke would linger because of atmospheric conditions. Implementation of these options would require an effective monitoring system using remote sensing combined with on-site verification, stiff penalties, and certain enforcement. Offering permits through an auction could improve the efficiency of distribution among companies when rationing is needed, but may not be socially acceptable.

Option 5: Reduce the amount of timber that is burned. Indonesian forestry policies are designed to depress domestic prices of timber relative to world prices. Policies that depress prices of wood products increase the 'waste' that must be disposed of by burning or other means. If these policies were eased or removed, more of the wood felled in land clearing would be sold for timber, thereby reducing the amount that is burned. And if wood were sold instead of burned, there would be less smoke. The attractiveness of technological alternatives to clear land without burning discussed in Option 3—or the level of subsidies required for adoption of these techniques—also is influenced by national policies. In addition, since conversion forests are being planted mostly to oil palm, it is important to study alternative uses for the vast amounts of oil palm wood that will be available in the future.

Option 6: Recognize long-standing land claims. It is important to have balanced consideration for the community, the economy and the environment. Involving members of the community in decisions that affect their livelihoods and their tenure security would help to minimize conflicts over land allocation, thereby reducing use of fire as a weapon.

Deeper investigation is needed to reveal more of the facts behind these fires. But even with the limited information at hand, it is possible to identify certain steps that can be taken to help ensure that a catastrophe of this scale will not be repeated.

- Bans on burning may have symbolic value but are not practical because of the higher cost of alternative land clearing techniques. The exception would be to ban burning on peat soils. Reducing costs of alternative techniques deserves further study. However, this is a longer-term strategy, since widespread adoption of environmentally benign no-burn techniques will be slow until costs fall.

- Regulating burning by large operators and introducing penalties for the effects of accidental fires also deserves further study. BAPEDAL—the Indonesian agency charged with environmental protection—has already made impressive efforts in this direction. The agency has laid the foundation to develop ways to restrict burning to periods when smoke does less harm and to impose penalties on large companies that allow fires to get out of control. Investments in equipment and human resources are needed to sustain and strengthen BAPEDAL's new capacity to detect fires, verify their causes, analyze policies and provide timely, accurate information.

- Recognizing long-standing land claims would help minimize conflicts over land allocation.

- Reducing or eliminating restrictions that depress domestic timber prices would decrease the amount of timber that is burned after land clearing. Among these options, this one would be the easiest to implement and would have immediate effects.

In Part VII we report on important action on recognition of longstanding land claims and we present further analysis of timber export restrictions within the context of the agreements on economic and financial policy reform between Indonesia and the IMF.

VII. Output 3.3. Action at the local and national level

This part of the report concerns **Project Output 3.3**, *development and implementation of country action plans by (a) preparing policy briefs for relevant stakeholders for integrating biodiversity conservation and climate change mitigation in agricultural development in the forest margins and for implementing this integration through appropriate economic incentives and institutional reforms, and (b) consulting with national policy makers, land use planners, land users and natural resource managers to initiate the framing of country action plans or the relevant amending of existing plans* .

Policy and institutional barriers to adoption of alternative land uses have been analyzed and workable options to address tenure insecurity and certain trade policy distortions were developed in consultation with policymakers and other stakeholders. Ongoing collaboration, contact, and presence by national and international members of the research team are essential for real impact on policy and technology options. Under any circumstances, but especially because of the social, political, environmental, and financial crises that Indonesia now must face simultaneously, it is neither feasible—nor perhaps even desirable—to expect a grand strategy or comprehensive national plans of action regarding sustainable land use alternatives to slash-and-burn. However, as demonstrated by the examples discussed below, even the present dire circumstances still present opportunities for collaborative development of policy options and programmes that can further environmental goals along with poverty alleviation among people living at the forest margins. These opportunities need to be seen within the context of urgent policy priorities and the ongoing process of reform in Indonesia.

VII.1 A Policy Breakthrough for Indonesian Farmers in the Krui Damar Agroforests[3]

Djamaloedin Soeryohadikoesoemo, Indonesia's Minister of Forestry from April 1993 to March 1998, signed an historic decree in January 1998 that established an official precedent for community-based natural resource management in Indonesia. Based on the Minister's concept for a distinctive forest-use classification, '*Kawasan dengan Tujuan Istimewa*' (KdTI), the new ministerial decree recognises the legitimacy of community-managed agroforests on a significant area of State Forest Land.

For the first time in Indonesia, this decree recognises the environmental and social benefits of an indigenous land use system (damar agroforests), the role of indigenous institutions in sustainability of this natural resource management system, and the rights of smallholders to harvest and market timber and other products from trees they planted. While the new KdTI area still is part of the State Forest Zone, this classification is unprecedented in that:

- it sanctions a community-based natural resource management system as the official management regime within an area of the State Forest Zone

[3] This section draws heavily on Fay *et al.,* 1998.

- it allows the harvesting of timber from within the State Forest Zone by local people
- it allows the limited harvesting of timber from within a watershed
- it devolves the management responsibility of State Forest Lands to a traditional community governing structure (Masyarakat Hukum Adat)
- these rights are provided without a time limit.

This first KdTI area is in the heartland of the Krui damar agroforests in Lampung Province on the Indonesian island of Sumatra. These magnificent damar agroforests have been described elsewhere (*Agroforestry Today* 6(4):12-13; 8(1): 8-10; 9(4)18-20). Through a process developed by the Krui people a century ago, these agroforests begin with land clearing and planting of upland rice, which is followed by a succession of treecrops, including coffee, fruit trees, various timber species, and damar (*Shorea javanica*), which produces resin as well as timber. Through a blend of natural succession with management by farmers, these agroforests develop over a period of decades into a complex, multi-strata agroforestry system that approximates a number of forest functions, including biodiversity conservation and watershed protection. Satellite images indicate there are approximately 55,000 ha of these mature agroforests in Krui. The new KdTI area covers 29,000 ha of damar agroforests at various ages that fall within the State Forest Zone, with the balance being on private land.

At the invitation of the Indonesian Minister of Forestry, ICRAF and NGO partners LATIN and WATALA worked closely with Forestry Department counterparts to identify and develop workable options for implementation of the Minister's KdTI concept in Krui. This effort benefited greatly from previous research on the ecological, social, and economic functions of the Krui agroforests conducted by ORSTOM scientists, some of whom are seconded to ICRAF SE Asia. Subsequently, a research consortium grew that includes the 2 Indonesian NGOs, the University of Indonesia, CIFOR, and the ICRAF/ORSTOM team. Results of research by this 'Krui Team' assisted local farmers in their efforts to gain official recognition by documenting the myriad benefits of the damar agroforests as a resource management system. Since 1995, the research consortium has been working with Krui farmers to literally place their agroforestry systems on the map and to articulate the environmental and economic benefits of their system. Research and community organising produced numerous maps and detailed description and analysis of the Krui agroforests. In March 1997, the consortium conveyed requests from village leaders to the Minister of Forestry to initiate a dialogue with government concerning the status of their lands. In June, the consortium helped organise field visits from key government officials and a two-day workshop where research results were presented and the status of the land was discussed. The results of these activities were reported to the Minister of Forestry and, six months later, the pathbreaking decree was signed.

ICRAF and the other partners in the Krui research consortium now are organising a process of consultation with villagers and local government to discuss the rights and responsibilities the new

KdTI classification provides and to plan for implementation of the KdTI concept in Krui. In addition, Krui farmers have requested that ICRAF explore ways to increase diversity and productivity of their damar agroforests. This work will centre on understanding the existing genetic diversity of the most important tree species in the agroforests and identifying superior provenances. ICRAF and ORSTOM also conduct research on local timber extraction practices and plan new research on outcome-based measures for rapid assessment of natural resource management objectives.

It is hoped that this research on implementation in the Krui KdTI area and on the new tools for environmental impact assessment will provide insights for the replication of this approach widely within Indonesia. The Krui experience has gained the attention of researchers working on similar problems as far away as Cameroon. African scientists visited the Krui agroforests as part of the activities of the Alternatives to Slash-and-Burn Programme (ASB) and they now have expressed interest in the details of the new classification in the hope that lessons can be shared between Indonesia and Cameroon regarding implementation options.

At least 7,000 families in the KdTI area will benefit directly from the decree's official recognition of their rights. If this pilot effort is implemented successfully, it is hoped that the KdTI prototype can be applied in numerous other locations in Indonesia, with benefits for hundreds of thousands of households through poverty alleviation, improved resource management, and reduction of social conflict. Indeed, this can be viewed as an effort by Minister Djamaloedin to address human rights issues arising from conflict over forestlands as well as the pursuit of environmental objectives and poverty alleviation.

Until this decree was issued, the Krui agroforests were at risk because of the uncertainty of their tenure status. One serious implication of this legal status was that a forestry company held the government-awarded right to manage this area, including the possible harvesting of an estimated 3 million commercially valuable trees planted by local people. In addition, local farmers expressed growing concerns over the uncertainty of their rights to the damar agroforests they have planted and are currently managing. Many damar farmers adopted a 'wait and see' strategy and chose not to plant damar and fruit trees until they would know for sure that they will be able to harvest the benefits of their work. This uncertainty clearly endangered the very future of a system that is renowned worldwide as an example of successful and sustainable management of forest resources by a local community.

VII.2 Analysis of timber export taxes and marketing restrictions[4]

Although Indonesia now faces extremely severe economic challenges, this difficult situation also presents certain opportunities to lay foundations for a stronger, healthier, and more equitable forestry sector. Removing existing constraints and disincentives that hamper agroforestry tree production by smallholders would benefit Indonesia overall while accelerating compliance with forestry components of agreements between Indonesia and the IMF. Smallholders have an important role to play in Indonesia's transition from 'mining' its natural forests to sustainable production of forest products.

Elimination of disincentives to smallholder production by deregulating agroforestry tree species is an important—and administratively easy—first step toward realizing farmers' potential contributions to meeting growing commercial demand for forest products and to rehabilitating 'critical' watersheds in Indonesia. The rehabilitation of more than 50,000 hectares of forest through damar agroforest establishment by local communities in Krui mentioned above, the 'Sengonisasi' program in West Java, the over two million hectares of productive rubber agroforests in Kalimantan and Sumatra, and the growing importance of teak in farmers' fields in Daerah Istimewa Jogyakarta are evidence of the potential of farm forestry in Indonesia. Experience of other countries in the region, particularly the Philippines, also indicates that smallholder production of forest products could be economically efficient, environmentally sustainable, and socially equitable.

Deregulation of trade and marketing of agroforestry species is a *win-win* opportunity for the newly-renamed Department of Forestry and Plantations, providing tangible benefits for small-scale farmers, the forestry industry, the national economy, and the environment. Smallholders would benefit immediately through relief from the burden of counterproductive regulations. In the medium term, domestic timber processors would gain from the expansion of a sustainable supply of raw materials. Significant increases in exports of agroforestry timber—from wood that currently is wasted--would help Indonesia earn foreign exchange. This would also produce environmental benefits through the expansion of tree production on degraded lands.

This section is in four parts. First, we define precisely what we mean by 'agroforestry species'. Second, we discuss existing disincentives to smallholder production of these species. Third, we suggest some principles as a conceptual basis for comprehensive deregulation of these species. Finally, we review advantages of deregulation of these species for Indonesia and discuss how these recommendations fit with Indonesia's agreement with the IMF.

Agroforestry Species Produced by Smallholders. Some of the most complex forestry policy questions concern management of Indonesia's 'old growth' natural forests. But there are a significant number of agroforestry tree species grown by smallholders (and by large-scale estate plantations) that

[4] This section is drawn from a series of policy memoranda prepared by TP Tomich and H de Foresta.

are not natural forest species. Complete deregulation of these agroforestry species thus poses no threat to Indonesia's natural forests.

After consultation with colleagues in the Department of Forestry and Plantations, an initial list of 30 agroforestry tree species were identified that all are good candidates for immediate deregulation (see Table VII.1). Three types may be recognized that help to clarify the ecological and economic roles of each species for smallholders.

Table VII.1 30 agroforestry species for immediate deregulation

Indonesian name	**Latin name**
Type I. Exotic species	
Karet	*Hevea brasiliensis*
Jati	*Tectona grandis*
Mahoni	*Swietenia spp.*
Pinus	*Pinus spp.*
Afrika	*Maesopsis eminii*
Type II. Indigenous multipurpose species	
Damar matakucing	*Shorea javanica*
Mindi	*Melia azedarach*
Kelapa	*Cocos nucifera*
Mangga	*Mangifera indica*
Durian	*Durio zibethinus*
Duku	*Lansium domesticum*
Cempedak	*Artocarpus integer*
Manggis	*Garcinia mangostana*
Kapok	*Ceiba pentandra*
Asem Jawa	*Tamarindus indica*
Kemiri	*Aleurites moluccana*
Type III. Pioneer timber species	
Sungkai	*Peronema canescens*
Sonokeling	*Dalbergia latifolia*
Sonokembang	*Pterocarpus indicus*
Jeungjing, Sengon	*Paraserianthes falcataria* or *Albizzia falcata*
Johar	*Cassia siamea*
Jabon	*Anthocephalus chinensis*
Bayur	*Pterospermun javanicum*
Surian	*Toona sinensis*
Terap	*Artocarpus elasticus*
Mahang	*Macaranga spp.*
Pulai	*Alstonia spp.*
Puspa	*Schima wallichii*
Simpur	*Dillenia spp.*
Terentang	*Campnosperma auriculata*

- ***Type I. Exotic species***. None of these species are found in Indonesia's natural forests. Consider rubber wood, which is a substitute for ramin, one of the most valuable natural forest species. With the depletion of ramin, rubber wood has emerged as an important by-product of natural rubber production. Teak, mahogany, and all but one of Indonesia's pines (*Pinus merckusii*) also are exotics. Although presently grown mainly in large-scale plantations dating from the colonial era, smallholders (including transmigrants) are strongly interested in planting these species (often beside roads and along fence rows) despite their relatively long gestation periods because of the high value of their sawn timber.

- ***Type II. Indigenous multipurpose species.*** Coconut is the most widespread of these common species. Farmers mainly plant them for non-timber products, but timber is a valuable by-product at the end of the tree's productive life. These species are grown in large quantities by smallholders. Although these are indigenous species, most trees of these species now are planted and only a small proportion of these trees are found in Indonesia's natural forests.

- ***Type III. Indigenous 'pioneer' timber species.*** Although indigenous to Indonesia's natural forests, these fast-growing, light-loving species specialize in gap filling and, hence, are rare in old-growth natural forests. Their ecological niche also means they are well suited to domestication and planting in farmers' fields. Species such as bayur have been semi-domesticated and now are almost exclusively produced in farmers' fields.

Disincentives to Smallholder Agroforestry. There are at least two major barriers to smallholder production of timber and other 'forest' products in Indonesia. First is tenure insecurity for millions of smallholders because of conflicting claims on land that no longer is natural forest. As discussed above, a long-term process may be necessary to develop workable and enforceable agreements between Government and local communities regarding land use and production sharing rights *and* responsibilities on these lands. Second are disincentives to smallholder production created by trade and marketing restrictions that undermine incentives regardless of where production takes place, even on private land. This section focuses on this second major barrier because the benefits of deregulation of trade and marketing could be felt immediately by millions of smallholders throughout the country.

Current regulations covering trade and marketing of timber and on some other 'forest' products are designed for natural forest products –'gifts from God'—but are inappropriately applied to agroforestry products, which are produced from farmers' own labor, land, and capital. These policies, which penalize smallholders who grow trees on their farms, include:

- **Export taxes.** Indonesia's timber export taxes are intended to promote domestic wood processing industries. The previous timber tax system had the same effect as an export ban because the tax rates were 'prohibitive' (the export taxes exceeded world market prices, so it did not pay to export). Those prohibitive taxes drove down domestic prices for all timber species. Export taxes for logs and sawn timber now are 30%; these taxes are scheduled to be reduced to 20% by the end of 1998. For the agroforestry species described above, these export taxes depress incomes of smallholder producers. The resulting harm to smallholder income and livelihoods is an unintended side effect of these export taxes.

- **Natural resource rents and royalties** (*IHH*). According to formal forestry regulations, IHH only applies to products harvested from State Forest Land (*Kawasan Hutan*). It is common practice—for example regarding damar resin in Krui and rattan species planted by farmers in

Kalimantan--to assess IHH regardless of a product's origin simply because it often is impossible to determine the origin *of some products* with any certainty.

- **Administrative procedures for harvesting and transporting timber and other products** which have been classified as 'forest' products – such as damar resin, kayu manis and kemiri. In addition to being an administrative burden, the current complex felling and trading procedures for timber and other products grown on farms create various opportunities for illegal levies.

In all these examples, trade and marketing policies that are intended for products from natural forests are inappropriately being applied to species that are planted by smallholders. The result is increased marketing costs, which reduce or eliminate farmers' profits. Particularly because these products all require substantial time and investment to produce, inappropriate application of these regulations make production of agroforestry products, including timber, much less attractive than farmers' other alternatives. In addition, various local levies (*retribusi*) on timber and other agroforestry products have been administered in ways that place a heavy burden on small-scale producers and traders. These local levies are inefficient because the economic costs are high compared to the revenue generated.

A Conceptual Framework for Deregulation. The following principles provide a framework for integrated assessment of policy options for deregulation of agroforestry species.

1. 'Resource rent taxes' should be applied only to products that are 'gifts from God', such as timber from Indonesia's ***natural*** forests. For example, 'resource rent taxes' should not apply to damar resin and timber produced by farmers in Krui and timber from rubber trees planted by farmers and estate plantations.

2. All direct taxes (including export taxes, taxes on forest products and 'resource rent taxes') should be eliminated for tree species that are mainly grown on small farms and large plantations. These taxes are difficult and expensive to administer compared to the revenue they raise. They are a nuisance to producers and, more importantly, they represent a strong disincentive to smallholders who would like to plant trees with commercial value.

3. The Government's Memorandum on Economic and Financial Policies issued on 15 January seeks to reorient production, processing, and marketing of forestry and agroforestry products toward market mechanisms and away from regulation and central planning. Market mechanisms are most efficient for handling processing and marketing of forest products--minimize government intervention in these commercial activities.

4. Priority in the forestry sector should go to management of those lands that are still covered with natural forests. Market forces alone are not sufficient for management of these natural forests (including parks and nature reserves as well as production forests), whose area and quality have been degrading at an alarming rate.

Reasons to Deregulate Agroforestry Species

1. **Accelerate deregulation for species that pose no threat to Indonesia's natural forests**. Unlike trees in natural forests, which are 'gifts from God', these agroforestry species are planted and managed by smallholders just like agricultural commodities.

2. **Alleviate poverty**. Current harvesting and trade regulations deprive poor households of income because they depress prices smallholders could receive for timber and other 'forest products' from trees that they grow. Therefore, deregulating harvesting and trade on agroforestry species would help alleviate poverty.

3. **Secure a sustainable timber supply**. Removing current regulations on harvesting and trade of timber for agroforestry species would significantly improve incentives for development of Indonesia's smallholder farm forestry subsector. This would be an important step toward realizing the potential of smallholders to make a bigger contribution to meeting growing commercial demand for timber.

4. **Rehabilitate 'critical' lands.** Deregulation of agroforestry species would raise the economic benefits of growing trees on degraded lands and provide a new stimulus for farmers to rehabilitate lands that were marginal for agricultural production. Therefore, deregulating harvesting and trade in agroforestry species would help promote reforestation and thereby produce environmental benefits on a local, regional, national and global scale.

5. **Enhance efficiency in meeting goals of the Department of Forestry and Plantations.** Since current harvesting and trade regulations do not differentiate products from natural forests from those harvested from farmers' fields, these regulations unnecessarily increase the Department's administrative burden. Deregulating agroforestry species would allow the Department to focus its limited budget and human resources on its 'natural' priority: management of State Lands that still are covered by natural forests in order to achieve a better mix of production and conservation.

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Annex B. Equipment provided and recommendations for transfer

A Shimadzu Gas Chromatograph was obtained with project funds and equipped for measurements of nitrous oxide. The equipment was placed in the laboratory of BIOTROP / Global Change Impact Centre (IC-SEA) and its future use for measurements related to the ASB project is covered by a memorandum of understanding, signed by Dr. Pedro Sanchez on behalf of ICRAF and Dr. Arsyad on behalf of BIOTROP, and by Dr. Meine van Noordwijk and Dr. Daniel Murdiyarso as scientists involved.

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38. Yadi Setiadi, PhD	Mycorrhiza Specialist, IPB
39. Djunaedi, Ir.	Soil Microbiologist, Graduate Student, IPB
40. Daniel Murdiyarso, PhD	Head/Ecosystem Modeller, Impact Centre for Southeast Asia, Southeast Asian Regional Center for Tropical Biology (BIOTROP)
41. Upik Rosalina, PhD	Forest Ecologist & Remote Sensing Specialist, BIOTROP
42. Agus Eka Putra, PhD	Forest Ecologist, BIOTROP

43. Iwan Setiawan, Ir.	Forester, BIOTROP
44. Setiabudhi	Vegetation Analyst, BIOTROP
45. A. Ngaloken Gintings, PhD	Director, Forest Products and Socio-Economics Research Development Center (FPSERDC)
46. Wesman Endom, Ir., M.Sc.	Researcher, FPSERDC
47. Machfudh, PhD	Researcher, FPSERDC
48. Asih S. Irawanti, Dra., M.E.	Researcher, FPSERDC
49. Retno Maryani, Ir., M.S.	Researcher, FPSERDC
50. Gede Wibawa, PhD	Agronomist, Rubber Research Institute Sembawa
51. Hisar Sihombing, PhD	Soil Scientist, Rubber Research Institute Sembawa
52. Arif Aliadi, Ir.	Program Director, The Indonesian Tropical Institute (LATIN)
53. Wibowo A. Djatmiko, Ir.	Program Coordinator, LATIN
54. Kusworo	Researcher, WATALA
55. Iwan Tjitradjaja, PhD	Director, P3AE UI, University of Indonesia
56. Hadi Pasaribu, PhD	Directorate General, Replanting and Land Rehabilitation, Department of Forestry
57. Andrew N. Gillison, PhD	Principle Scientist, Center for International Forestry Research (CIFOR)
58. Nining Liswanti, Ir.	Research Assistant, CIFOR
59. Dennis P. Garrity	Regional Coordinator, International Centre for Research in Agroforestry (ICRAF)
60. Pratiknyo Purnomosidhi, Ir., MS.	Associate Research Officer, ICRAF
61. Suyanto, Ir., MS.	Agricultural Economist, ICRAF
62. Thomas P. Tomich, PhD	Natural Resource Economist, ICRAF
63. Yanti Kusumanto, M.Sc.	Research Officer and Project Manager, ICRAF
64. Fred Stolle, M.Sc.	Research Associate, GIS and Remote Sensing Analyst, ICRAF
65. Danan Prasetyo Hadi, Ir.	Assistant Research Officer, GIS, ICRAF
66. Chip Fay	Tenure Specialist, ICRAF
67. Suseno Budidarsono, Drs., M.Sc	Associate Research Officer, Agricultural Economics, ICRAF
68. Martua Thomas Sirait, M.Sc.	Associate Research Officer, Community Forestry Policy, ICRAF
69. Meine van Noordwijk, PhD	Soil Ecologist, ICRAF
70. Grégoire Vincent, PhD	Ecological Modeller, ICRAF
71. Betha Lusiana, Ir.	Associate Research Officer, ICRAF
72. Subekti Rahayu	Database Management, ICRAF
73. Quirine M. Keterings, M.Sc.	Researcher, PhD Student, ICRAF
74. Hubert de Foresta, PhD	Forest Ecologist, ORSTOM/ICRAF
75. Genevieve Michon, PhD	Agroecologist, ORSTOM/ICRAF
76. Eric Penot, MSc.	Rubber agronomist, CIRAD/ICRAF
77. Erwidodo, PhD	Economist, CASER

Annex D. List of Persons Trained -- ASB PHASE II

No.	PARTICIPANTS	INSTITUTIONS	EVENT			
			Policy Analysis Matrix	Belowground Biodiversity-Lampung	Belowground Biodiversity-Jambi	Century Model
1	Bustanul Arifin	University of Lampung	x			
2	Agus Hudoyo	University of Lampung	x			
3	Retno Maryani	Forest Products and Forestry Socio-Economics Research and Development Centre, Ministry of Forestry	x			
4	Setiasih Irawanti	Forest Products and Forestry Socio-Economics Research and Development Centre, Ministry of Forestry	x			
5	Machfudh	Forest Products and Forestry Socio-Economics Research and Development Centre, Ministry of Forestry	x			
6	Wesman Endom	Forest Products and Forestry Socio-Economics Research and Development Centre, Ministry of Forestry	x			
7	Prajogo U. Hadi	Center for Agro Socio-Economic Research, Agency for Agricultural Research and Development, Department of Agriculture (CASER)	x			
8	Gelar Setya Budhi	Center for Agro Socio-Economic Research, Agency for Agricultural Research and Development, Department of Agriculture (CASER)	x			
9	Arif Aliadi	The Indonesian Tropical Institute (LATIN)	x			
10	Wibowo A. Djatmiko	The Indonesian Tropical Institute (LATIN)	x			

11	Dr. Daniel Murdiyarso	Bogor Agricultural University		x	x	x
12	Dr. Meine van Noordwijk	ICRAF-South East Asia		x	x	x
13	Dr. Kurniatun Hairiah	Brawijaya University		x	x	x
14	Dr. Suryo Hardiwinoto	Gadjah Mada University (UGM)		x	X	
15	Dr. S.M. Sitompul	Brawijaya University				x
16	Pratiknyo Purnomo S.	ICRAF-South East Asia		x	x	
17	Dr. Robert Simanungkalit	Central Research Institute for Food Crops		x	X	
18	Dr. Iswandi Anas	Bogor Agricultural Univ.		x	x	
19	Dr. Yadi Setiadi	Bogor Agricultural Univ		x	x	
20	Dr. F.X. Susilo	Lampung University		x	x	
21	Sri Murwani	Lampung University		x		
22	Gde Swibawa	Lampung University		x		
23	Agus Cahyono	Gadjah Mada University (UGM)			x	
24	Agus Eka Putra	SEAMEO-BIOTROP			x	
25	Setiabudi	SEAMEO-BIOTROP			x	
26	Asmahan	Bogor Agricultural Univ (Student)			x	
27	Indrayati	Gadjah Mada University (UGM) (student)			x	
28	Nining Liswanti	CIFOR			x	
29	Dr. Andy Gillison	CIFOR			x	
30	Dr. Mike Swift	Tropical Soil Biology Fertility (TSBF)			x	
31	Haris Kriswantoro	Bogor Agricultural Univ (Student)			x	x
32	Hendrien Beukema	ICRAF			x	
33	Quirine Ketterings	ICRAF (student)			x	
34	Agus Priyono	Gadjah Mada University			x	
35	Sandy Williams	ICRAF (student)			x	
36	Didik Suprayogo	Brawijaya University				x
37	Edwin Rowe	ICRAF (student)				x
38	Betha Lusiana	ICRAF-South East Asia				x
39	Subekti Rahayu	ICRAF-South East Asia				x
40	Iwan Setiawan	SEAMEO-BIOTROP				x
41	Desi Ariyadi Suyamto	IC-SEA-BIOTROP				x

Annex E.

Policy Analysis Matrices for Six Major Land Use Systems

of Sumatra's Peneplains

Studies of private and social profitability:
Major land use systems in lowland Sumatra

Land use system: Small-scale forest extraction

Specific example: NTFPs & occasional small-scale

Scenario 1

Extraction area : 13,179 ha

NTFPs: petai, fish, durian and jengkol, (all extracted every year) and honey (extracted once in three years)

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	24,978	698	8,307	1,023	15,973
Social prices	32,309	912	10,847	2,053	18,497
Effect of divergences	(7,331)	(214)	(2,540)	(1,030)	(2,524)

Scenario 2

Extraction area : 35,061 ha

NTFPs: petai, fish, durian, jengkol, rattan and song birds (all extracted every year) and honey (extracted once in two years)

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	12,594	263	4,380	444	7,951
Social prices	16,193	343	5,571	837	9,442
Effect of divergences	(3,599)	(80)	(1,191)	(1,063)	(1,491)

Team members: Arif Aliadi and Wibowo A. Djatmiko

Study sites: Rantau Pandan District, Jambi Province

Production PAMS: 1 'whole forest' PAM for entire community forest area, with component PAMs as necessary for specific activities disaggregated for gathering of tradables (timber, rotan, birds nests) and for hunting and fishing and other discrete activities; gathering activities that generate joint nontradable outputs will be aggregated.

Discounting period for production PAMS: 25 years.
Note, however, that the team identified patterns and fluctuations in extractive activities over the past ten years or so and used these data to derive estimates of annual averages. These averages then were discounted over a 25-year period to enable comparability with other studies.

Resource degradation concerns? Need to be alert to possible depletion of resources, but the PAM is intended to represent a steady state (if that is the case)

Processing PAMS: not applicable

Small-scale forest extraction, *continued.*

Regional externalities (to be noted, but not measured) in production or processing?
No negative regional externalities expected.

Data challenges and other special features:
This team's data collection assignment was probably the most difficult because of the following factors:

1. Difficulty of identifying the major forest products gathered over the past ten years or so and understanding extraction patterns because of the variety of NTFPs, seasonal variation, and inter-year variation.
2. Delineation of forest boundaries and total area.
3. Difficulty in assessing the sustainability of extraction practices; in other words, are forest resources being depleted?
4. Distinguishing household activities from community activities.
5. Effect of tenure insecurity on resource management incentives.
6. Identifying and quantifying activities to maintain and secure use rights and resource access and to circumvent regulations
7. Many of these activities are illegal.

Policy issues / **simulations:**

1. Elimination of quantitative export restrictions, export taxes, and marketing restrictions that apply to most of the major products.
2. Level of effort to secure and maintain use rights as a proxy for impact of tenure uncertainty.
3. Technical options for enrichment planting and forest management.
4. Public policy regarding pricing of timber from natural forests.

Studies of private and social profitability: Major land use systems in lowland Sumatra

Land use system: Shifting cultivation

Specific example: upland rice / bush fallow rotation

Scenario 1
Short fallow upland rice

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	453,903	20,615	554,954	95,725	(217,391)
Social prices	589,258	25,862	655,034	88,395	(180,033)
Effect of divergences	(135,355)	(5,247)	(100,079)	(7,330)	(37,358)

Scenario 2
Long fallow upland rice

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	371,375	11,245	372,418	63,808	(76,096)
Social prices	482,120	14,107	362,034	52,959	53,021
Effect of divergences	(110,745)	(2,862)	(100,079)	(10,850)	(129,117)

Team members: Bustanul Arifin and Agus Hudoyo

Study sites: Rantau Pandan District, Jambi Province

Production PAMS:
2 or more PAMs for differing fallow periods to be identified after consulting with farmers to determinate critical periods to re-establish soil fertility (say, for example, fallow periods of 5 years and 10 years)

1 or more PAMs for wet rice in order to make a whole farm/whole forest PAM in collaboration with other teams.

Discounting period for production PAMS: 25 years, with multiple fallow rotations to examine effects of any resource degradation.

Resource degradation concerns? Yes, at least 1 PAM (the one for the shortest fallow period) is expected to show declining production of upland rice.

Processing PAMS: not applicable

Regional externalities (to be noted, but not measured) in production or processing? There is a possibility of sedimentation from soil erosion for shortest fallow period.

Data challenges and other special features:
1. Determining if fallow periods are changing.
2. Data on effects (if any) of shortening fallow period on upland rice profitability.
3. Build a whole farm/whole forest PAM for the Rantau Pandan site in collaboration with the small-scale forest extraction team and the smallholder rubber team.

Policy issues / **simulations:**
1. How do population growth, tenure insecurity, and other factors affect the length of the fallow period in the shifting cultivation system?
2. How do institutions and policies affect links between shifting cultivation and deforestation within the whole farm/whole forest context?

Studies of private and social profitability: Major land use systems in lowland Sumatra

Land use system: Agroforestry & treecrop monoculture

Specific example: smallholder rubber agroforests and smallholder rubber monoculture

*Smallholder agroforest 1 (Rubber Agroforest using **seedlings** as planting materials)*

	Revenues *(Rp)*	***Cost*** *(Rp)*				***Profits*** *(Rp)*
		Purchased inputs		***Domestic factors***		
		Tradable	***Non tradable***	***Labor***	***Capital***	
Private prices	2,055,157	460,651	166,067	1,397,684	29,144	1,611
Social prices	2,876,566	610,322	208,654	1,958,916	26,173	72,501
Effect of divergences	(521,409)	(149,671)	(42,586)	(561,232)	2,971	70,890

*Smallholder agroforest 2a (Rubber Agroforest using **clones** as planting material): An **optimistic** production scenario*

	Revenues *(Rp)*	***Cost*** *(Rp)*				***Profits*** *(Rp)*
		Purchased inputs		***Domestic factors***		
		Tradable	***Non tradable***	***Labor***	***Capital***	
Private prices	6,089,282	837,312	200,000	2,767,524	81,993	2,202,453
Social prices	8,538,408	1,008,768	208,696	3,627,439	70,931	3,622,575
Effect of divergences	(2,449,127)	(171,456)	(8,696)	(859,914)	11,062	(1,420,122)

*Smallholder agroforest 2b (Rubber Agroforest using **clones** as planting material): A **pessimistic** production scenario*

	Revenues *(Rp)*	***Cost*** *(Rp)*				***Profits*** *(Rp)*
		Purchased inputs		***Domestic factors***		
		Tradable	***Non tradable***	***Labor***	***Capital***	
Private prices	3,791,028	837,312	200,000	2,767,524	81,993	(95,615)
Social prices	5,149,816	1,008,768	208,696	3,627,439	70,931	234,228
Effect of divergences	(1,358,788)	(171,456)	(8,696)	(859,914)	11,062	(329,842)

*Smallholder rubber **monoculture**, a government project but planted with GT 1 clonal seedlings*

	Revenues (Rp)	Cost (Rp)				Profits (Rp)
		Purchased inputs		Domestic factors		
		Tradable	Non tradable	Labor	Capital	
Private prices	1,869,930	649,395	200,000	1,882,598	(659,098)	(166,931)
Social prices	2,654,219	813,154	208,696	2,596,512	28,991	(993,133)
Effect of divergences	(784,289)	(163,758)	(8,696)	(713,914)	272,848	(170,769)

Team members: Prajogo Hadi and Gelar Satya Budhi

Study sites: Rantau Pandan District and Bungo Tebo District in Jambi Province; perhaps other peneplains districts of Jambi Province.

Production PAMS:
1 smallholder rubber monoculture PAM
2 smallholder rubber agroforests PAMs, of which 1 is for the Rantau Pandan site and the other is for Pelepat (or a comparable) site; planting material will be seedlings.
Additional smallholder rubber agroforest PAMs as necessary to represent major differences in technology (for example, clonal planting material), management (rubber specialists versus mixed farms), or agroforest composition (importance of fruit, timber or other species).

Discounting period for production PAMS: 25 years.

Resource degradation concerns? No.

Processing PAMS: 1 PAM, to be based on the nearest crumb rubber factory, which is only a few years old.

Regional externalities (to be noted, but not measured) in production or processing? No negative externalities for production; note water pollution or other negative externalities of processing.

Data challenges and other special features:
1. Typology of rubber agroforests. (ICRAF team can help)
2. Typology of smallholder practices in rubber agroforests.
3. Finding mature rubber monoculture. (There are plots-ICRAF team can help with locations).

Policy issues / simulations:
1. Removal of prohibitive export tax on rubber wood.
2. What limits the spread of higher-yielding clones?
3. If rubber smallholders' management practices are changing, why is that so? What effect will that have on profitability of agroforests versus monoculture?

Studies of private and social profitability:
Major land use systems in lowland Sumatra

Land use system: Large-scale forest extraction

Specific example: logging in lowland dipterocarp forest

Actual annual cutting area

	Revenues *(Rp)*	***Cost*** *(Rp)*				***Profits*** *(Rp)*
		Purchased inputs		***Domestic factors***		
		Tradable Inputs	***Tradable Capitals***	***Labor***	***Capital***	
Private prices	1,437,097	102,821	834,600	240,501	389,873	(130,698)
Social prices	3,397,392	121,629	862,151	291,840	19,737	2,102,036
Effect of divergences	(1,960,295)	(18,808)	(27,551)	(51,339)	370,136	(2,232,734)

Constant annual cutting area

	Revenues *(Rp)*	***Cost*** *(Rp)*				***Profits*** *(Rp)*
		Purchased inputs		***Domestic factors***		
		Tradable Inputs	***Tradable Capitals***	***Labor***	***Capital***	
Private prices	460,619	108,812	883,227	139,569	133,447	(804,436)
Social prices	1,203,620	128,387	912,382	180,350	12,102	(31,602)
Effect of divergences	(743,002)	(19,575)	(29,156)	(42,781)	121,345	(772,834)

Team members: Machfudh and Wesman Endom

Study sites: Jambi Province, perhaps peneplains sites in adjacent provinces.

Production PAMS: At least 1 for representative concessionaire that apparently is committed to long-run production on its concession.

Discounting period for production PAMS: 25 years; note that 20 years is the current concession period. (However, the regeneration cycle is longer).

Resource degradation concerns? Need to be alert for possible depletion of resources, but the PAM is intended to represent a steady state (if that is the case). It was decided to focus on a concessionaire that is investing and managing for the long run, even if some forest depletion is happening. Although 'unsustainable' practices may be the norm, these are not very interesting for the purpose of assessing whether 'sustainable' logging is profitable.

Processing PAMS: At least 1 for an integrated processing facility.

Regional externalities (to be noted, but not measured) in production or processing? Possible sedimentation from soil erosion during logging–especially from logging roads; note water pollution or other negative externalities of processing facilities.

Data challenges and other special features:
Identifying suitable firms and building rapport in order to gain access to necessary data.

Policy issues / simulations:

1. Trade restrictions, including prohibitive export taxes on logs and sawn timber.
2. Other forestry taxes and royalties, and fees.
3. Perverse incentives from concession period being shorter than timber harvest cycle.
4. Public policy regarding pricing of timber from natural forests.
5. Subsidised investment credits?

Studies of private and social profitability: Major land use systems in lowland Sumatra

Land use system: Annual-cropping systems on uplands of transmigration projects.

Specific example: continuous cropping of cassava, degrading to Imperata cylindrica.

Monocrop cassava with low external input application, beginning from the first year of cultivation

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	4,804,005	595,371	1,901,957	2,422,002	(71,324)
Social prices	5,632,473	950,100	2,278,692	2,718,365	(314,684)
Effect of divergences	(784,468)	(354,730)	(376,735)	(269,363)	243,360

Monocrop cassava with external input application, beginning from year 7 of cultivation

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	4,803,008	138,351	1,920,343	2,384,695	359,619
Social prices	5,764,916	346,512	2,404,975	2,788,983	224,446
Effect of divergences	(961,908)	(208,160)	(484,632)	(404,288)	135,173

Monocrop cassava without external input application

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	4,061,491	0	1,558,747	1,957,690	545,054
Social prices	4,569,727	0	1,829,010	2,137,514	603,203
Effect of divergences	(508,236)	0	(270,263)	(179,824)	(58,149)

Team members: Suseno Budidarsono (and Pratiknyo)

Study sites: Transmigration sites in North Lampung District, Lampung Province; perhaps Kuaman Kuning transmigration site in Jambi Province.

Production PAMS:
1 or more for cassava-based PAMs
1 or more maize-based PAMs
1 or more PAMs for any goods or services (e.g. roofing, grazing on shoots after burning) from *Imperata*-infested plots.

Discounting period for production PAMS: 25 years.

Resource degradation concerns? Yes, at least 1 PAM (for continuous cassava) is expected to show declining production.

Processing PAMS: 1 PAM, to be based on the nearest cassava factory, which produces cassava pellets for export.

Regional externalities (to be noted, but not measured) in production or processing? There is a possibility of sedimentation from soil erosion; note water pollution or other negative externalities of processing.

Transmigration systems, continued.

Data challenges and other special features:
1. Data on effects (if any) of continuous cropping on profitability of annuals. (ICRAF staff have data from field trials; agronomic simulation models also are available)
2. Data on productivity of *Imperata* grasslands.

Policy issues / simulations:
1. Cassava export quotas.
2. Other trade policy restrictions.
3. Is it feasible (technically, financially, and economically) to grow annual crops continuously on the upland soils typical of Sumatra's peneplains?
4. Alternative land use systems for Transmigration settlements.
5. Technical, financial, and economic feasibility of converting *Imperata* grasslands to other uses.

Studies of private and social profitability:
Major land use systems in lowland Sumatra

Land use system: Large-scale monoculture plantations

Specific example: Oil palm & industrial timber (for pulp)

Oil palm plantation

	Revenues (Rp)	Cost (Rp)			Profits (Rp)
		Tradable Inputs	Domestic factors		
			Labor	Capital	
Private prices	1,954,807	556,866	881,296	241,296	275,346
Social prices	4,116,465	848,834	1,493,440	294,595	1,479,596
Effect of divergences	(2,,161,657)	(291,968)	(612,144)	(53,299)	(1,204,246)

Team members: Retno Maryani and Irawanti Setiasih

Study sites: Jambi Province, perhaps peneplains sites in adjacent provinces.

Production PAMS:
1 oil palm PAM
1 PAM for *Paraserianthes falcataria*; also known as *Albizia falcata* ('Sengon')
Perhaps 1 PAM for *Acacia manguim*

Discounting period for production PAMS: 25 years.

Resource degradation concerns? None are known, but CIFOR is conducting long-term studies in other countries.

Processing PAMS:
1 palm oil mill PAM
1 or more pulp mill PAMs

Regional externalities (to be noted, but not measured) in production or processing? Possible sedimentation from soil erosion during logging-especially from logging roads; note water pollution or other negative externalities of processing facilities.

Data challenges and other special features:
Gaining access to data, especially for industrial timber firms.

Policy issues / simulations:
1. Import and export taxes and other trade restrictions on oil palm products.
2. Trade restrictions on imports and exports in the forestry sector.
3. Other forestry taxes and royalties, and fees.
4. Public policy regarding pricing of timber from natural forests.
5. Subsidized investment credit.

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