

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, multi-strata 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 further verification (Section V.2).
- Potential profitability of some tree-based alternatives 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 penepains 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.

1. 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.

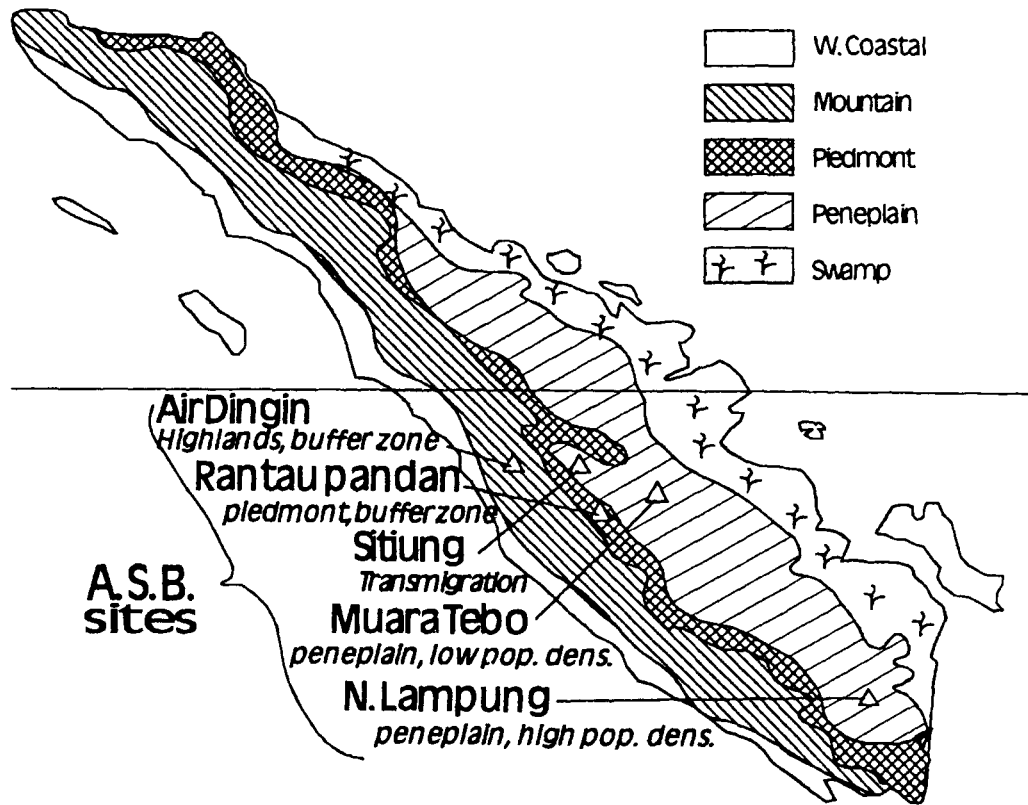
Indonesia, Brazil, and Cameroon were the first three countries to join in the ASB research effort in 1994. Indonesia's forests covered over 1 million square km in 1990 (World Bank 1997) and ranked third in area – behind the Amazon and the Congo Basin – among the world's remaining tropical rainforests. 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.

1.1 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 **penepplain 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 penepplains 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 penneplain. 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

1.2 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 berdasari,’ 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.

1.3 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 penneplains.

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.

1.4 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 <i>Imperata cylindrica</i>	Smallholdings in a government settlement project
Grasslands / pasture	<i>Imperata cylindrica</i>	Sheet <i>Imperata</i> (>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 (<i>Acacia mangium</i>) or for sawn timber (<i>Paraserianthes falcata</i>). (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 or 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 <i>Imperata cylindrica</i> 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.

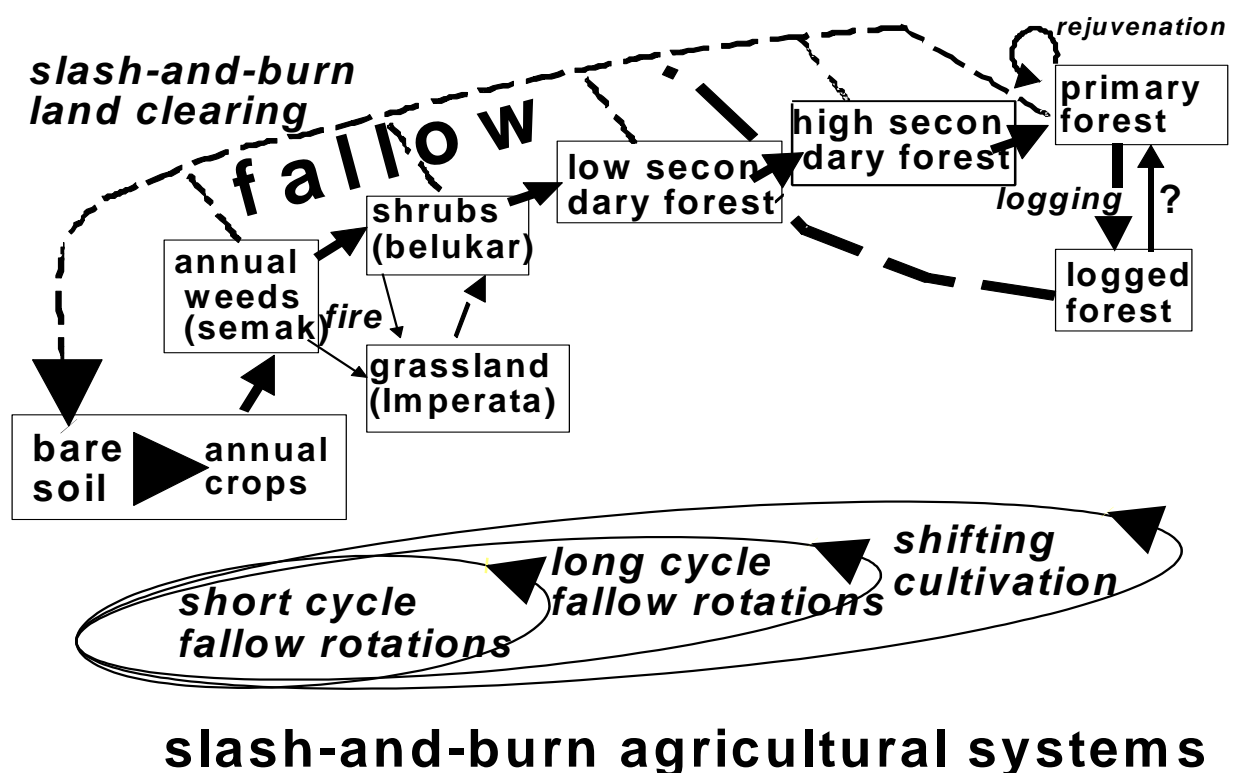


Figure 1.2 Transitions between land covers as part of fallow rotation systems

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.

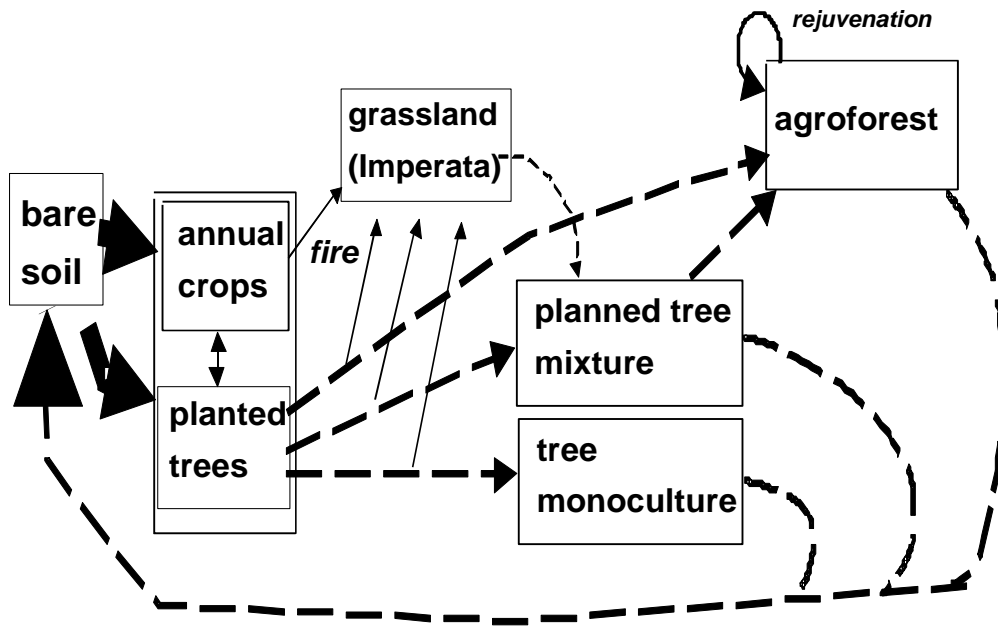


Figure 1.3 Land use systems that are alternatives to traditional slash-and-burn systems.

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	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.

1.6 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.