

# ASB Lecture Note 2

## Land use practices in the humid tropics and introduction to ASB benchmark areas

Meine van Noordwijk, Pendo Maro Susswein, Thomas P Tomich, Chimere Diaw, and Steve Vosti



# **Land use practices in the humid tropics and introduction to ASB benchmark areas**

Meine van Noordwijk , Pendo Maro Susswein, Thomas P Tomich,  
Chimere Diaw, and Steve Vosti

December 2001

Bogor, Indonesia

Published in December 2001

Published by:  
International Centre for Research in Agroforestry  
Southeast Asian Regional Research Programme  
PO Box 161, Bogor, Indonesia  
Tel: +62 251 625415; fax: +62 251 625416; email: [icraf-indonesia@cgiar.org](mailto:icraf-indonesia@cgiar.org)  
Web site: <http://www.icraf.cgiar.org/sea>

© copyright ICRAF Southeast Asia

Cover illustration: Wiyono

Layout: T Atikah & DN Rini

# Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns

Meine van Noordwijk, Sandy Williams and Bruno Verbist (Editors)

Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being. However, integration of environment and development concerns and greater attention to them will lead to the fulfilment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. No nation can achieve this on its own; but together we can - in a global partnership for sustainable development. (Preamble to the United Nations' Agenda21 on Sustainable Development; <http://www.un.org/esa/sustdev/agenda21chapter1.htm>).

## Background to this series of lecture notes

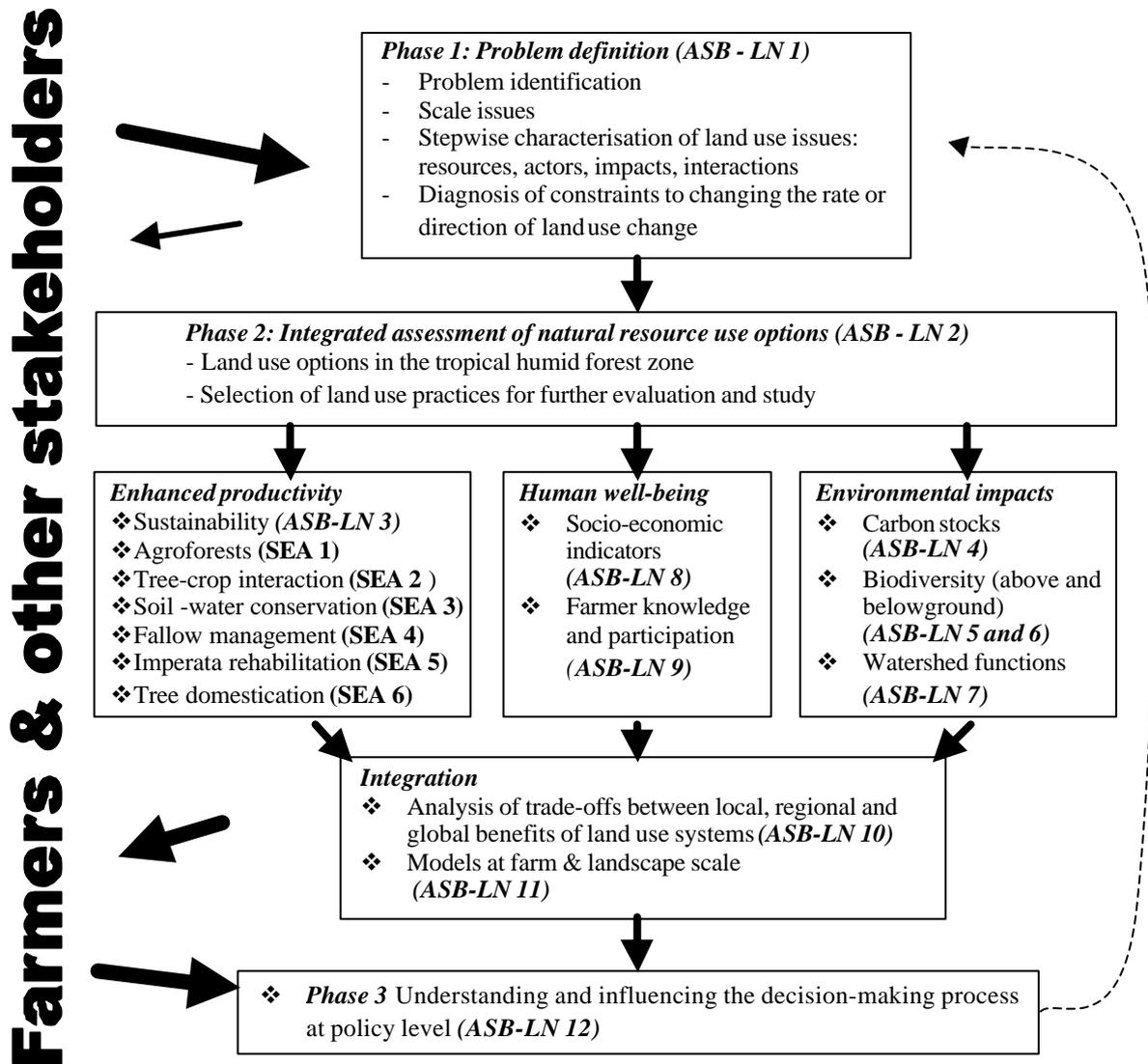
Much of the international debate on natural resource management in the humid tropics revolves around forests, deforestation or forest conversion, the consequences it has and the way the process of change can be managed. These issues involve many actors and aspects, and thus can benefit from many disciplinary perspectives. Yet, no single discipline can provide all the insights necessary to fully understand the problem as a first step towards finding solutions that can work in the real world. Professional and academic education is still largely based on disciplines – and a solid background in the intellectual capital accumulated in any of the disciplines is of great value. If one wants to make a real contribution to natural resource management issues, however, one should at least have some basic understanding of the contributions other disciplines can make as well. Increasingly, universities are recognising the need for the next generation of scientists and policymakers to be prepared for interdisciplinary approaches. Thus, this series of lecture notes on integrated natural resource management in the humid tropics was developed.

The lecture notes were developed on the basis of the experiences of the Alternatives to Slash and Burn (ASB) consortium. This consortium was set up to gain a better understanding of the current land use decisions that lead to *rapid* conversion of tropical forests, shifting the forest margin, and of the *slow* process of rehabilitation and development of sustainable land use practices on lands deforested in the past. The consortium aims to relate local activities as they currently exist to the global concerns that they raise, and to explore ways by which these global concerns can be more effectively reflected in attempts to modify local activities that stabilise forest margins.

The Rio de Janeiro Environment Conference of 1992 identified deforestation, desertification, ozone depletion, atmospheric CO<sub>2</sub> emissions and biodiversity as the major global environmental issues of concern. In response to these concerns, the ASB consortium was formed as a system-wide initiative of the Consultative Group on International Agricultural Research (CGIAR), involving national and international research institutes. ASB's objectives are the development of improved land-use systems and policy recommendations capable of alleviating the pressures on forest resources that are associated with slash-and-burn agricultural techniques. Research has been mainly concentrated on the western Amazon (Brazil and Peru), the humid dipterocarp forests of Sumatra in Indonesia, the drier dipterocarp forests of northern Thailand in mainland

Southeast Asia, the formerly forested island of Mindanao (the Philippines) and the Atlantic Congolese forests of southern Cameroon.

The general structure of this series is



This latest series of ASB Lecture Notes (**ASB-LN 1 to 12**) enlarges the scope and embeds the earlier developed ICRAF-SEA lecture notes (**SEA 1-6**) in a larger framework. These lecture notes are already accessible on the website of ICRAF in Southeast Asia: <http://www.icraf.cgiar.org/sea>

In this series of lecture notes we want to help young researchers and students, via the lecturers and professors that facilitate their education and training, to grasp natural resource management issues as complex as that of land use change in the margins of tropical forests. We believe that the issues, approaches, concepts and methods of the ASB program will be relevant to a wider audience. We have tried to repackage our research results in the form of these lecture notes, including non-ASB material where we thought this might be relevant. The series of lecture notes can be used as a basis for a full course, but the various parts can also ‘stand alone’ in the context of more specialised courses.

## **Acknowledgements**

A range of investors (or ‘donors’) have made the work of the ASB consortium possible over the past years, some by supporting specific parts of the program, others by providing core support to the program as a whole. These lecture notes build on all these investments, but were specifically supported by the ASB Global Steering Group, with funds provided by the Asian Development Bank, the World Bank via the CGIAR, by ICRAF core funds, by the Netherlands' Government through the Direct Support to Training Institutions in Developing Countries Programme (DSO)-project and by the Flemish Office for Development Cooperation and Technical Assistance (VVOB). Both biophysical and policy research was supported by a Regional Technical Assistance Grant from the Asian Development Bank. Many researchers and organisations have contributed to the development of ideas, collection and synthesis of data, and otherwise making the program what it is today. A team at the International Centre for Research in Agroforestry (ICRAF), consisting of Kurniatun Hairiah, Pendo Maro Susswein, Sandy Williams, SM Sitompul, Marieke Kragten, Bruno Verbist and Meine van Noordwijk developed these lecture notes. A first test of their suitability was provided by a course on ‘Ecology for Economists’ organised by the Economy and Environment Program for Southeast Asia (EEPSEA) program – we thank David Glover, Hermi Francisco and all participants to that course for their suggestions. Key researchers within the consortium provided support and agreed to act as co-authors on the various chapters. Editorial comments on draft forms of the various lecture notes were obtained from Fahmuddin Agus, Georg Cadisch, Min Ha Fagerström, Merle Faminow, Roeland Kindt, Chun Lai, Ard Lengkeek, Jessa Lewis, Chin Ong, Per Rudebjer, Goetz Schroth, Douglas Sheil, Fergus Sinclair, Sven Wunder and others. Overall responsibility for any shortcomings in the lecture notes remains with the editorial team.

### **ASB-consortium members**

Details of the ASB consortium members and partner organisations can be found at:  
<http://www.asb.cgiar.org/>

### **Copyright**

This material is considered to be an international public good that can be freely copied for use in an educational, non-commercial context, provided that the source is acknowledged.



## Lecture Note 2

# LAND USE PRACTICES IN THE HUMID TROPICS AND INTRODUCTION TO ASB BENCHMARK AREAS

By Meine van Noordwijk, Pendo Maro Susswein, Thomas P. Tomich,  
Chimere Diaw, and Steve Vosti

## Contents

I. OBJECTIVES	2
II. LECTURE	2
1. LAND USE SYSTEMS	2
1.1 Land Use and Land Cover	2
1.2 Shifting cultivation as a sequence of land cover types forming a single land use	3
1.3 Land use systems and practices in the humid tropics: identification, definition and classification	5
1.4 Intensification and relationships between the four large groups of land use systems	11
2. LAND USE CHANGE AND THE ASB EVALUATION MATRIX	13
2.1 From land use to natural resource management system	13
2.2 What is the effect of forest conversion on biodiversity, stored carbon, filter functions, and watersheds?	14
2.3 The ASB evaluation matrix	14
3. SAMPLING STRATEGY	15
3.1 Sampling land cover types as part of land use systems	15
3.2 Sampling within the ASB project	17
Summary	21
III. INTRODUCTION TO THE ASB BENCHMARK AREAS	22
1. SUMATRA	22
1.1 Overview	22
1.2 Farmer-developed agroforestry systems in Sumatra	25
1.3 Land use change in the Jambi benchmark areas	26
2. CAMEROON	26
2.1 The biophysical context of the Forest Margins Benchmark of southern Cameroon	26
2.2 Agricultural Land Use systems in the Forest Margins Benchmark	30
2.3 The socio-economic context of farming systems in the Cameroon Forest Margins Benchmark	31
3. BRAZIL	33
3.1 Characterisation of land use systems	33
3.2 Land use patterns: sequences that begin with forest	33
IV. READING MATERIALS	35

# I. Objectives

- To relate '*land cover*' as an ecological reality to '*land use*' from a farmer's perspective
- To introduce a generic land use typology for the humid tropics, and examples of the diversity of its local representatives
- To discuss a sampling strategy for use in assessing the social, economic, and environmental attributes of local representatives of these systems

# II. Lecture

## 1. Land use systems

### 1.1 Land Use and Land Cover

*Land cover* may be defined, simply, as anything that is on (or covers) the ground. Land cover may be observed using remote sensing tools. It has specific attributes, such as vegetation, carbon and nutrient storage, and forms a habitat for plants and animals. Thus grasslands, trees, forests, deserts, cropped fields and buildings are, depending on the scale of observation, all recognisable elements of land cover. *Land use* is an action performed on the land, by humans, in order to meet one or more objectives. In some cases the same words can describe both land cover and land use; pastures, for example, are both a cover and a type of land use. However, land use systems can also consist of a sequence of land cover types. For example, at different points in time, a patch of land that is part of a shifting cultivation system of land use can have as land cover a bare field, a cropped field, a bushy young fallow, a secondary forest or even an old-growth forest. Moreover, a specific example of land cover can be part of several land use systems; a 'cropped field' can be part of a permanent cropping system or part of a long cycle rotation or an example of any system in between these extremes (see Figure 1).

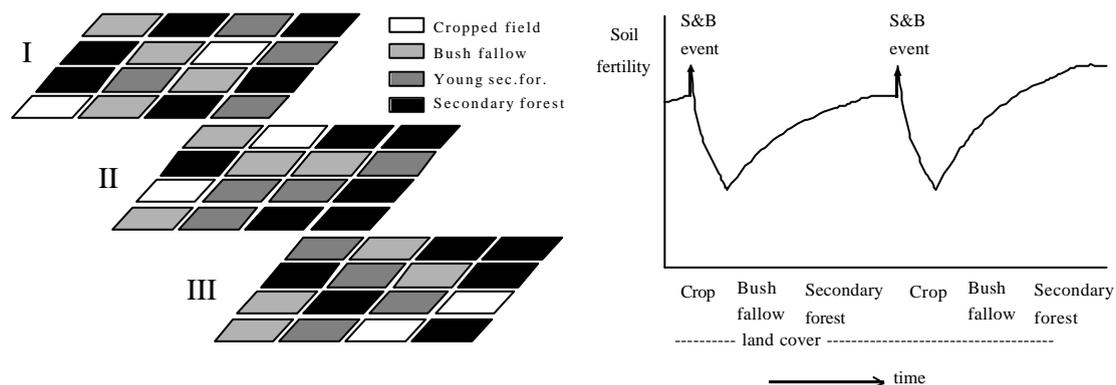


Figure 1. (left) Diagram of the spatial appearance of land cover in a shifting cultivation system at three subsequent time periods; (right) Diagram of soil fertility change in a sequence of land covers that together form the land use system of 'shifting cultivation'. Here the fallow length is sufficient to restore soil fertility and production potential over a complete cycle.

Land cover can be formally defined as the biophysical state of the earth's surface, its vegetation and its immediate subsurface. The term *land use* incorporates in its meaning

both the biophysical attributes of the land over the typical lifespan of a (production) system and the intent underlying that treatment – the human purpose for which land is used.

The word *forest* can be used to indicate both land cover and land use. The original Latin word referred to land outside towns and villages, claimed by the ruler as domain for hunting and exploitation. In Latin, a different word (*silva*) referred to the woody vegetation that we now associate with the English word *forest*. The classification of land as ‘state forest land’ does not really depend on the actual land cover, but more on a function of that land and on assertions of control over that land. For example, in parts of Indonesia we may find that there are more trees on village, non-forest, land than there are (remaining) in what is called ‘state forest’. In daily use *forest* refers to land cover which is dominated by trees, but its meaning also includes stands of completely natural vegetation, monocultural, even-aged plantations, or any type of vegetation within this range. Because *forest* is not a clearly defined term, the words *deforestation*, *reforestation* and *afforestation* also cause a lot of confusion. If we are interested in the environmental, social and economical consequences of forest conversion and land use change in the humid tropics, we need to define these terms. Clarity is especially important if we want to communicate efficiently between disciplines and countries, or if we wish to cross language barriers; the same words may have different connotations and uses in different languages.

Suggested exercises:

- Consider an aerial photograph or satellite image of an area you know. Can you design a system of terminology that allows you to classify every patch (or pixel) on the map as belonging to a land cover type? Could you do the same for different land use types?
- Discuss the meaning and use of various nouns used to denote *forest* in your language/country. Do the terms refer primarily to a land cover type, or to a land use type?

## 1.2 Shifting cultivation as a sequence of land cover types forming a single land use

Natural forests are rich in plant and animal species, but only a few of these are actually edible. Historically, with regard to a hunter-gatherer lifestyle (based on a subsistence economy), the maximum human population density was low in the forest and on the forest margins. Thus many of the remaining hunter-gatherers of the world became specialised suppliers of forest products to the outside world, obtaining a significant share of their dietary requirements through exchange.

The origins of agriculture may lie in the efforts of hunter-gatherer communities to promote the growth and reproduction of desirable plant species. However, the opportunities for such agricultural experimentation are much greater outside a forest. Essentially, agriculture has its roots in clearing forest vegetation to make space for plants (crops) with a higher proportion of edible or otherwise useful products. Slash-and-burn methods are used to clear forest for the creation of agriculture in the humid forest zone.

Many forest plant species are able to regenerate from stumps or seeds after the type of disturbance caused by slash and burn forest clearing; this natural regeneration will compete with the crops that farmers plant. The clearance of vegetation by burning concentrates a large share of the nutrient capital of the forest into the ash and topsoil layer, and crops can use this. However, this source of fertility rapidly declines with time, while the forest regenerates from stump or seed (‘weeds’ from the farmer’s perspective). So, within a few years, farmers find it easier, and more rewarding, to open a new patch of forest, rather than

struggling to cultivate the same patch. From this point on, land cover on the cleared patch develops largely through natural processes of forest regeneration, although the farmer may continue to harvest products from the patch for some time. After 50-100 years, the forest on the previously cleared site may have developed into what is known variously as ‘old-growth’, or ‘high’ or ‘primary forest’. We can thus observe a succession of land cover types which all relate back to an initial clearing of the forest for food crops. Using the example given in Figure 1, depending on the stage at which ‘fallow’ vegetation is next cleared for a further round of cropping, we can classify the sequence of land cover types into three land use types. If the land cover type cleared is secondary forest, we can classify the land use type as “shifting cultivation”. Likewise, if the land cover type cleared is young secondary forest, we can classify the land use type as “long fallow rotation”. Finally, if the land cover type cleared is bush fallow, we can classify the use type as a “short fallow rotation system”. However, after clearing, the subsequent land cover type (i.e. a cropped field) will be the same for all three of these land use types. This last example shows, therefore, that simply identifying a land cover type on a plot at a particular point in time will not allow you to deduce the ‘land use’ of that plot.

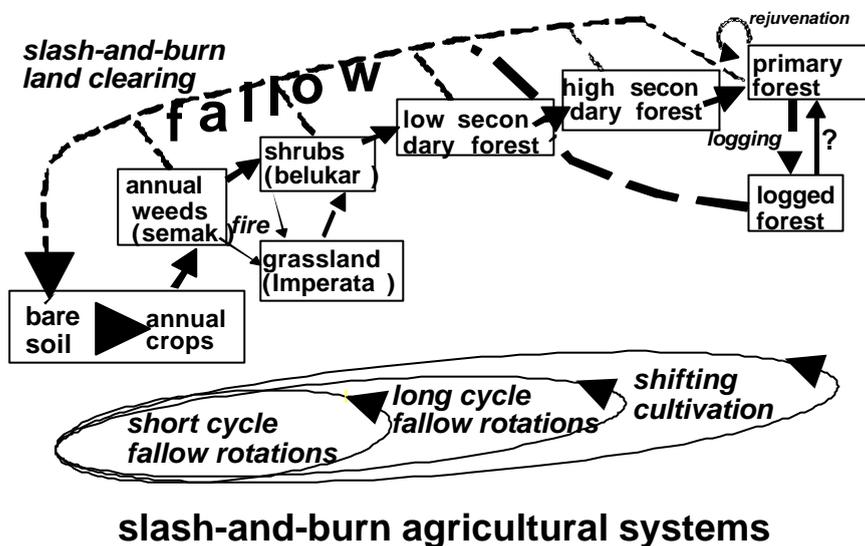


Figure 2. Transitions between land covers as part of fallow rotation systems

As Figure 2 illustrates, succession of vegetation does not necessarily proceed in a linear sequence. When fire is used in the landscape (e.g. for clearing a new plot) it can escape and return nearby fallow land to an earlier open stage. If that happens, there’s a chance that grasses such as *Imperata cylindrica* will take over from the forest regeneration, and that the area will become grassland. Such grasses both increase the likelihood of subsequent fire and depend on fire for their continuation. In short fallow rotation systems the chances of this type of grassland formation increase, as forest regeneration is weakened; tree stumps may not survive under repeated clearing, while the influx of seeds from forest trees is reduced in a more intensively used landscape.

At this point it is worth noting that the term ‘**slash-and-burn**’ is commonly used to describe both a *technique* for land clearance and for a land use *system* (‘slash-and-burn’ agriculture, shifting cultivation). Although we may see that forests are being cleared using a slash-and-burn technique, we cannot know what the subsequent type of land use system will be. The reasons for forest clearance range from extensive food crop production, with gradual recovery of forest functions in the fallow vegetation, to the establishment of permanent pasture, a permanent tree crop monocultural plantation or a planted ‘forest’. In

the following sections we use 'slash and burn' to mean a land clearing technique, and refer to the associated land use practice as crop-fallow rotations or shifting cultivation.

### **1.3 Land use systems and practices in the humid tropics: identification, definition and classification**

In this section, a broad classification system (based on different land covers) will be applied to general land use systems ('meta' land use types). The main features of these will then be described, along with examples of real land use systems in the ASB benchmark areas. Box 1 introduces concepts that explain why land use classifications are important.

#### **Box 1. Why classify land use?**

We classify objects or ideas by grouping similar things together within the same category, isolated from the next word or term by a 'barrier', boundary or definition. Usually, terminology refers to a dimension or axis along which things can be compared; intermediate forms can be recognised once we have identified the words which form the extremes of this ideological axis. Thus, for example, we can describe a wide range of land use systems as intermediate between long-cycle shifting cultivation and permanent cropping, on the basis of the ratio between the length of the crop and the fallow cycle. Names for intermediate systems, such as 'short fallow rotation' can then be defined on the basis of this axis.

In science, the reasons for classification vary. Certainly there exists a desire to sort ideas systematically, allowing ease of access and identification and enhancing our ability to analyse similar things within the same group. In terms of land use, classification involves the identification of the land use systems or practices, and the grouping of those systems or practices with similar characteristics into the same category (categories are thus separated from each other by boundaries of definition). Land use classification becomes necessary when there is a need to analyse certain land use practices and changes in land use and cover, or when we wish to compare similar land use systems and practices. Such classification systems can be tightly structured. Moreover, such a 'tight' classification system can be 'operational', in the sense that it can be used to classify any possible land use system. Having a 'tight' operational definition becomes crucially important if different land uses are to be recognised for purposes of governance, such as land use planning, policy implementation and zoning, legal constructs, tax and subsidy schemes and carbon credit schemes. An example of the need for such a 'tight' classification system is provided by the Kyoto protocol on climate change, which mentioned that 'afforestation' and 'reforestation' may be eligible to receive 'carbon credits'. In the absence of a uniform definition of 'forest' (see lecture note 1, section 2.1; and LULUCF report of IPCC), the terms 'deforestation' and 'reforestation' did not have an operational definition. The distinction between 'afforestation' and 'reforestation' needs a length of time that a piece of land has been 'non-forest', before making it a 'forest' qualifies as 'afforestation'.

However, when trying to impose our classification of discrete land-use types onto reality, it is important to note that no single criterion allows the formation of meaningful classes. Instead, only an 'approximation of the truth' is possible. In this sense, the 'boundaries' created to separate the different land use classes are simply points of reference, and do not necessarily mark either the end or the beginning of one land use class. Thus different land uses do not have distinct borders but can be thought of as having distinct structures and functions.

### 1.3.1 Forest use as a land use system

Human exploitation of forests can be based on above and belowground resources (Figure 3). **Aboveground**, the usual division is between timber and non-timber forest products (NTFPs). NTFPs may be collected in less destructive ways than timber harvesting (logging), although this is not necessarily the case for all products. **Belowground**, we can distinguish between the short term benefits of high soil fertility, after slash-and-burn conversion of forests in a long-fallow rotation, and the value of the deforested land for mining, permanent agriculture, plantations, roads, cities or other non-forest land uses. This latter value may include a speculative element.

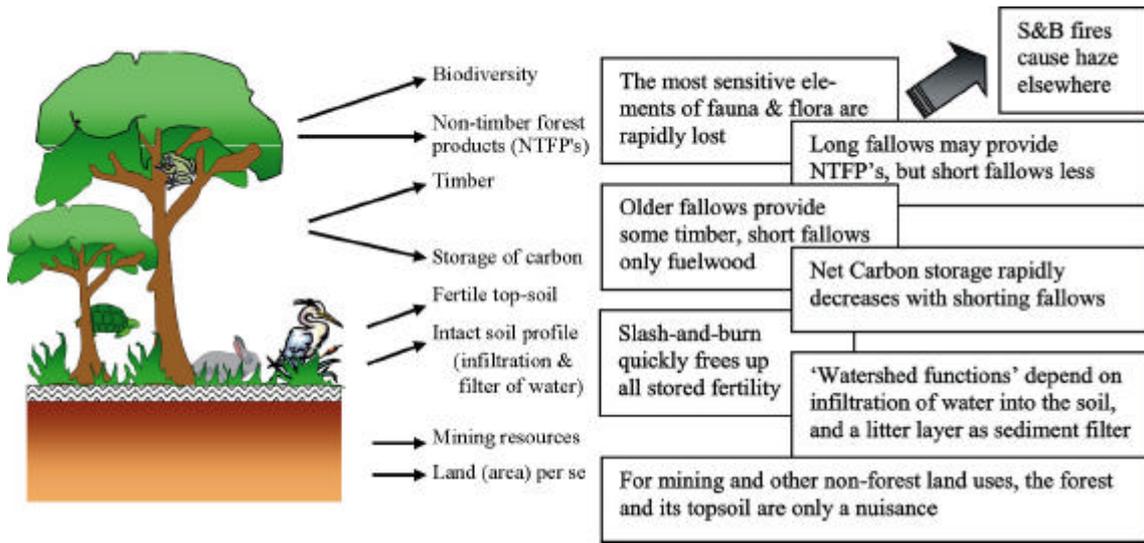


Figure 3. This diagram illustrates the functions forests perform (in terms of the use of trees, soils and the land occupied) with regard to their usefulness to local land users and external groups with vested interests. A conversion from natural forest into forest used for various commercial/agricultural activities (timber, NTFPs or crop-fallow rotations) or permanent conversion to non-forest land uses may be acceptable (or desirable) from some perspectives, but may be undesirable according to other points of view.

There is increasing recognition that, besides their value as a resource for local users and newcomers, forests are of value to the outside world in terms of the conservation of biodiversity, watershed protection and carbon storage. These three 'environmental service functions' refer to the functions of the soil, as well as to the aboveground forest ecosystem.

**Damage done to the forest** ecosystem and its 'environmental service functions' varies depending on the use to which it is put. The collection of NTFPs involves relatively little disturbance, for example. However, such disturbance increases progressively with activities such as logging and conversion into non-forest land uses (short-fallow rotations, long-fallow rotations semi-permanent agriculture or non-agricultural land use). Interactions between these activities are common. For instance, logging roads provide easy access for farmers who may then open the remaining forest using slash-and-burn methods.

*Three broad types of forest use maintain the land as 'forest':*

- $F_n$ : natural forest, kept in its natural state (e.g. in national parks), which allows the conservation of biodiversity and maintenance of high C stocks, and which provides watershed protection functions and other non-material values,
- $F_m$ : community-managed forests that are a source of NTFPs and small amounts of timber for local use,

- **F<sub>1</sub>**: forests used for logging, provided that the system is based on a sustainable harvesting regime with sufficient time allowed for recovery between harvests, and with minimum damage being caused during timber harvesting.

Many other types of forest use do not maintain the land as ‘forest’, for example logging before conversion to an oil palm plantation. This type of forest use exists on a potentially large share of current forest cover, but is treated here as a *transition* to the subsequent land use.

### 1.3.2 Systems primarily based on tree products

We introduced above the concept of the community-managed forest ( $F_m$ ), which is a source of NTFPs and of small amounts of timber. Management systems in such forests often involve the regulation of the intensity of harvests and the overall protection of resources (e.g. rules for grazing intensities). The danger of depletion sometimes looms large, especially where such forest resources can be traded outside the village or community. The first step in the prevention of such depletion is usually some form of regulation within a local community. For example, rules can be developed on how much can be harvested in any given year. The next step should be to safeguard the existing resource and its regeneration over a longer timeframe (Box 2, Figure 4).

#### Box 2. Domesticating forest resources

Wiersum (1997) identified three thresholds in the process of domestication: ‘controlled utilization’ (the separation of open-access from a controlled harvesting regime); ‘purposeful regeneration’ (the separation of dependence on natural regeneration from interventions that generally require control over subsequent utilization) and ‘domestication’ (a movement toward a horticultural or plantation style production system).

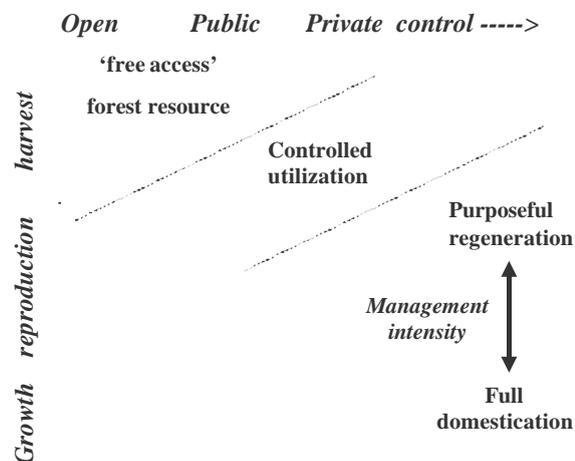


Figure 4. Stages in the ‘domestication’ of forest resources, on the basis on the various types of control (tenure) exerted the land and on the type of control exerted over the reproduction and growth of the plants involved (modified from Wiersum, 1997)

Essentially, farmers living in the forest margin have available to them two methods by which they can increase the density of plant sources for forest products within their environment. The first is to promote the desirable species within an existing forest, by using or creating gaps that allow a desirable tree (or other plants) to grow; the second involves planting tree species in between crop rows in recently cleared gardens, and letting

them grow with the fallow vegetation. This method modifies the fallow, increasing its direct production function rather than its function with respect to the subsequent cropping period. The resulting vegetation typically contains a mix of species planted deliberately, and plants that, though regenerated spontaneously, are nurtured or tolerated by the farmer. After some time, the vegetation will look, and in many ways function, like a forest, but this is a forest made and managed by the farmer, hence the term ‘agroforest’.

There are different types of tree-based systems, which are categorised as ‘systems dependent on tree products’.

**T<sub>e</sub>** Extensive tree production systems, in the form of agroforests (i.e. multistrata, mixed-species systems). Here a substantial proportion of the vegetation comprises spontaneously regenerated secondary forest species. More mature forms may have an uneven age structure, as they allow internal rejuvenation in gaps, rather than a cyclical, field-level renewal of the whole vegetation. The cyclical forms may still contain food crops in the initial years, but the number of years of annual crops is very small in relation to the total length of the whole cycle/rotation (the system has a low R-value; see Box 3). In these systems, the length of the fallow is determined by the economic lifespan of the tree crop, rather than by the need for growing food crops.

**T<sub>m</sub>** Intensified, simple, mixed-tree agroforestry systems. These are dominated by planted species. Examples are coffee and shade trees in plantations of mixed tree species.

**T<sub>s</sub>** Simple, typically monocultural, plantations of even-aged tree crops (typically utilising more purchased inputs and greater capital investment as well as labour). These may be intercropped with food crops in the early stages of rotation.

Suggested exercise and discussion topics:

- List the main tree crops in your area. Which ones are local species, and which ones originate from elsewhere in the tropics? Can the same tree crop be grown using the three types of management intensity (distinguished here as T<sub>e</sub>, T<sub>m</sub>, and T<sub>s</sub>)? If not, why not?
- In Indonesia, farmers describe their ‘agroforests’ as ‘gardens’, emphasising that they are not forest because forest land is claimed by the State. Do you know of equivalent land use systems elsewhere in the world? Does the terminology used to describe those systems refer primarily to a land use, land cover or ownership category?

### 1.3.3 From shifting cultivation to permanent cropping: systems primarily based on annual crops

A simple method used to classify land use systems based primarily on annual crops is founded upon the relative length of the fallow period. Ruthenberg (1976) introduced such a system of classification on the basis of the R-value (Box 3).

**C<sub>e</sub>**: Extensive crop-based systems with an R-value of less than 33%.

**Shifting cultivation** and **long fallow** rotations involve abandoning previously-cropped fields and allowing natural regeneration and succession to occur. If the fallow length is > 25 years, then the vegetation in the field may become high secondary forest, and the system would have an R-value of 7% ( $100 \times 2 / 27 = 7\%$ ; assuming that crops were grown for 2 years). If the fallow length is > 10 years, then the vegetation in the field may become young secondary forest and the system would have an R-value of 17% ( $100 \times 2 / 12 = 17\%$ ).

If the fallow length was even shorter (e.g. 6 years or so, after 3 years of cropping) then the R-value would be higher: 33 % in this case ( $100 \times 3/9 = 33\%$ ).

**Box 3. Ruthenberg's 'R' value  
(Ruthenburg, 1976)**

'R' value is the number of years of annual food crop cultivation expressed as a proportion of the length of the cycle of land utilisation (below). The greater the 'R' value the more intense the land use practice.

$$R = (\text{number of years of cultivation} \times 100) / \text{length of cycle of land utilisation.}$$

The length of the cycle of land utilisation = the sum of the number of years of arable farming + number of fallow years. So, for 2 years of foodcrops, followed by 10 years of fallow,

$$R = (2 \times 100) / (2 + 10) \quad \text{i.e. } 16.7$$

Length of the average fallow period (years) for different values of R, depending on the length of a cropping period (annual crops).

R (%)	Length of a cropping period (years)			
	1	2	3	4
16.7	5	10	15	20
33.3	2	4	6	8
66.7	0.5	1	1.5	2

Terminology as used in this lecture note:

R =	16.7	33.3	66.7
	-----X-----	-----X-----	-----X-----
Shifting cultivation	Long fallow rotation	Short fallow rotation	Permanent cropping

ALSO: If the land use system is in equilibrium and the number of plots opened for growing food crops in any year is constant, we can derive that the fraction of the total area under crops (the land cover classification) equals the R value as well.

Thus: R = proportion of the area under annual crop cultivation as a percentage of the total area available for arable farming

**NB**

- 'R' values for existing land use systems in Sumatra can be found in Table 3.
- The R value does not depend linearly on fallow length i.e. one year cropping and one year fallow gives the same R value as a five years cropping and five years fallow.  
For more information about intensification of fallow systems and the 'R' value, please see the ICRAF-SEA lecture note on Indigenous Fallow Management (Burgers *et al.*, 2000).

**C<sub>m</sub>** and **C<sub>i</sub>**: Involve **medium intensity and intensive short fallow cycles**, with a fallow length of 2-5 years and an R value of 33 – 67%. In the medium intensity class C<sub>m</sub> natural vegetation processes are relied upon for the fallow period; in the more intensive C<sub>i</sub> class, the farmer actively manages the fallow to get vegetation that restores soil fertility more rapidly and hence increases the productivity of the subsequent cropping period.

**C<sub>p</sub>**: Involves permanent cropping or systems with **very short fallow cycles** and an R-value of more than 67%. The crop can be either a perennial (or multi-annual) crop such as

pineapple or sugarcane, or a combination/rotation of shorter-lived annual crops. Further distinctions within this category are based on the type of crop and how the water supply is managed (e.g. technically irrigated or rainfed).

### 1.3.4 Systems primarily based on animal products

A wide range of animals (or their products) can also be harvested as ‘forest products’, including ‘bushmeat’, songbirds, other pets or honey. However, for a variety of reasons, and unlike useful plant species, people have had little success in domesticating forest animals (except for chicken and pigs). Most domestic stock originated in more open environments, and not in forest. Ruminants such as deer can graze early stages of fallow vegetation, and an extensive form of animal husbandry is compatible with a fallow-crop cycle; some tree crops can be combined with grazers as well.

Examples of land use systems dependent on ‘Animal products’ are given below.

**A<sub>e</sub>** Use of spontaneous grassland as a source of fodder, with little effort to increase quantity and/or quality of fodder.

**A<sub>i</sub>** Intensified grassland, managed to provide more and/or higher quality fodder

Of the countries within the humid tropics studied in the ASB project, Brazil is dominated by pastoral farming as a land use system (occupying 22% of agricultural land in 1994), a point which should be contrasted with the dominance of agroforestry and crop farming in Indonesia and Cameroon respectively.

Table 1. Land use systems in the humid tropics and examples that were chosen as their representatives in ASB benchmark areas in Brazil, Cameroon, and Indonesia.

Main products	Land use system	Western Amazon benchmark area in Acre and Rondonia, Brazil	Congo Basin benchmark area in southern Cameroon	Humid lowlands of SE Asia benchmark area in the peneplains of Sumatra, Indonesia
Forest products	F <sub>n</sub> Natural Forest			Natural forest
	F <sub>m</sub> Managed Forests	Small-scale selective logging using low-impact techniques, with some on-farm processing	Community managed forests	Community-based forest management
	F <sub>l</sub> Logged Forests	Commercial logging		Commercial logging (large scale)
Tree crops	T <sub>e</sub> Extensive Agroforests (complex, multistrata agroforestry systems)	Brazil nut and rubber extraction from natural forests (not planted, but actively managed)	<ul style="list-style-type: none"> <li>• Extensive Cocoa agroforests with fruit trees and shade trees</li> <li>• Extensive Cocoa agroforests with shade trees, no fruit trees</li> </ul>	Rubber agroforests planted with rubber seedlings

Main products	Land use system	Western Amazon benchmark area in Acre and Rondonia, Brazil	Congo Basin benchmark area in southern Cameroon	Humid lowlands of SE Asia benchmark area in the peneplains of Sumatra, Indonesia
	T <sub>m</sub> Intensive Agroforestry	Cupuacu, Brazil nut, peach palm and mahogany	<ul style="list-style-type: none"> <li>• Intensified Cocoa agroforests with fruit trees and shade trees</li> <li>• Intensified cocoa agroforests, with shade trees, no fruit trees</li> </ul>	Intensified rubber agroforests planted with PB 260 clonal rubber
	T <sub>s</sub> Simple, intensive treecrop systems	Coffee mixed with rubber or bandarra (a fast-growing timber tree species).	<ul style="list-style-type: none"> <li>• Hybrid oil palm monoculture (small-holders), short fallow</li> <li>• Hybrid oil palm monoculture, long fallow</li> </ul>	<ul style="list-style-type: none"> <li>• Hybrid oil palm monoculture (large-scale enterprise)</li> <li>• Rubber monoculture (smallholders)</li> </ul>
Annual crops	C <sub>e</sub> Extensive crop / long fallow systems		Mixed fields of melonseed, plantains, maize and cocoyams with fallow rotation of 15 years (R=2/17=0.12)	Upland rice (2 years) with fallow rotation of 10 years or more
	C <sub>m</sub> Medium intensity, Crop / short fallow systems	2-year annual production followed by 2- to 5-year fallow	Mixed fields of groundnuts, cassava, cocoyams, maize, leafy vegetables, and plantains with fallow rotation of 4 years (R=1.5/5.5)	Upland rice with fallow rotation of 3-5 years
	C <sub>i</sub> Intensive, crop / short fallow systems	Legume-based or nitrogen-fixing tree-based fallows 2-5 years		
	C <sub>p</sub> Continuous annual cropping systems			Monoculture cassava (often degrading to <i>Imperata cylindrica</i> )
Animal products	A <sub>e</sub> Pasture / Grasslands	Grass-based pastures, no internal fencing or management		<i>Imperata cylindrica</i>
	A <sub>i</sub> Intensive Pasture	Legume-based pastures with internal fencing and management		

#### 1.4 Intensification and relationships between the four large groups of land use systems

The higher the percentage of an area cultivated annually, in relation to the total area available, the more stationary the farming practice becomes. This happens when the fallow period is shortened in favour of cultivation, so that the R-value reaches or exceeds the value of 33 %. Thus, the system-type changes, from shifting cultivation to either a

more stationary form of cultivation (with fallow) or to a form of semi-permanent cultivation. This is the process of land use intensification. The ASB hypothesis is based on land use intensification and can be summarised as

*intensifying land use as an alternative to slash-and-burn, can simultaneously reduce deforestation and poverty by providing higher yields per unit area of converted forest and by absorbing more labour.*

We can visualize the four broad groups of land use systems described above (Table 1) as a ‘tree’, with a common stem and ‘branches’ reaching out in different directions (Figure 5). Within each ‘meta’ land use system a number of sub-classes are to be found (see section 1.3). The links between the branches and the stem of the tree can be illustrated as follows: forests managed for local forest products ( $F_m$ ) can be thought of as a starting point for the agroforest-tree-crop gradient, but can also be the long-fallow point of an intensification gradient based on annual crops.

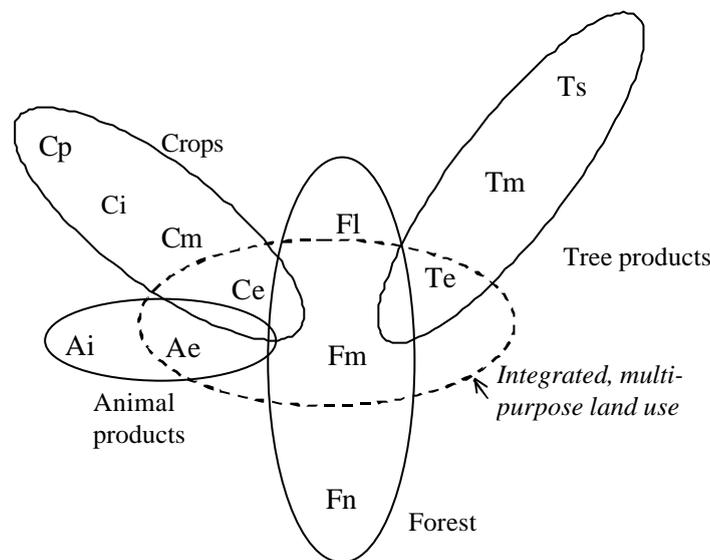


Figure 5. Four ‘meta’ land use systems based individually on forest (F), tree crop (T), crop (C) and animal production (A) systems.

Within each of the branches of this tree (meta land use systems, Figure 5) an ‘intensification gradient’ can be distinguished, with the most intensive forms of land use being found at the ends of the branches. There is a higher use of total factor inputs (land, labour, external inputs, capital) in these systems, which are intended to secure a higher output. Across the tree as a whole, however, it is more difficult to judge ‘intensification’, as the R value can not be used here; intensification can still be defined as an increase in ‘total factor’ inputs, that include capital and labour. In the center of the diagram we find extensive crop, tree product and animal based systems which, when considered as separate entities, appear to be low-intensity forms of land use. However, within the area marked by a dotted line in Figure 5, there can be a large overlap between these systems. The overlap can indicate that similar products can be obtained from the different systems (e.g. NTFPs) and functions are interchangeable (e.g. animals may be grazed in any of the systems within that area in Figure 5). Thus the overall intensity of land use in these systems may be medium to high, due to their multiple functions and multiple outputs.

Examples of the local representatives of the ‘meta’ land use systems chosen for study by the ASB project can be found, for reference, in Table 1.

## 2. Land use change and the ASB evaluation matrix

### 2.1 From land use to natural resource management system

The transition from 'land cover' to 'land use system' is useful for purposes of stratified sampling, data interpretation and representation, but we have to always keep in mind that the farmers may not perceive the systems or the consequences of all their decisions in the same way. A conceptual diagram (Figure. 6) shows how farmers' choices to 'use, extract and exploit' and/or to 'care for and plant' influence the landscape, with consequences for profitability as well as biodiversity, C-stocks and watershed functions. Farmers' choices are themselves influenced by the knowledge/information available to them, by market supply and demand, by push and pull factors affecting migration, and by the positive and negative incentives that are provided through the institutional framework in which the farmers operate. Overall the impact of institutions which form the framework may be sub-optimal. Indeed, this is probably an understatement as such a frame work consists of many conflicting and overlapping elements. Local institutions for credit, market access or land tenure can often be a bottleneck to development. Shown in the diagram below (Figure 6.) are a number of feedback loops that may influence farmers' decisions. The opportunities for 'use' and for 'local environmental functions' depend upon the efforts made to 'care and plant'. Institutions can modify the incentives perceived by farmers, migration decisions and market access. The knowledge that farmers derive from the actual performance of the land use system and that can be passed on within the local community forms a major feedback to the subsequent choices and decisions of farmers. These feedback loops may qualify as a 'land use system' to an outside observer. External impacts of land use on environmental functions can lead to various 'actions' to change the local institutions. This last feedback loop, (which may lead to a modification of institutions via stakeholder actions) represents a higher level 'system', that can be indicated as a *natural resource management system*.

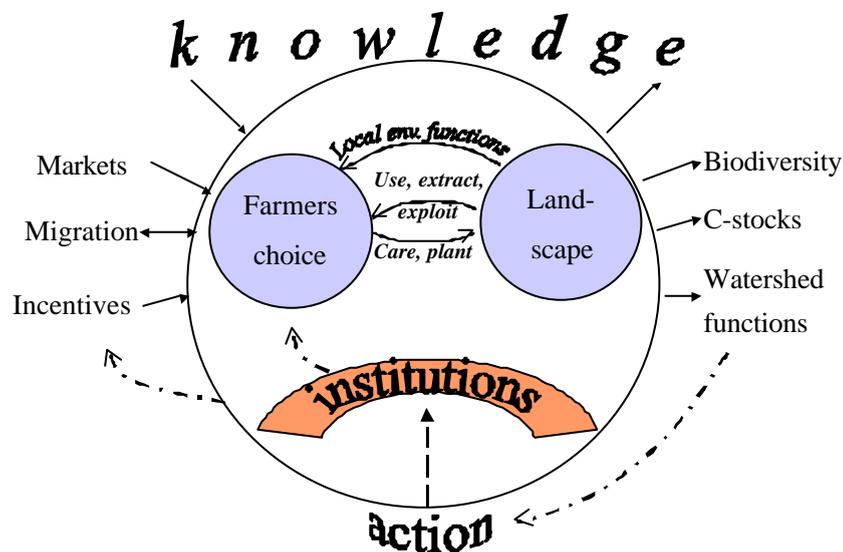


Figure 6. Schematic view of farmers' decisions, the factors influencing these decisions and the effects they have on the landscape.

In lecture notes 4-7 we will consider the processes used to understand and quantify the varied effects land use patterns have on natural resources. In lecture notes 3, 8 and 9 we will consider elements of farmers' decision-making processes, and in lecture note 12 we will explore how the effects that institutions have upon the 'natural resource management system' can be understood and improved.

## 2.2 What is the effect of forest conversion on biodiversity, stored carbon, filter functions, and watersheds?

Loss of natural forest, through the conversion of forest lands to other land uses, leads, regardless of the techniques used for land clearance, to a loss of *biodiversity* and to the destruction of what should be considered the largest living ‘museum of natural history’. Forest conversion unfortunately relegates a large number of plants, animals and microorganisms to history, often before we know their properties and values. These issues are discussed in detail in lecture notes 5 and 6.

Conversion of forests, by whatever means, also releases large amounts of *stored carbon* into the atmosphere, and thus increases the rates of global warming and climate change, which are primarily a result of the use of fossil fuels (see lecture note 4).

The only real alternative to slash-and-burn, with respect to these two problems, is to ‘leave the forest a forest’, making sure that all who might use such a technique have the option of earning their livelihood in a more attractive manner.

The conversion of forests can also reduce their *filter functions*, which regulate the flow of *water and sediment* across a landscape; this can increase the chances of flash floods and landslides, and can reduce the quality of the water on which users downstream depend.

The severity of these problems depends on where, when and how forests become the subject of more intensive land use practices. It is clear, however, that if there are no relevant policies in place, or if policies contradict each other<sup>1</sup>, local farmers, new migrants to the forest margin, and plantation companies will continue their slash-and-burn practices. The importance of policy research is considered in lecture note 11.

## 2.3 The ASB evaluation matrix

The central task of the ASB research program is to identify those land use systems which have the best chance of fulfilling multiple environmental, agronomic, socioeconomic, and policy objectives, and to quantify any tradeoffs that exist among these objectives. Measurement of field-level differences in 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 amongst 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 definition implies that such a use alternative will make a significant contribution to each of the broad sets of criteria discussed above, with regard to global environment, agronomic sustainability, smallholders’ concerns, and policymakers’ objectives.

A general matrix format was developed (Tomich *et al.*, 1998) as an alternative to the futile quest for a single indicator. This matrix is a framework used to organise 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 Table 2. The columns, within the Table illustrating this matrix, are the general classes of criteria discussed above. The rows are the

---

<sup>1</sup> e.g. policies aimed at reducing smoke haze may be ineffective if other policies result in the government issuing licenses to companies for large scale conversion of forest land to oil palm plantations.

four ‘meta’ land uses that were selected for global comparisons across ASB study sites. These rows correspond to specific land uses found in Table 1.

Table 2. The ASB matrix: a framework for the evaluation of land use options from a broad range of stakeholder perspectives

‘Meta’ Land use option (see table 1)	Global environmental concerns	Agronomic sustainability	Smallholders’ socio-economic concerns	Policy and institutional issues
Forest products				
Tree crops				
Crops (annual)				
Animal products				

### 3. Sampling Strategy

#### 3.1 Sampling land cover types as part of land use systems

In order to evaluate the land use systems from this broad range of stakeholder perspectives, we need a ‘tight’ operational definition that identifies where we should sample. Such a definition requires decisions to be made regarding how broad a spectrum of variation we wish to consider in the measurements within each type. The broader the range, the fuzzier our data sets may be; the narrower the range the less representative they may be outside the specific benchmark areas. Such a definition also means that we have to specify the exact sequence of stages (land covers) that, combined, form the land use system (see, for example, Table 3). For assessments of C stocks, biodiversity, profitability and the like, we will need to integrate the measured values over the various stages of the land use system, as will be explained in more detail in subsequent lecture notes.

The various aspects of a particular land use system should be measured on the same sites. We may otherwise end up with, for example, biodiversity data from the most extensive forms of the system far from the village or road, and profitability assessments for the more intensively managed forms close to the village or road, which would bias the assessment of tradeoffs.

Studies on the impacts of land use, like many earth and social sciences, have to be observational rather than based on designed experiments with independent replication. Nevertheless, alternative explanations for various phenomena, and for their variation over time and space, can be assessed and hypotheses (‘models’) can be tested and rejected. However, what is the source of random variation in the spatial, and/or temporal, models proposed? A range of statistical methods is available which can help overcome these problems, for example stratified random sampling, systematic sampling, cluster analysis and geostatistics. For further information on the use of statistics and on sampling, please see the very useful and accessible (on-line) series of guideline booklets by the Statistical Services Centre, UK (Statistical Services Centre, 2001).

Table 3. 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 <sub>h</sub>																
Rubber monoculture	0.08	NF LF	UR CR	UR CR	CR	CR	CR	CR	CR <sub>h</sub>																		
Oil palm monoculture	0	NF LF	OP	OP	OP <sub>h</sub>																						
Industrial timber monoculture	0	NF LF	IT	IT	IT	IT	IT	IT	IT	IT <sub>h</sub>	IT	IT <sub>h</sub>	IT	IT <sub>h</sub>													
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 <i>Imperata cylindrica</i>	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 (see Box 1 for further explanation)

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

In the ASB benchmark areas, stratified sampling within each benchmark area was used as a sampling procedure, based on recognised strata that were defined beforehand. The criteria for each stratum can be found in Table 4. In practice we selected representative local villages where the relevant, identified, land use practices occurred; social, economic, and environmental attributes could then be assessed. In each village, group interviews were conducted and a number of households were chosen using random sampling, and household surveys were conducted within the samples chosen.

**Exercise:**

What other sampling schemes can you suggest which could be used to carry out similar research? What are the advantages and disadvantages of choosing such sample schemes?

## 3.2 Sampling within the ASB project

### 3.2.1 Indonesia

The land use systems shown in Table 4, are those selected for the ASB study. However, this is by no means an exhaustive list of land uses in Sumatra's peneplains. For instance, there are countless complex, multi-strata 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 in portions of Kalimantan. Similarly, rubber, oil palm, and timber monoculture are not the only simple tree crop systems, however they are the most extensively used examples of such a 'land use system' category.

### 3.2.2 Specifications for major land use practices at the forest margins in southern Cameroon

NB This section is adapted from Ericksen, P. (2000)

*The land use alternatives considered, their distinguishing characteristics and the assumptions made for the purposes of analysis:*

#### 1. Intensive cocoa with mixed fruit tree shade canopy

The level of management, and the use of fungicides and insecticides in this cocoa production system are high. Such systems are found in southern Cameroon. They tend to be in areas of more pronounced land pressures and are associated with good market access. A description of this and other cocoa agroforests can be found in Duguma and Gockowski (1998) and Gockowski and Dury (1999). The cocoa shade canopy includes a productive component of fruit trees composed of avocado, mango, African prune (*Dacryodes edulis*), and mandarin oranges. Cocoa yields are typically around 500 kg ha<sup>-1</sup> at maturity and total fruit off-take is around 920 kg ha<sup>-1</sup>. The system is often established in a *Chromolaena odorata* fallow, with intercropping of groundnuts, maize, leafy vegetables, plantains and cocoyams during the first few years of establishment. Another variant of the system is recognised and taken into account when sampling, namely a system where fruit trees are not a commercial component due to limited market access<sup>2</sup> (see Table 1).

---

<sup>2</sup> It was pointed out, during a country working group discussion, that although fruit trees are almost always a component of cocoa agroforests, it is only in areas with easy market access that they assume commercial importance. This is due to the relatively bulky nature of fruit and low value to weight ratio.

Table 4. Specifications for major land uses at the forest margin of the penneplains of Sumatra, Indonesia

<b>Main products</b>	<b>Land use system</b>	<b>Corresponding land use in lowland Sumatra</b>	<b>Type / scale of operation</b>	<b>Landscape mosaic context</b>	<b>Description</b>
Forest products	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.
	Managed forest	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.
	Logged forest	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.
Tree crops	Extensive agroforests (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.
	Intensive agroforests	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.

Main products	Land use system	Corresponding land use in lowland Sumatra	Type / scale of operation	Landscape mosaic context	Description
	Simple intensive treecrop systems	Rubber monoculture	Smallholders' plots of 1-5 ha	Indigenous smallholder landscape	(Former) 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.
		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 falcataria</i> ).
Annual crops	Crop / long fallow systems	Upland rice / bush fallow rotation (shifting cultivation). Upland rice with fallow rotation of 10 years or more	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 is 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.
	Crop/short fallow systems	Upland rice with fallow rotation of 3 – 5 years			
	Continuous annual cropping systems (crops and grasslands)	Monoculture cassava degrading to <i>Imperata cylindrica</i> grassland	Smallholders' plots of 1-2 ha within large-scale settlement projects	Large transmigration project divided into small plots	Reference point: monocrop cassava with little use of purchased inputs. (See the land cover Table [3] for pattern.) Reference point: monocrop cassava with intensive use of purchased inputs.

## 2. Extensive cocoa with mixed fruit tree shade canopy

This extensive cocoa production system is more characteristic of the less populated areas of the benchmark. These are, however, characterised by relatively good market access.<sup>3</sup> Fruit tree composition and use are similar to (1) above. Fungicide use was assumed to be 50% of the intensive cocoa systems with no control of capsid bugs.<sup>4</sup> Cocoa yields are typically around 265 kg ha<sup>-1</sup> at maturity and total fruit offtake is around 920 kg ha<sup>-1</sup>. This system is usually established on forested land or on a long fallow with intercropping of plantain, cocoyam and melonseed during the first three years of establishment. Again, another variant of this system is recognised in which fruit trees are not a commercial component due to limited market access.

## 3. Improved *Tenera* hybrid oil palm systems

The hybrid *Tenera* variety of oil palm is produced in a monoculture at a planting density of around 143 trees ha<sup>-1</sup>. Two variants of the system are recognised for the purposes of sampling. The first encompasses systems established after *Chromolaena odorata* fallows, with intercropping of groundnuts, maize, leafy vegetables, and cocoyams often practised during the first year of establishment; the second includes systems established in land converted from forest, with inter-cropping of plantain, cocoyam and melonseed during the first two years of oil palm establishment. Yields in the latter system are often slightly higher than in the former.

## 4. Community-managed forest.

The concept of community forests in the forest margins benchmark is amorphous, although a statutory definition is currently evolving following the 1994 Forestry Law act. This defined a procedure through which communities can gain legal tenure to forest tracts of 5,000 ha. Such a tenure agreement permits a community to legally harvest and sell timber. It is currently illegal for a farmer to cut down and sell timber growing on his land even if he has legal title to the land. He may, however, harvest it for his own construction purposes. Another concept of community forest is found in the community's dependence on the common property resources in forested land for its livelihood, by harvesting wild fruits, honey, building materials, rattan, fish, game, and medicinal plants.

The perennial *alternatives to slash-and-burn* systems discussed above were compared with the two predominant annual food crop systems:

## 5. An intercropped food field planted in a short fallow.

This is the typical mixed food crop system of southern Cameroon, and is managed by women. The chief role of this crop system is to feed the household by marketing food surpluses, a role which is increasing in importance as market access improves. Surplus revenues tend to be controlled by women. The two dominant crops are groundnuts and cassava. Other crops that are often associated with this system, though at lower densities, include cocoyams (*Xanthosoma sagittifolium*), maize, leafy vegetables (*Solanum nigrum* complex, *Corchorus spp.*) and plantains (for purposes of analysis). Fields are often converted from *Chromolaena odorata* fallows.

---

<sup>3</sup> Many producers with more intensive systems shifted to these more extensive types of systems when cocoa prices collapsed in 1989.

<sup>4</sup> The two major agronomic constraints for cocoa production in southern Cameroon are cocoa blackpod disease (caused by *Phytophthora megakarya*) and capsids (plant sucking bugs belonging to the family *Miridae*); without control, they typically reduce yields by more than 50%.

6. An intercropped food field planted after a long fallow.

Melonseed (*Cucumeropsis mannii*), plantain, maize and cocoyam are planted into fields that have been left fallow, often for around 15 years. Although both male and female labour is used in this field system, the cash income from this field tends to be controlled by men. This field type became a major commercial alternative for cocoa farmers when cocoa prices collapsed in 1989.

Together, the two latter cropping systems account for an estimated 75% of all annual and biennial cropland in the benchmark area (Gockowski *et al.* 1998a).

There are several other important land use systems that were not evaluated by ASB Cameroon. These include shaded *robusta* coffee systems, industrial plantations of oil palm and rubber, horticultural cropping systems, and various inland valley food-crop systems.

### 3.2.3 Classification of land use systems in Acre (AC) and Rondonia (RO), Western Brazil

Table 5. Land use systems in the ASB Brazil benchmark sites

Main products	Land use system	Description*
FOREST PRODUCTS	Natural forest (AC)	
	Managed forest (AC)	
Tree products	Coffee/rubber (RO)	
	Coffee/Bandarra (fast growing timber species) (RO)	
ANIMAL PRODUCTS	Traditional pasture (AC)	
	Improved pasture (AC)	
CROP SYSTEMS	Annual fallow (AC)	
	Improved fallow (AC)	

\* This Table is based on an evaluation of agricultural intensification in western Brazil (Acre and Rondonia) given by Vosti *et al.* (in press).

## Summary

- Land use systems can be classified according to different methods, depending on the needs and objectives of the research. The ASB project used Ruthenberg's 'length of fallow cycles' method. In this case, a distinction was drawn between land use systems and land use practices that define land use systems as a 'broad set' within which land use practices are 'sub-sets'. Such a distinction was drawn for functional purposes and may differ for other research projects.
- For the selection of a sample area and sampling scheme, characterisation and diagnostic data for the different land use practices is needed (see lecture note 1). From this information, the most representative land use practices within each land use system were chosen for analysis
- After the selection of a 'sample area,' a sampling scheme was developed (e.g. 'stratified random sampling'). This dictated how households representing the different land use practices should be chosen for interview.

### III. Introduction to the ASB benchmark areas

This section provides background information on the different ASB benchmark areas and gives descriptions of the main land use practices. It is meant as a background for the specific sampling results discussed in Lecture notes 3 – 8.

This section utilises the ASB ‘Characterisation and Diagnosis’ exercise (Lecture note 1), which identifies both the different biophysical and socio-economic conditions of the chosen sites and, relative to land use practices, the different stakeholders.

#### 1. Sumatra

NB this section contains excerpts from van Noordwijk *et al.* (1995) and Tomich *et al.* (1998).

##### 1.1 Overview

The global ASB project identified the island of Sumatra as representative of the **lowland humid tropical forest zone in Asia**. Within Sumatra, five major agro-ecological zones (Map 1) were identified, with boundaries running from NW to SE and approximately parallel to the coast. These include:

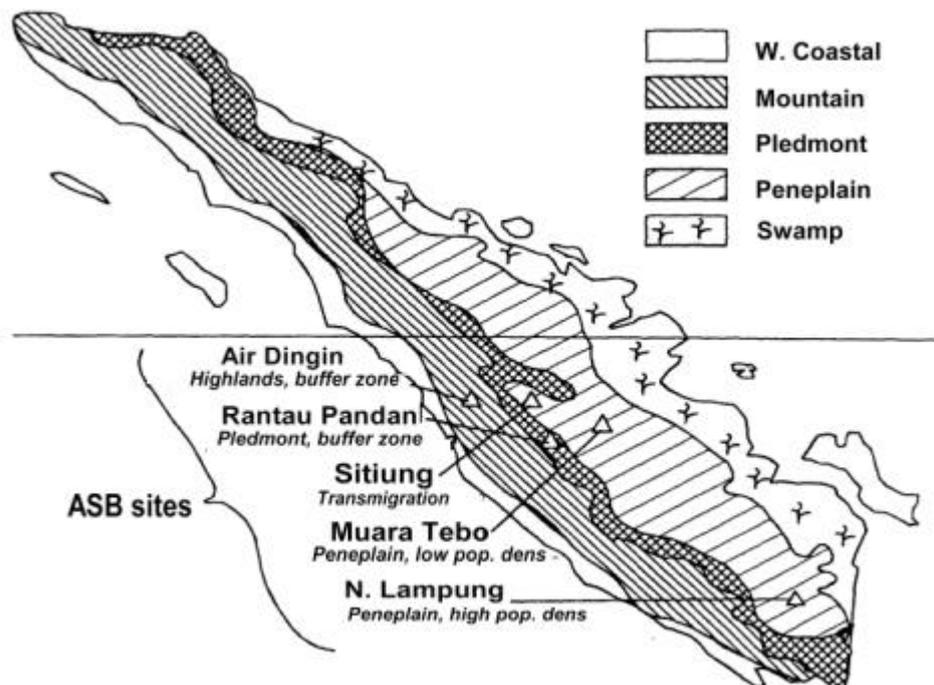
1. A narrow western coastal zone,
2. A mountain zone, dominated by andosols and latosols of reasonable to high soil fertility
3. A narrow piedmont (foothill) zone, constituting the lower slopes of the mountain range on the NE side and dominated by latosols and red-yellow podzolics;
4. A broad peneplain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

Within Sumatra there exists a clear gradient in population density, ranging 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 plain, mountain zone, and the piedmont have been inhabited for long periods of time. Historically, the peneplains were sparsely inhabited, with the human population concentrated along the riverbanks on relatively favorable sites. With the advent of rubber a century ago, the 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 (transmigration), large-scale logging, and various large-scale public and private land development projects since the 1970s.

Because of these activities, most of the remaining fragments of lowland tropical rainforest are in the piedmont zone; 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 the conservation of the remaining rainforests in Asia.

To assess how well ASB's Sumatran research sites in Jambi and Lampung represent the 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. This combined 7 biophysical variables, which spanned ranges of precipitation, temperature, evapotranspiration, and altitude. The results for Asia indicate a high degree of similarity between the ASB sites in the penneplains 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.



Map 1. Agroecological zones of Sumatra

The Sumatran sites, and Indonesia's Outer Islands more generally, are distinctive among ASB study areas because of the intense competition for land which exists between smallholders and large-scale operators. This dualism in the type and scale of operations is central to an assessment of 'best bet' land use alternatives in Indonesia (it is also 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 considered in 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. However, we stress that this presumption is questionable. To study the issue of scale, paired comparisons of smallholder and large-scale land use alternatives were included in the research design for both forest extraction (which contrasted community-based forest management with large-scale commercial logging) and simple treecrop systems (which contrasted smallholder rubber monoculture with large-scale oil palm and industrial timber monoculture). There are no large-scale systems, which correspond to complex, multistrata agroforestry, crop/fallow systems, or continuous annual crops.

The dualism obvious in the scale of these operations produces an important distinction, in the context of **landscape mosaic**, between the ecological functions of an indigenous smallholder landscape mosaic and the landscape produced by large-scale plantation monoculture. Table 4 (above) shows the corresponding land use systems in Sumatra, and also provides information on two characteristics of Sumatran systems (type/scale of operation and landscape mosaic) that are particularly important in Indonesia.

Slash-and-burn is the most common method used for land clearance and is applied to a large range of forest types by a range of land users, leading to a range of new land use systems (indicated by solid arrows in Figure 7). The use of 'slash-and-burn' to convert natural forest into temporary food-crop based land use systems is **not** the most common conversion system. Most common is the conversion from forest to 'tree-crops', such as rubber and oil palm plantations.

Agroforests are initiated using the slash-and-burn clearance of forest/existing agroforests and the intercropping of upland foodcrops. However, the primary objective of slash-and-burn is the establishment of tree-crops, like rubber, and of various fruit and timber species. Although created by local people, this management system accommodates natural regeneration. As a result, agroforests replicate certain elements of forest structure and ecology (Michon and de Foresta, 1995). These agroforests are included as one of the major alternatives to unsustainable slash-and-burn agriculture in Sumatra (Figure 8).

Slash-and-burn methods are also used for converting logged-over forests into tree crop (oil palm) plantations, industrial timber estates or (typically crop-based) government re-settlement (transmigration) schemes (Figure 8). Logged-over forests are supposed to be allowed to regenerate. However in practice, as is the case in Sumatra, large areas have been converted to other land uses based on (local) government plans. A substantial part of the remaining logged forests have been converted by spontaneous migrants, usually into rubber gardens. The negative sloping diagonal in Figure 8 shows the various types of 'shifting cultivation', 'long rotation fallow' and 'short rotation fallow', where forest or shrub land is opened to grow food crops.

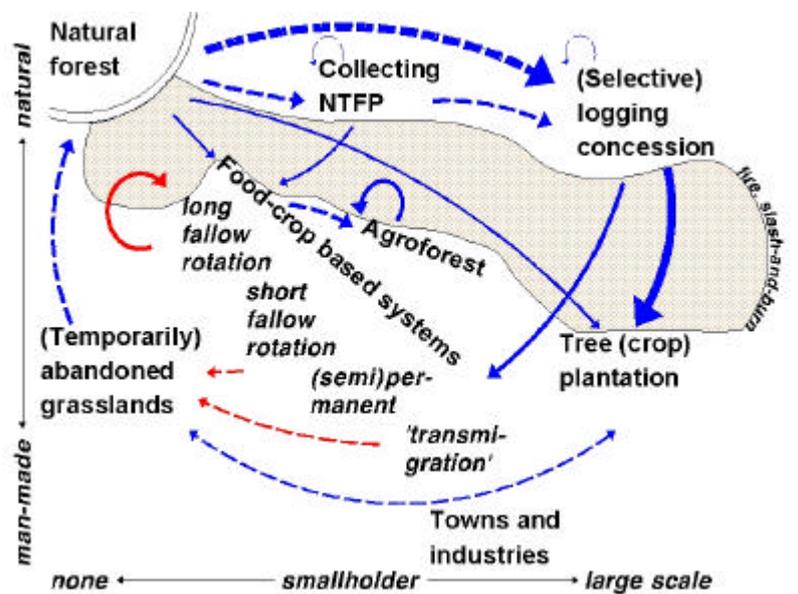


Figure 7. The transformation of forest soils to other land use types, as found in Sumatra. All transformations in the shaded areas use '**slash-and-burn**' as a method for land clearance; the '**agroforests**' are the major farmer-developed alternative to slash-and-burn based food crop production systems (Van Noordwijk et al., 1998).

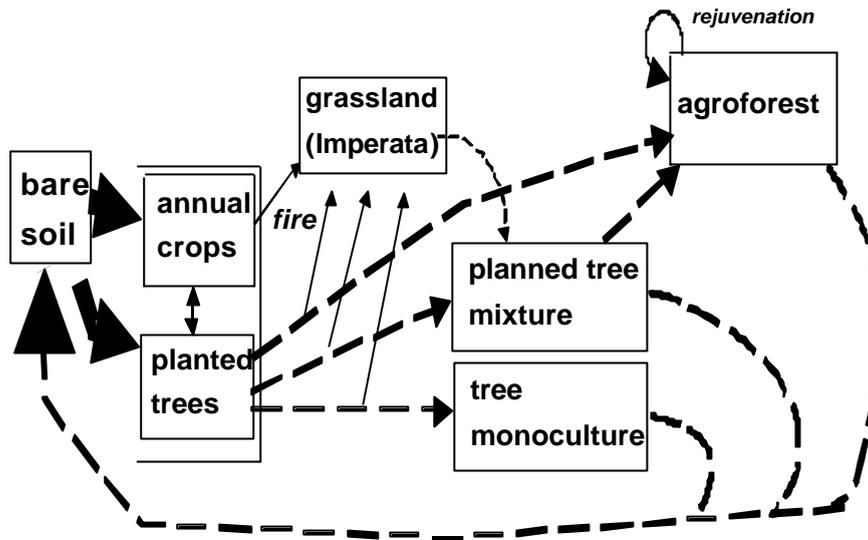


Figure 8. Land use systems that are alternatives to traditional slash-and-burn systems

## 1.2 Farmer-developed agroforestry systems in Sumatra

In the past, the main agroforestry system used in SE Asia was a form of 'shifting cultivation' in which fallow periods helped restore soil fertility depleted during cropping years. The system still exists in parts of Indonesia, but in other parts of the country more intensive cropping or agroforestry systems have already replaced it. Figure 9 demonstrates that in most of Sumatra the dependence on 'shifting cultivation' or 'swidden' systems dropped rapidly in the period 1900 - 1930. This drop was largely caused by the introduction of 'Para' rubber (*Hevea brasiliensis*) to SE Asia from Brazil. Tapping latex from planted *Hevea* trees became far more attractive than the traditional practice of collecting latex from a considerable range of species that occurred naturally in primary and secondary forest in the lowlands. Furthermore, the *Hevea* tree, as a 'secondary forest' species, could, once planted in rice fields, compete with the natural forest regrowth of a forest fallow. The value of the rubber produced by this crop rapidly transformed the land use system from one dominated by upland rice, with secondary products derived from the forest fallow, to one dominated by rubber with secondary forest and upland rice as a secondary element in the first 1 or 2 years, partly repaying the cost of the establishment and guarding of the plot.

One of the incentives for establishing extensively managed 'rubber agroforests' was that, according to local rules and tradition ('adat'), the household that plants trees could claim full land use rights (or 'ownership') of that land. This provided an incentive to rapidly transform the landscape, which previously consisted of various stages of secondary forest succession on the more accessible lands close to the rivers, into rubber agroforestry.

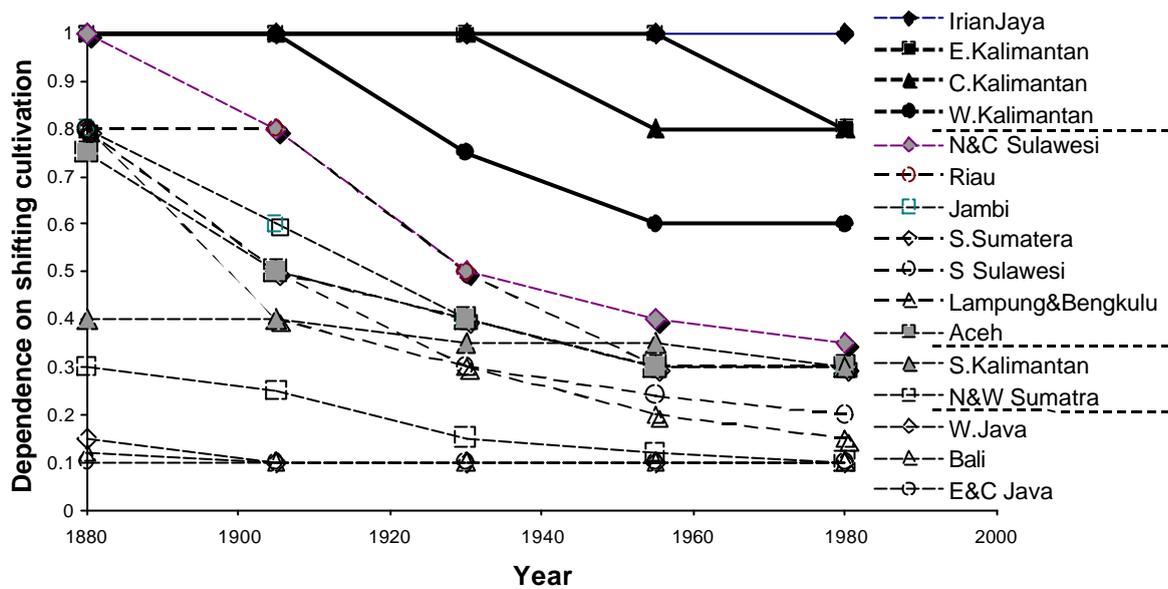


Figure 9 Historical transition from shifting cultivation to permanent agriculture for different provinces of Indonesia (Richards and Flint, 1993, cited in van Noordwijk *et al.* (1995).

### 1.3 Land use change in the Jambi benchmark areas

The two benchmark areas in Jambi (the lowland peneplain site of Pelepat and the piedmont site of Rantauandandan) differ substantially in the amount of land use change which occurred in the period 1982-1996 (see figure 10). In the lowland, peneplain road development, transmigration and oil palm plantations caused a radical change in the landscape, whilst in Rantauandandan a more gradual intensification took place.

## 2. Cameroon

In the Congo basin (composed of Congo–Brazzaville, the Democratic Republic of Congo, Gabon, CAR, Equatorial Guinea and Cameroon), most deforestation can be attributed to smallholder agriculturalists using extensive slash-and-burn. The main land use system is a crop/short fallow system, while the major land use practice is groundnut/cassava-based mixed food fields.

NB the following sections are adapted from Ericksen P. (2000).

### 2.1 The biophysical context of the Forest Margins Benchmark of southern Cameroon

ASB technological interventions and policy recommendations for the Congo basin are based on research conducted in the forest margins benchmark area of southern Cameroon (Figure 10). Covering 1.54 M ha, the benchmark spans a gradient of population density and also encompasses significant spatial variation in market access, soils and climate. For the purposes of the report's analysis, three blocks of the benchmark are distinguished and can be ordinally ranked (high to low) with respect to intensity of resource use; these blocks are, respectively, the Yaoundé block, the Mbalmayo block and the Ebolowa block. The range of socio-economic and biophysical conditions in the benchmark permit the study and targeting of short, medium and long fallow agricultural systems over areas with population densities ranging from 4 to 100 persons km<sup>-2</sup>.

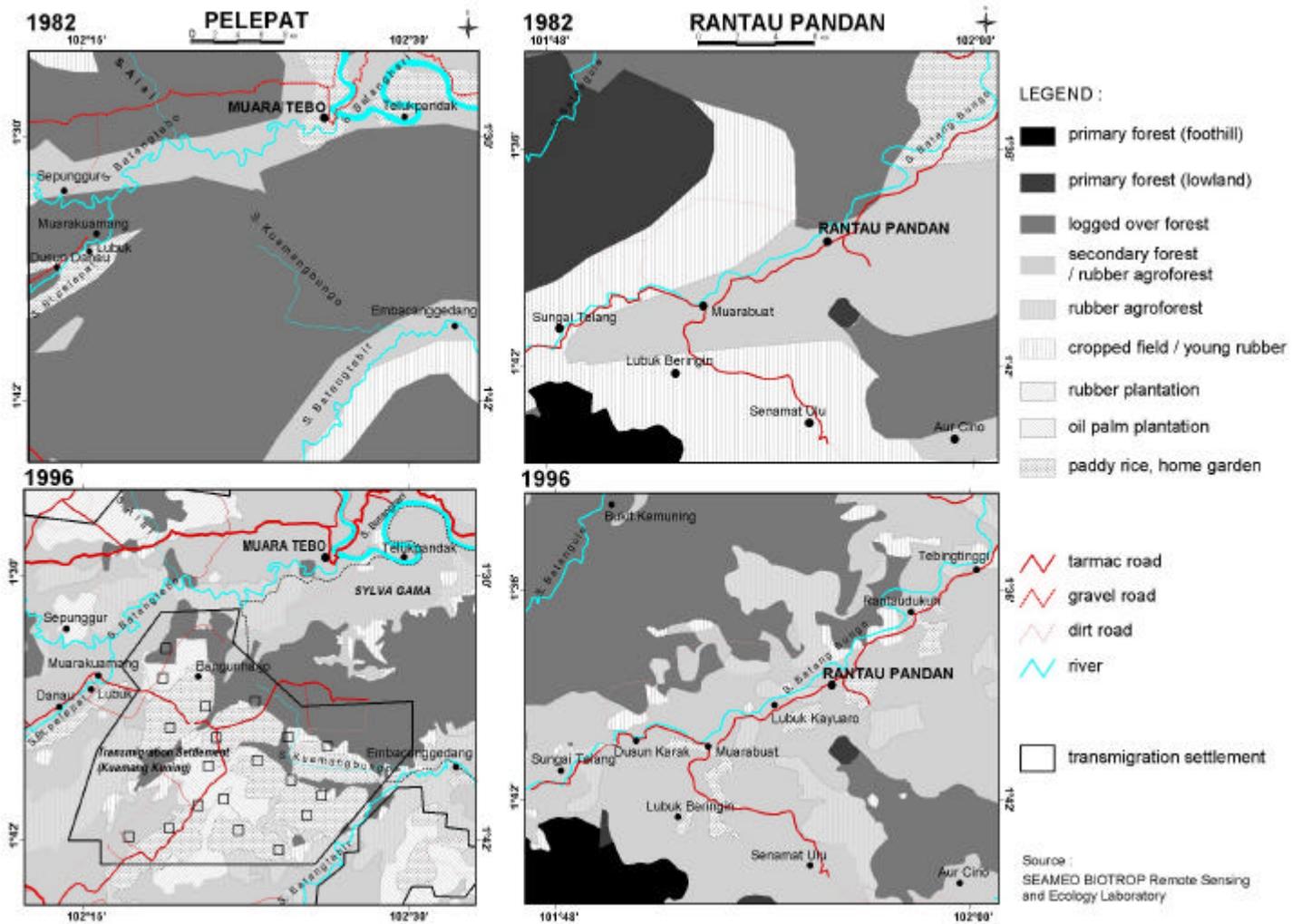


Figure 10. Land use change in the Jambi benchmark areas (Pelepat [lowland peneplain] and Rantan Pandan [piedmont]) 1982-1996.

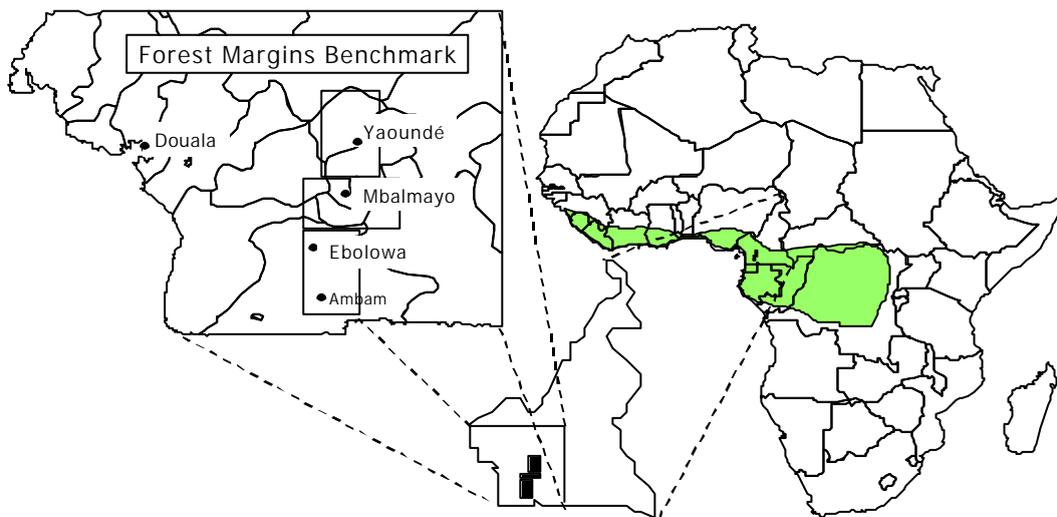
The red and red-yellow soils in the benchmark areas fall mainly into the broad FAO soil class of Orthic Ferrasols, which are suitable for cocoa, coffee, oil palm and rubber if the clay content is high. Four soil profile classes—Saa, Yaoundé, Mbalmayo and Ebolowa—with distinctive physiochemical properties, form a north-south fertility gradient. Annual precipitation falls in a bimodal pattern and ranges from 1350 mm to 1900 mm, with an increasing precipitation gradient from the northwest to the southeast.

Cameroon’s National Environmental Management Plan (NEMP) divides the country into 4 major ecological regions: the Sudano-Sahelian zone, in the far north; the savanna zone; the coastal-marine zone and the tropical forest zone. Within these regions, NEMP further subdivides the tropical forest zone into the degraded forests of the Center and Littoral Provinces, and the dense humid forests of the Southwest, South and East Provinces. Letouzey (1985) provides a more disaggregated classification of the humid forest, dividing the zone into 16 evergreen types and 4 semi-deciduous types. An intermediate classification, used by Garland (1989), which builds on Letouzey’s divisions, groups the humid forest zone into 4 types of climax vegetation:

1. Dense moist evergreen Atlantic forest, which is further subdivided into the coastal and Biafran forests
2. Cameroon-Congolese forest
3. Semi-deciduous forest
4. Mangrove forests

For the purposes of this study, we choose to use this latter classification because there exist important distinctions in biodiversity richness across these classifications (Table 6).

The coastal forests lie between the mangrove forests and the Biafran forests, and are characterised by an abundance of the dense hardwood *Lophira alata* (Azobé), one of the most important commercial timber species. The abundance of this species is tied to human influence, as it thrives in clearings. Because of relatively easy access to the port of Douala, these coastal forests have been logged several times and are now a relatively depleted source of timber.



Map 2. ASB forest margins benchmark in southern Cameroon.

Table 6. Floristic characteristics and extent of moist forest ecotypes in Southern Cameroon.

Type of forest ecosystem	Area km <sup>2</sup>	Biological characteristics
1. Dense humid evergreen Atlantic forest (Biafran)	54 000	Very high floristic diversity with marked endemism. Contains flora with affinities to South American forests, and is a center of diversity for various plant taxa, including the genera <i>Cola</i> , <i>Diospyros</i> , <i>Garcinia</i> and <i>Dorstenia</i> . The Biafran forest type is characterised by associations of species from the family Caesalpinaceae.
2. Dense humid Cameroon-Congolese forest	81 000	Intermediate in floristic diversity between the Atlantic forest and the semi-deciduous forest. The flora has affinities with Congo basin forests. This is an important ecosystem for large primates and elephants.
3. Dense humid semi-deciduous forest	40 000	Often fragmented, and subject to fire during the dry season. Particularly rich in commercial timber species although less biologically diverse than other tropical forest types.
4. Mangrove	2 434	Dominated by red mangrove ( <i>Rhizophora racemosa</i> ) with fewer occurrences of white mangrove ( <i>Avicennia nitida</i> ). It is found on the coast, to the east and west of Mount Cameroon. It has suffered some ecological damage (eutrophication) as a result of the large-scale use of industrial plantation fertilizers and pesticides. Tree growth is correlated with rainfall. In coastal areas, to the north of Douala, red mangrove heights can reach 25 m.

Source: IUCN 1994

In terms of floral diversity, the most important forest ecotype is the Biafran forest. Over 200 plant species have been counted within a 1 000 m<sup>2</sup> transect of a Biafran forest. This, purportedly, represents a higher plant diversity than any other forest in Africa or Southeast Asia and is greater than most South American forests (Garland 1989). The Biafran forest is a centre of genetic diversity for important genera such as *Cola* spp., *Diospyros* spp. (ebony) and *Garcinia* spp. (which includes the bitter cola). These forests, which were Pleistocene refuges, are also characterised by a high number of endemic species.<sup>5</sup> There are also certain plant species that show affinities with the forest communities found along the Atlantic coast of South America. These forests are under high human population pressures. The most important conservation reserve of this forest ecosystem is the Korup National Park in the Southwest Province.

The Cameroon-Congo and its semi-deciduous forests, which are widespread in the southeast of the country, have a much lower rate of plant endemism than the Biafran forests, but are especially important in terms of charismatic faunal diversity in the southeast corner of the country, where large tracts are uninhabited. Most of Cameroon's estimated 25,000 elephants reside in these forests. Densities of 2.8 elephants km<sup>-2</sup> and 3.2 gorillas km<sup>-2</sup> were estimated within the 225 000 ha proposed as the Boumba-Bek park, with park populations estimated at 6 524 ± 2 586 for elephants and 7 233 ± 2 097 for gorillas (Ekobo 1995). These are among the highest densities reported for the Congo basin.

As with plants, diversity of fauna and fish species is, in general, higher in the humid forest zone of Cameroon than elsewhere in the country. Of the 250 mammalian species in Cameroon, 162 exist in the moist forests, with 132 of these species being found only

<sup>5</sup> During the Pleistocene ice age, the climate of central Africa was much drier and large areas that are now forested were covered by savanna.

in this habitat. Similarly, of the 542 fish species identified, 294 exist in the freshwater resources of the moist forest zone, of which 78 are endemic to Cameroon (Vivian, 1974). The number of fish species in Cameroon is greater by twofold than the total in the whole of Europe.

The climax vegetation in the Forest Margins Benchmark is of two main types. The first is the dense, semi-deciduous forest characteristic of the Yaoundé block, which extends southwards into the Mbalmayo block. The second is the dense, humid, Congolese forest in the southern reaches of the Mbalmayo block, which extends to the Ebolowa block. In addition, there are small pockets along the western border of the Ebolowa and Mbalmayo block that are characterised by the biologically diverse, moist, evergreen, Atlantic forest.

## **2.2 Agricultural Land Use systems in the Forest Margins Benchmark**

During phase I, a characterisation survey was conducted in 15 villages distributed across the benchmark. In each village 15 households were randomly selected. The most important food cropping system in the Cameroon benchmark is the groundnut/cassava-based mixed food field, which largely guarantees household food security, and, in areas with market access, generates marketable surpluses. Women farmers manage this system, which is typically planted twice—in March-April and again in August-September. The next most important systems, and the largest source of household agricultural revenues, are cocoa plantations. It is mainly men that manage these systems, although, in certain instances, widowed household heads also manage such systems. The third most frequently encountered field system (70 % of surveyed households) is the plantain/banana field. In the southern portion of the benchmark, where population pressures are low, the plantain/melon-based (*Cucumeropsis mannii*) field is frequently encountered. Both the plantain and plantain/melon-based fields are generally targeted at longer period fallow fields and secondary forests. Input intensive, horticultural monocrops and maize, intended for the fresh-produce market, are frequently encountered in the Yaoundé block, which has the best access to urban markets of the three blocks. These horticultural systems have spread rapidly within the last 20 years. Another process associated with increasing resource use intensification and farming systems diversification is the differentiation of field types (Gockowski and Baker 1996). ASB survey results reveal that 62% of the households in the Yaoundé block had 5—8 distinct field types, versus only 28% and 44% in the Mbalmayo and Ebolowa blocks, respectively.

Farms in the Cameroon benchmark are generally small and fragmented. The average number of annual crop fields is slightly more than 4. According to unpublished Ministry of Agriculture field measurements taken in the 1980s, the mixed groundnut field, producing the predominant annual food crop, has an average size of slightly over 1,300 m<sup>2</sup>. The mean annual land cover associated with in productive agricultural land use (a figure which does not include fallow fields) was 2.6 ha per household in the Yaoundé block, 2.4 ha in the Mbalmayo block, and 3.6 ha in the Ebolowa block. Roughly fifty percent of the coverage of this area is accounted for by complex cocoa agroforests.

The livestock sector is not well developed in the benchmark. Cattle farming is practically non-existent (because of tsetse fly) and sheep, goat and poultry farming are generally practised in a free-range and extensive fashion. The only significant commercial livestock production occurs in the urban peripheries of Ebolowa, Yaoundé and Mbalmayo, where intensive and semi-intensive commercial pork and poultry farms

are found. In high population density areas, crop damage from free-range livestock is not tolerated, and the fencing of home gardens or the tethering of animals is practised.

Farmer-elicited production constraints vary with the intensity of resource use. In the high intensity Yaoundé block, grassy weeds, maize stemborers and poor soils are the problems most frequently cited by farmers. Increased references to poor soil by farmers in the Yaoundé block reflect the lower level of woody biomass available, in these farming systems, for ash fertility input following slash-and-burn techniques, giving less fertile soil even though, in terms of CEC, pH, and soil structure, these soils are generally much better than those of the Ebolowa block. In the lower intensity Ebolowa and Mbalmayo blocks, rodents and other animal pests, broadleaf weeds and grassy weeds are more frequently cited as problems (Gockowski *et al.* 1998a).

Using ASB household survey results and secondary data, land cover and land planted in 1994 were estimated (Gockowski *et al.* 1998a). Across the benchmark, 24.8% of the total land area was estimated to be the subject of some form of agricultural use (including fallow fields), although there were significant differences across blocks. Slightly over 100,000 ha of fallow were cleared annually to create food crop fields, representing approximately 3.3% of the total land area. The predominant productive land use system was cocoa, accounting for 3.8% of total land area in the benchmark and representing 48% of total productive agricultural land use. Food crop systems (led by the groundnut-cassava mixed crop field and followed by melon-based and plantain-based systems) accounted for the use of the remaining productive land. Estimates based on remote sensing found 58.9% of land in the Ambam area of the Ebolowa block to be still under primary forest cover, as opposed to 22.0% around Ebolowa, 5.3% around Mbalmayo and only 3.7% around Yaoundé (Thenkbail 1999). The remote sensing images also revealed the invasion of *Imperata* grasslands in portions of the Yaoundé area.

### **2.3 The socio-economic context of farming systems in the Cameroon Forest Margins Benchmark**

Institutions and infrastructure are, in general, much better developed in the Yaoundé block, where population densities are higher, than in the Mbalmayo or Ebolowa blocks. Remote sensing estimates indicate a rural road density in Yaoundé that is three times denser than in the Ambam area. Institutional development is also more evolved in the Yaoundé block, where traditional, customary land tenure institutions are evolving gradually towards individualistic, legally-recognised land ownership and an increased incidence of land titling (IITA unpublished data). An important facet of institutional, cross-block differences is the development, in the Yaoundé block, of a fairly competitive marketing system for both outputs and inputs. Farmers, in general, have easy access to purchased inputs, which are heavily applied by both cocoa (fungicides and insecticides) and horticultural (fungicides, insecticides and fertilisers) producers.<sup>6</sup> In the rest of the benchmark, farmers can spend more than a full day acquiring inputs.

Institutional constraints in the Ebolowa and Mbalmayo blocks have major implications for agricultural intensification; overcoming these will require innovative policy-led interventions. The weakness of technology generation and diffusion institutions is a major institutional problem that affects almost all the benchmark. From 1986 until 2000, the national agricultural research system had no operational budget and, as a result, the flow of innovations slowed considerably. The seed technology diffusion system is underdeveloped, with almost no private sector involvement (with the

---

<sup>6</sup> A recent survey of tomato producers in one of the IITA research villages in the Yaoundé block found that 76% purchased their pesticides, and 82% their fertilizers, from a farm chemical supply store located within the village limits (IITA 1999 unpublished data).

exception of imported horticultural seeds and hybrid maize imported from South Africa). The most important crops at the household level are vegetatively propagated (cassava, plantains, cocoyams, yams, and sweet potatoes). This fact inhibits private sector involvement in varietal development and diffusion. The extension service has recently been reinvigorated through a World Bank-sponsored programme of training and visits, but there are major questions about sustainability once project funds are no longer available, as well as concerns over a lack of appropriate technologies.

One of the most rapid changes affecting the agricultural sector throughout the Congo basin has been the tremendous growth in urban populations. Both Douala and Yaoundé have grown at rates exceeding 6% in the years since they gained independence. This means that the number of urban consumers is doubling roughly every 12 years. The most important single market in the benchmark is Yaoundé, with over a million inhabitants. The largest markets for food as a commodity, in terms of value, are plantains, cassava and cocoyams. Approximately 80% of the total tonnage of these three crops sold in Cameroon is produced in the humid forest zone (MINAGRI survey statistics, 1984-1990). The rapid escalation of urban demand for food is increasing income opportunities from food crops and encouraging the diversification process, especially in areas where market access and infrastructure are adequate. Nonetheless, food crop revenues are still dwarfed by cocoa and *robusta* coffee revenues across the forest zone. Prior to the collapse of coffee and cocoa prices in the late 1980s, revenues from these two crops were estimated to be three times larger than all the food crop sales from the humid forest provinces of Cameroon combined. They still tend to comprise the largest portion of household income, although their relative share has probably fallen.

In general, households in the Yaoundé block have to face higher land pressures (as measured by the ratio of annual crop fields to fallow fields) and so have intensified their production systems to a much greater degree than households in the Mbalmayo or Ebolowa blocks. This fact is a result of high population densities, good rural infrastructure (resulting in excellent urban market access) and the development of market institutions. The intensification of the production process in the Yaoundé block is the result of numerous factors, which include the augmentation of purchased inputs (agrochemicals and labour), increased tillage practices (ridging and mounding), crop management strategies (planting in rows, use of improved varieties, mulching, new crop sequences), and an increasing differentiation between field types targeted at specific spatial and temporal niches (Gockowski *et al.*, 1998a). Commercialisation strategies across households are also a function of this intensification process. Intensively managed horticultural production systems are an important strategy for households in the Lekie division of the Yaoundé block. At the opposite end of this spectrum, however, are households that pursue an extensive production strategy but use almost no purchased inputs or management innovations to produce plantains and cocoyams for the market. These households tend to be located in areas of abundant land and to use long fallows. An increase in the land and labour productivity of extensive plantain/cocoyam systems would deflect smallholder pressures on the forest margin. Another cross-block difference obvious in livelihood strategies is that, as forest resources decrease across the different blocks, less time is allocated by householders in respective blocks to natural resource-based activities such as non-timber forest product gathering, fishing, and hunting. Households in the Yaoundé block, for example, devote a much smaller proportion of their efforts to such activities than households in the other blocks. Conversely, non-farm orientated employment has become more common in the Yaoundé block, where the non-agricultural rural economy is better developed.

Sectoral and macroeconomic policy reforms, which have occurred since the late 1980s, have had an important impact on slash-and-burn agricultural systems. Most of these reforms have occurred in the cocoa and coffee sectors as, during this period, the state

disengaged from, and liquidated, the national marketing board associated with these crops. At the same time, fertiliser and pesticide subsidies (which ranged from 60-100%) were ended. Most of these reforms were forced through as part of a structural adjustment package, which was associated with the World Bank and the IMF, and was intended to help the Cameroon government diminish massive internal and external deficits. Unfortunately, these reforms took place in the context of, and indeed were necessitated by, an overvalued FCFA and by depressed world commodity markets. As a result, cocoa and coffee producers in Cameroon, faced with historically low prices, neglected their plantations and shifted their resources to horticultural production and the production of plantain and cocoyams. Such restructuring put significant additional pressure on the forest margins, as new forest lands were cleared and used for annual food crop production (Gockowski *et al.*, 1998b).

### **3. Brazil**

#### **3.1 Characterisation of land use systems**

The following text is adapted from, and the references cited are contained within, Vosti *et al.*, 2001.

Land uses characterising this region were estimated using samples taken from approximately 150 households in the benchmark site. These households were located in two colonisation projects (Pedro Piexoto in Acre and *Theobroma* in Rondônia) and were surveyed in 1993/94 and 1995/96. The trends characterising these households are illustrative of broader trends in the region. Although, in 1993/94, primary forest covered the majority (62%) of the areas associated with farms, pasture dominated the open areas and accounted for 20% of total land use. The most prevalent food crops were (and remain) rice, corn, beans and manioc, which together accounted for 7% of the land used. Cultivated perennial tree crops accounted for 4% of total land use, and included coffee, and, to a lesser extent, bananas and cacao (Vosti and Witcover, 1996; Witcover *et al.*, 1996; Vosti *et al.*, 1998a).

By 1996 the use of pasture had increased, reaching a farm area coverage level of 28%, at the expense of virtually all other land covers including forest (Vosti *et al.*, 1998a). In other words, agriculture had been more extensive. Can the intensification of agriculture, including its forest and livestock components, modify this trend towards forest clearance, and with what consequences for environmental sustainability, growth and poverty alleviation? Some characteristics of small-scale agriculture in the region help explain why this land use continues to encroach upon forested areas, and provide clues to mechanisms that might counter this trend.

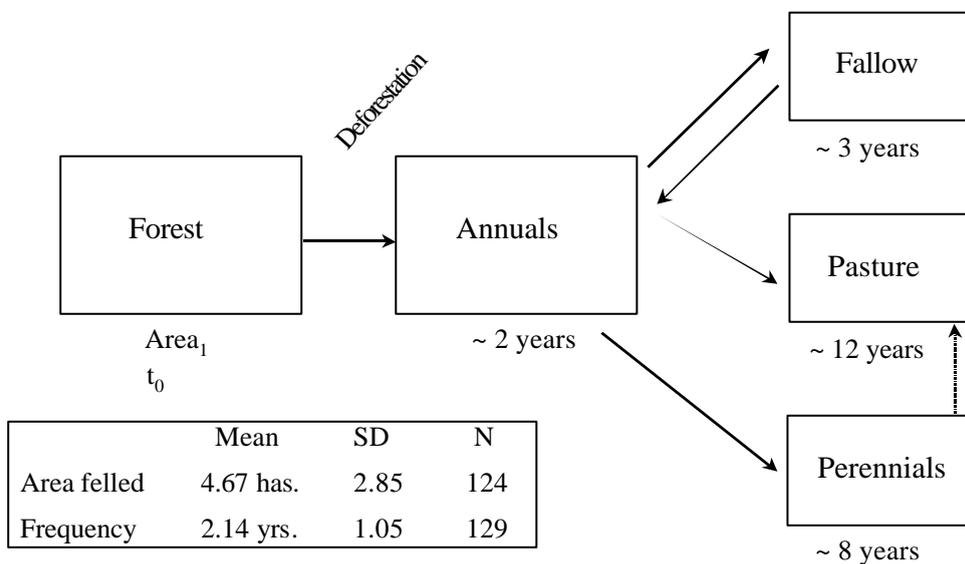
#### **3.2 Land use patterns: sequences that begin with forest**

Agriculture in the forest margins of western Brazil generally begins with completely, or partially, forested lots and is extended by means of slash-and-burn agriculture, rather than shifting cultivation (Fujisaka *et al.*, 1996). May (the onset of the dry season) marks the start of the agricultural year. Demand for labour (especially for adult males) peaks early, in the forest-felling months of May to July. In August or September, with the start of the rains, farmers burn deforested areas and plant them with annuals, perennials or pasture. The rainy season intensifies in January and February, tapering off in April. After the first-season's harvest (in December and January) a second crop (beans) follows, which, having been planted in March, is harvested in June.

Without external nutrient sources, a given plot of land is, typically, forced to proceed through a series of uses over a period of time. In effect, slash-and-burn agriculture

destroys the relatively efficient, continuous nutrient cycle of the forest ecosystem and exchanges it for a one-time transfer of forest-stored biomass to the soil. In the first year after burning, the increased availability of soil nutrients from the biomass, and a reduction in soil acidity (thanks to the basic properties of ash), help to ensure good yields. But crop uptake of nutrients at planting, and the release of litter (crop residues and root decay) at harvest, favor a net loss of nutrients from the site. Depending on the soil type and the crop planted, nutrient deficiencies appear in the second or third year of consecutive planting after burning if no fertilizer is added (Palm *et al.*, 1996). Yields can drop off steeply, especially for some annuals. This drives the farmer to assign the plot of land an agricultural activity to which the nutrient-depleted soil is more agronomically adapted (although productivity still falls over time in the absence of external inputs), or to let the land lie fallow in order to increase its nutrient level and reduce compaction.<sup>7</sup>

Figure 11 gives a schematic of this process, which begins with forest and illustrates the major sequences of land use observed in the region. Each type of land cover (shown by a separate box in the Figure) may be the result of a number of historical land use pathways since the initial clearance of the forest. As time passes, land grows more susceptible to the incursion of weeds; if not attended to, this process can progress to a point where secondary forest regrowth dominates all other cover. In forest margin areas, natural biological processes (for example weeds and pests) combine with nutrient outflows to limit the productivity of a given piece of land. As a result of this, external inputs, increased labour and/or careful choice of land cover (or some other combination of the three) are required for production to continue on that land (Ruthenberg, 1976). As illustrated by Figure 11, current generic land use patterns which lead to environmental degradation coexist with deforestation, which continues at the average rate of about 4.7 ha every two years (out of an average farm size of 83 ha).



A number of years noted below each land use box indicates time continuously in a given land use (not time elapsed from  $t_0$ ).

Figure 11. Observed land use trajectories in Brazil

<sup>7</sup> Some agroforestry and pasture systems, when properly managed, come closer to replicating the forest system, and should thus use nutrients more efficiently and be more sustainable than annual cropping in tropical conditions (Palm *et al.*, 1996).

## IV. Reading Materials

### Textbooks

- Ruthenberg H. 1976. *Farming Systems in the Tropics*. Oxford University Press.
- Lassoie J, Buck L and Fernandes ECM. (Eds.). 1998. *Agroforestry in Sustainable Agricultural Ecosystems*. Lewis Publishers/CRC Press.

### Book chapters

- Angelsen A and Kaimowitz D. 2001. When Does Technological Change in Agriculture Promote Deforestation? In: Lee, D.R. and Barrett, C.B. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CABI Publishing, Wallingford, UK. pp 89-114.
- Gockowski J, Scherr SJ, and Durón G. 2001. Implications of Resource-use Intensification for the Environment and Sustainable Technology Systems in the Central African Rainforest. In: Lee, D.R. and Barrett, C.B. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CABI Publishing, Wallingford, UK. pp 171-219.
- Lee DR, *et al.* 2001. Introduction: Changing Perspectives on Agricultural Intensification, Economic Development and the Environment. In: Lee, D.R. and Barrett, C.B. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CABI Publishing, Wallingford, UK. pp 1-16.
- Michon G and H de Foresta. 1995. The Indonesian agroforest model forest resource management and biodiversity conservation. *Conserving biodiversity outside protected areas. The role of traditional agro-ecosystems*. P. Halladay and D. A. Gilmour, IUCN: 90-106.
- Tomich TP, *et al.* 2001. Agricultural Intensification, Deforestation and the Environment: Assessing Tradeoffs in Sumatra, Indonesia. In: Lee, D.R. and Barrett, C.B. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CABI Publishing, Wallingford, UK. pp 221-244.
- Vosti S, *et al.* 2001. Intensifying small-scale agriculture in the western Brazilian Amazon: issues, implications and implementation. In: Lee, D.R. and Barrett, C.B. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CABI Publishing, Wallingford, UK. pp 245-266.

### Proceedings

- Faminow MD, and SA Vosti. 1998. Livestock-deforestation links: Policy issues in the Western Brazilian Amazon. In: *Livestock and the environment international conference*, ed. Arend J. Nell. Wageningen, The Netherlands: World Bank, Food and Agriculture Organization, and the International Agricultural Centre.
- Lund HG. 1999. Off-on, in-out: Concepts for inventorying trees off-forest. In: *Off-forest tree resources of Africa*, ed. Temu, A.B. Lund, G. *et al.* Proceedings of a workshop held at Arusha, Tanzania, 12-16 July 1999.

### Scientific journal articles

- Carpenter G, Gillison AN, Winter J. 1993. DOMAIN: a flexible modelling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation* 2, 667-680.
- de Foresta H and Michon G. 1997. The agroforest alternative to *imperata* grasslands: When smallholder agriculture and forestry reach sustainability. In: Garrity DP ed. *Agroforestry innovations to rehabilitate imperata grasslands*. Agroforestry Systems Special Issue. Vol. 36: 1-3. p 105-120.

- Garrity DP and Agustin PA. 1995. Historical land use evolution in a tropical acid upland agroecosystem. *Agriculture, Ecosystems and Environment* (53): 83-95.
- Garrity DP, ed. 1997. *Agroforestry innovations to rehabilitate imperata grasslands*. Special Issue ed. 1-3 vols. Vol. 36, *Agroforestry Systems*. p 284.
- Gauthier R. 1996. "Vertebrate pests, crop and soil: the case for an agroforestry approach to agriculture on recently deforested land in N-Lampung". *AGRIVITA*, vol. 19 N°4: 206-212
- Palm CA, Swift MJ and Woome PL. 1996. "Soil biological dynamics in slash-and-burn agriculture". *Agriculture, Ecosystems and Environment*. 58: 61-74.
- Thenkabil PS. 1999. Characterisation of the alternative to slash-and-burn benchmark research area representing the Congolese rainforests of Africa using near-real-time SPOT HRV data. *International Journal of Remote Sensing*, 20(5):839—877.
- Vandermeer J, van Noordwijk M, Ong C, Anderson J and Perfecto Y. 1998. Global change and multi-species agroecosystems: concepts and issues. *Agriculture, Ecosystems and Environment* 67: 1-22.
- Van Noordwijk M, Lusiana B, Suyanto and Tomich TP. 1996. "Soil and other constraints to agricultural production with and without trees in the North, Lampung Benchmark area of the 'Alternatives to Slash-and-burn Project'". *AGRIVITA*, vol. 19 N°4: 136-145

## Reports / Manuals

- Ericksen P (ed.). 2000. *Alternatives to Slash-and-Burn: Summary Report and Synthesis of Phase II in Cameroon*. ICRAF, Nairobi, Kenya. 75 pp.
- FAO 1996. *Forest resources assessment 1990 - Survey of tropical forest cover and study of change processes*. FAO Forestry paper 130. ISSN 0258-6150.
- Friday KS, Drilling ME and Garrity DP. 1999. *Imperata Grassland Rehabilitation using Agroforestry and Assisted Natural Regeneration*. Bogor: ICRAF, Southeast Asian Regional Program. p 167.
- Gockowski J and D Baker. 1996. An ecoregional methodology for targeting resource and crop management research in the humid forest of Central and West Africa" Paper presented at 1996 Biennial Meeting of Rockefeller Social Science Research Fellows, 15—17 Aug., 1996, Nairobi, Kenya.
- Gockowski J, Baker D, Tonye J, Weise S, Ndoumbé M, Tiki-Manga T, and Fouaguégué A. 1998. *Characterisation and diagnosis of farming systems in the ASB Forest Margins Benchmark of southern Cameroon*. Mimeograph. Yaoundé, IITA Humid Forest Ecoregional Center. 65 p
- Fujisaka S, G Escobar, *et al.* 1996. *Plant community diversity relative to human: land use in an Amazon forest colony*. Cali, Colombia, CIAT: 33.
- Tomich T, *et al.* 1998. *Alternatives to Slash-and-Burn in Indonesia: Summary Report and Synthesis of Phase II*. ASB-Indonesia Report no. 8. ICRAF-SEA.
- Turner II, *et al.* 1995. *Land-use and Land Cover Change*. Science Research Plan, IGBP Report no. 35, HDP Report no.7; 132 pp.
- van Noordwijk M, *et al.* 1995. *Alternatives to Slash-and-Burn in Indonesia. Summary Report and Synthesis of Phase I*. ASB-Indonesia Report no. 4. ICRAF-SEA. 154 pp.
- Watson RT, *et al.* 2001. *A report on the key findings from the IPCC Special Report on Land-Use, Land-Use Change, and Forestry*. Also on [www.ipcc.ch/press/sp-lulucf.htm](http://www.ipcc.ch/press/sp-lulucf.htm)

## Magazine articles

- de Foresta H and Michon G. 1994. Agroforests in Sumatra where ecology meets economy. *Agroforestry Today*, Oct.-Dec., 4 (6): 12-13.
- Penot E. 1995. Taking the 'Jungle' out of the rubber, improving rubber in Indonesian agroforestry systems. *Agroforestry Today* 7 (3-4): 11-13.

## Lecture notes / Websites

Burgers P, Hairiah K and Cairns M. 2000. Indigenous fallow management (IFM). Lecture Note, ICRAF-SEA. 18 pp. <http://www.icraf.org/sea>

De Foresta H, *et al.* 2000. Complex agroforests. Lecture Note, ICRAF-SEA. 18 pp. <http://www.icraf.org/sea>

Statistical Services Centre. 2001. Statistical Good Practice Guidelines. SSC Guidelines Series. The University of Reading, Reading, UK. <http://www.rdg.ac.uk/ssc/dfid/booklets.html>

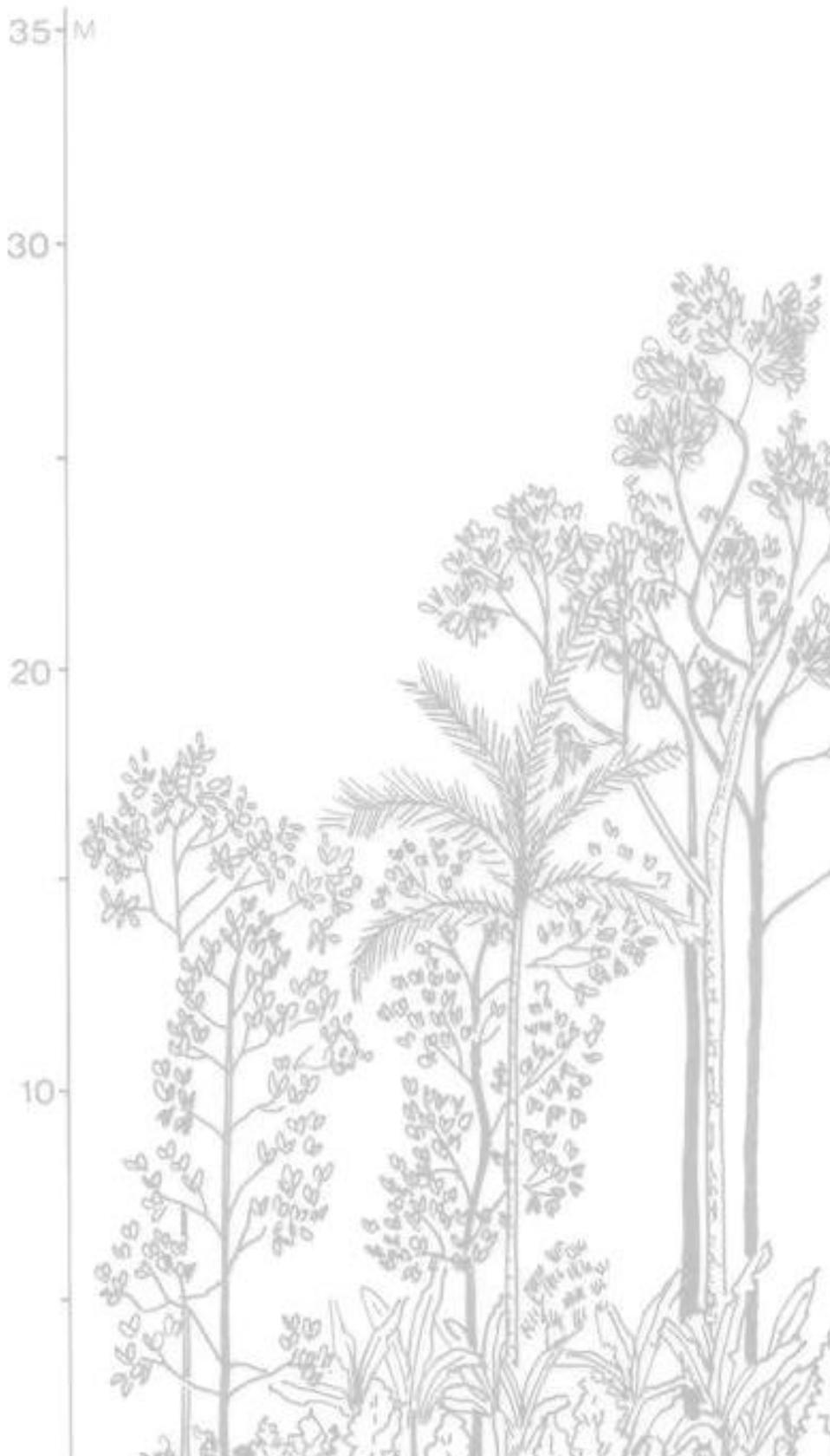


## Contents of this series of lecture notes

- 1.** Problem definition for integrated natural resource management in forest margins of the humid tropics: characterisation and diagnosis of land use practices  
*by: Meine van Noordwijk, Pendo Maro Susswein, Cheryl Palm, Anne-Marie Izac and Thomas P Tomich*
- 2.** Land use practices in the humid tropics and introduction to ASB benchmark areas  
*by: Meine van Noordwijk, Pendo Maro Susswein, Thomas P Tomich, Chimere Diaw and Steve Vosti*
- 3.** Sustainability of tropical land use systems following forest conversion  
*by: Meine van Noordwijk, Kurniatun Hairiah and Stephan Weise*
- 4A.** Carbon stocks of tropical land use systems as part of the global C balance: effects of forest conversion and options for 'clean development' activities.  
*by: Kurniatun Hairiah, SM Sitompul, Meine van Noordwijk and Cheryl Palm*
- 4B.** Methods for sampling carbon stocks above and below ground.  
*by: Kurniatun Hairiah, SM Sitompul, Meine van Noordwijk and Cheryl Palm*
- 5.** Biodiversity: issues relevant to integrated natural resource management in the humid tropics  
*by: Sandy E Williams, Andy Gillison and Meine van Noordwijk*
- 6A.** Effects of land use change on belowground biodiversity  
*by: Kurniatun Hairiah, Sandy E Williams, David Bignell, Mike Swift and Meine van Noordwijk*
- 6B.** Standard methods for assessment of soil biodiversity and land use practice  
*by: Mike Swift and David Bignell (Editors)*
- 7.** Forest watershed functions and tropical land use change  
*by: Pendo Maro Susswein, Meine van Noordwijk and Bruno Verbist*
- 8.** Evaluating land use systems from a socio-economic perspective  
*by: Marieke Kragten, Thomas P Tomich, Steve Vosti and Jim Gockowski*
- 9.** Recognising local knowledge and giving farmers a voice in the policy development debate  
*by: Laxman Joshi, S Suyanto, Delia C Catacutan and Meine van Noordwijk*
- 10.** Analysis of trade-offs between local, regional and global benefits of land use  
*by: Meine van Noordwijk, Thomas P Tomich, Jim Gockowski and Steve Vosti*
- 11A.** Simulation models that help us to understand local action and its consequences for global concerns in a forest margin landscape  
*by: Meine van Noordwijk, Bruno Verbist, Grégoire Vincent and Thomas P. Tomich*
- 11B.** Understanding local action and its consequences for global concerns in a forest margin landscape: the FALLOW model as a conceptual model of transitions from shifting cultivation  
*by: Meine van Noordwijk*
- 12.** Policy research for sustainable upland management  
*by: Martua Sirait, Sandy Williams, Meine van Noordwijk, Achmad Kusworo, Suseno Budidarsono, Thomas P. Tomich, Suyanto, Chip Fay and David Thomas*



**DSO**



INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY  
 Southeast Asian Regional Research Programme  
 Jl. CIFOR, Situ Gede, Sindang Barang  
 PO Box 161, Bogor 16001, Indonesia  
 Tel: +62 251 625415, fax: +62 251 625416, email: [icraf-indonesia@cgiar.org](mailto:icraf-indonesia@cgiar.org)  
 Web site: <http://www.icraf.cgiar.org/sea>