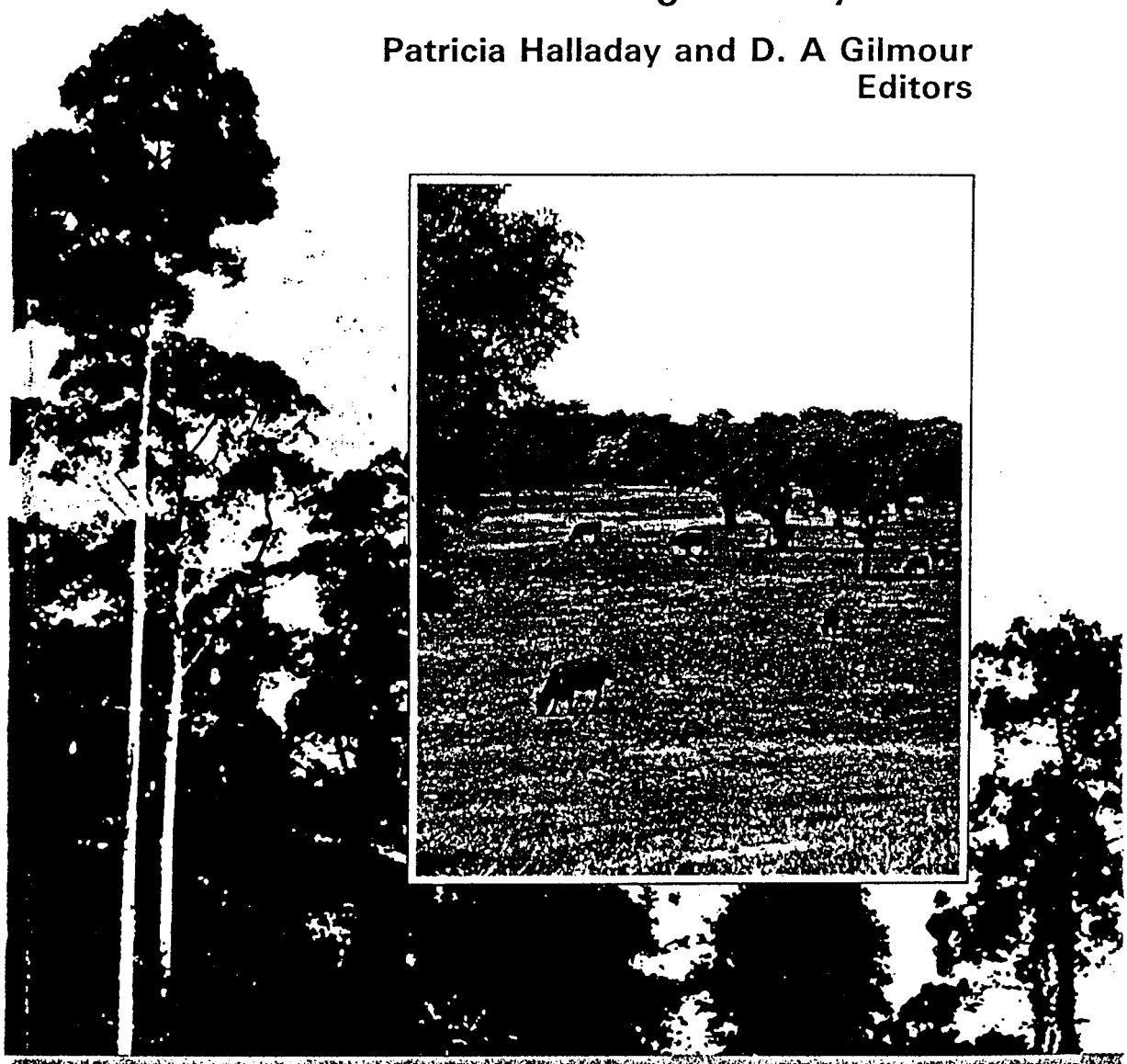
IUCN Forest Conservation Programme

Conserving Biodiversity Outside Protected Areas

The role of traditional agro-ecosystems

Patricia Halladay and D. A Gilmour
Editors



Centro de Investigación F. González-Bernáldez
Comunidad de Madrid
Universidades Complutense y Autónoma
AMA Andalucía
IUCN The World Conservation Union

The Indonesian agro-forest model

Forest resource management and biodiversity conservation

Geneviève Michon and Hubert de Foresta

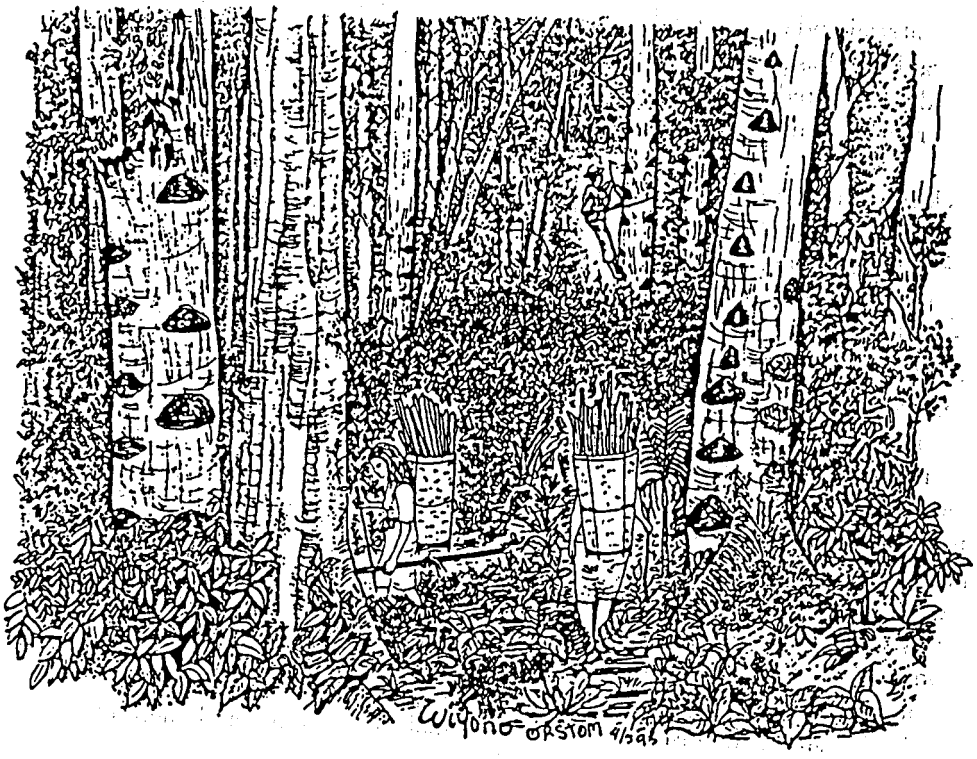
Abstract

Rural life in Indonesia is still greatly dependent on forests, although resource use by local populations often tends to be exploitative. While predation of *in situ* resources does exist, there are also interesting examples of conservative resource management outside natural forests by local populations throughout the archipelago. As native populations' traditional access to natural forests becomes more and more limited, forest resources are often managed through an agro-forestry reconstruction of the ecosystem: the agro-forest. In the present context of degradation of natural ecosystems and of generalized dilapidation of their resources, indigenous agro-forests reaffirm traditional responsibility over natural resources by native farmers and societies. Besides management of useful species, these agro-forests also allow conservation of a good part of animal and plant diversity. In Sumatra, results of a comparative study on biodiversity levels between natural forests, several agro-forests and monospecific plantations show the high potential of this original type of resource management system in conserving forest biodiversity in agricultural lands.

Introduction

In Indonesia, disagreements between the forestry sector and the peasant world have become common. As is usually the case, foresters see farmers as forest destoyers, totally unable to manage forest resources or protect biodiversity. Successive powers in Indonesia, from the Dutch colonial administration to the modern Indonesian Republic, have constantly tried to relocate and assimilate forest people in order to achieve total appropriation of the forest. At the same time, however, the forest's appeal for peasants has been increasing. Beside providing foods and material for daily life and being a reserve of fertility for agricultural fields, the forest has served as a reservoir of potentially cultivable species, from fruit trees to latex and resin species, and presently timber. But, above all, the forest has been the basis of economic exchange between forest dwellers — farmers more than hunter-gatherers, or at least part-time farmers — and the outside world. The age-old involvement of forest dwellers in the trade of forest products has continually gained in importance with the

Figure 12. Dipterocarp agro-forest, Lampung, Sumatra



Most of these systems are obvious agro-forestry combinations; for example trees and agricultural crops. They involve a small number of components, usually one tree species and one to a few annual or short-cycle species, on the same piece of land. Because of the small number of components, these types of agro-forestry associations will be referred to as simple agro-forestry systems.

Outside Java, however, the outer islands are known mainly for their destructive mode of agriculture, particularly pioneer shifting cultivation. To some observers, vegetation bordering agricultural areas — especially those which are still in transition from the primary forest — is often misunderstood to be a mix of virgin and degraded forest.

But experienced agronomists and foresters know that these are not patches of natural unmanaged vegetation, but are in most cases kebun, the Indonesian word for tree garden or tree plantation. They are, in fact, true agro-forestry plots, with a complex mix of trees and herbs. A whole facet of Indonesian agriculture evolved around traditional forest resources: fruits and spices as well

as forest material and commercial products. Integrating these resources in agricultural lands has gradually shaped original agro-forestry systems, in which common domesticated tree species of tropical gardening — various fruit trees as well as rubber, cinnamon, coffee — are associated with forest trees (Michon, 1985).

This kind of agro-forestry combination, which takes the form of a forest, both in appearance and function, is called complex agro-forestry system or agro-forest (de Foresta and Michon, 1990; de Foresta and Michon, 1991). Such systems involve a high number of components (trees as well as tree seedlings, lianas, herbs); their appearance and function are close to those observed for natural ecosystems, either primary or secondary forests.

These complex agro-forestry systems are encountered in most peasant agricultures throughout the humid tropical world, and are highly developed in Indonesia. The Javanese pekarangan is one of many examples of complex agro-forestry systems.

Most complex agro-forestry systems are not home-gardens, but are far more extended tree plantations. They were developed outside Java, sometimes over hundreds of years, within shifting cultivation systems. These complex agro-forestry systems are quite successful, and are developed with either fruit species, local forest species providing timber and other commercial products (rattans, resins, spices) or exotic trees such as rubber. In terms of quantity and production, their diversity, dynamism and importance make them a major element of smallholder agriculture in the great outer islands.

In the hills and lowlands of Kalimantan and eastern Sumatra, the last tracts of mixed dipterocarp forest are being exploited for timber and rapidly converted. But smallholder "jungle rubber" agro-forests, in which rubber trees are associated with numerous tree species providing either fruits or timber, preserve a diverse forest cover for an estimated area of 2.5 million hectares, complementing either irrigated or dry rice cultivation (de Foresta, 1992; Gouyon et al. 1993).

On the western coast of Sumatra, villagers have used an impressive model of complex agro-forestry for more than 100 years (Figure 12). It is based on a dipterocarp tree exploited for its resin (Torquebiau 984; Mary and Michon, 1987; Michon and Bompard, 1987; Michon and Jafarsidik, 1989; de Foresta, 1992). The illipe nut gardens of west and central Kalimantan are also examples of complex agro-forestry systems integrating dipterocarps (Momberg, 1992).

All over Sumatra, various types of complex agro-forestry systems make use of numerous fruit species as well as economic spices (cinnamon, nutmeg, clove) and timber species (Michon, 1985; Mary, 1986) under a canopy of

durian or kemiri trees.

In eastern Kalimantan, impressive fruit forests called lembo have developed, which seem to be among the richest systems as far as tree species are concerned (Sardjono, 1987; Sardjono, 1988; Sardjono, 1992). In Lombok, north Sulawesi, agro-forests are centered around a sugar-producing palm. In the Moluccas, agro-forests associate fruit or nut trees with the traditional spice trees, clove and nutmeg.

In terms of production these agro-forestry systems are of the utmost importance, at regional as well as national levels. They provide 80 per cent of the rubber latex consumed and exported by Indonesia, roughly 95 per cent of the various fruits marketed in the country, between 75 and 80 per cent of the dipterocarp resins traded in and outside the country, a significant part of rattans and bamboos, an immense part of the firewood used in the country, and the majority of such items as medicinal plants and handicraft material. Moreover, they ensure the self-sufficiency of most rural households in complementary foods, fuelwood and light and heavy construction material.

It is important to note that most of these systems are definitely not homegardens, but more extended systems which have evolved from previous clearings in natural forests. They belong more to the world of plantation agriculture than to subsistence agriculture, as the main reason for their establishment is providing monetary income for rural households.

A forest and its ecological integrity

Agro-forests are extremely close to natural forest formations in their dominance, diversity and origin of most of their species. Some of them have the structural as well as functional characteristics of a primary forest ecosystem, with high specific richness, great ecological complexity and closed mineral circulation systems. As with natural forests, agro-forests can be considered sustainable in the long term. But agro-forests are more than a biological copy of the forest. They represent a totally original form of appropriation of forest resources by indigenous people. More than natural forests, which are at present a highly threatened public domain, agro-forests represent a viable space for sustainable management of forest resources and forest biodiversity by indigenous people.

Indigenous management of forest resources

From the beginning, the age-old involvement of forest farmers in the trade of forest products has shaped the structure and evolution of indigenous agro-forests. It was the need for sustainable management of commercial forest

resources that led to the first development of agro-forests. Economic species, such as benzoin or cinnamon trees in Sumatra, were introduced into native tree gardens or swiddens as far back as the 16th century (Marsden, 1783). The Dayak people in western Borneo have built their agro-forests around illipe nut-producing dipterocarps. Villages in Mollucas are surrounded by agro-forests which combine traditional local spice trees: nutmeg and clove, with forest nut trees. More recently, farmers in the southwestern part of Sumatra cultivated a resin-producing dipterocarp, resulting in an agro-forest tens of thousands of hectares in size.

Agro-forests have gained in importance with the introduction of colonial tree crops. The case of rubber is an example: rubber, a forest species — though not native to the area — has totally replaced native forest species in the local economies of forest villages. Less than 50 years after its introduction and rapid acceptance by farmers, Brazilian rubber dominated the non-fertile lowlands of Sumatra and Borneo in agro-forests. Since 1945 they have produced more than 80 per cent of the latex exported by Indonesia.

The composition of agro-forests continues to change. Formerly abundant forest products are becoming scarce; several of these resources, such as rattan in Kalimantan, gain in importance in agro-forests. The most promising forest resource of the 21st century is probably timber. Some farmers in south Sumatra have introduced dipterocarps in their rubber agro-forests, while farmers on the west coast of Sumatra have developed systematic commercial exploitation of traditional timber species into the durian/cinnamon agro-forests.

Biodiversity in agro-forests

The successive integration of commercial tree crops did not fundamentally change the actual form of agro-forests. Today, in spite of a common marked specialization, dominant tree crops are still associated with large primary forest trees or with tree species of secondary vegetation. Apart from major species, either cultivated or selected and protected, which form the frame of the agro-forest, vegetation includes an important spontaneous component — the "weed" of modern agriculture — which is not eradicated but managed according to its usefulness. This may represent up to 50 per cent of the tree stand alone, not taking into account lianas, epiphytes or undergrowth species. Near Padang, in west Sumatra, which is one of the most populated and intensively managed areas on the island, agro-forests include more than 30 commonly-managed tree species. There are several hundred additional species, which establish naturally and are utilised often. Qualitative analyses of plant diversity in Indonesian agro-forests have been discussed elsewhere (Bompard and

Michon, 1985; Michon and Bompard, 1987; Michon and de Foresta, 1990). What is stressed here is a more quantitative assessment of biodiversity levels in agro-forests, and critical comparisons of biodiversity levels between natural forests, agro-forests and other types of agricultural management. This will help define the capacity of complex agro-forestry systems to allow the conservation of animal and plant forest species.

Table 12. Comparison of diversity in Collembola

		n spp. per sample	frequency per sample	total n spp.	total frequency
leaf litter	primary forest	20.6	117.4	47	587
(mean values)	rubber agro-forest	22.8	161.4	47	807
	rubber estate	11.6	83.2	23	416
soil	primary forest	13.7	48.4	57	1211
(mean values)	rubber agro-forest	16.0	63.2	55	1579
	rubber estate	8.3	36.4	28	364

Biodiversity assessment

In order to assess biodiversity levels, several groups have been studied, including higher plants (from ferns to dicotyledons), birds, mammals and soil mesofauna. Comparative studies have been conducted in three locations on the island of Sumatra, between agro-forests (damar agro-forests in southern Sumatra, rubber agro-forests in eastern Sumatra and durian/cinnamon agro-forests in western Sumatra), related neighbouring natural forests, and, in one location, monospecific (rubber) plantations. This study is in its final phase, and the information must be refined by further analysis. The data does provide preliminary information, however.

For soil fauna (Deharveng, 1991 and 1992), 500 soil and litter samples were analyzed, including more than 50,000 arthropod samples and 20,000 *Collembola* samples, 80 per cent of which are new species. Results show that diversity levels are quite similar between forest and agro-forest (Table 12 and Figure 13), but far lower in plantations. None of the most common species of the forest populations are absent in the related agro-forest; however, many rare species exist, and results do not prove that rare species in the forest also exist in the agro-forest. It is obvious that, for soil fauna, agro-forest is a much preferred option to industrial plantations as far as diversity is concerned.

Table 13. Comparison of bird diversity

	primary forest Mua/Krui/Man	rubber agrof. Muarabungo	damar agrof. Krui	durian agrof. Maninjau
observed richness	179	105	92	69
average richness per sample (n. spp.)	26.4	18.5	15.4	15.1
rare species (%)	79.9	72.3	75	62.3

Source: Thiollay, 1994
Rare species are those which account for less than 1% of the total population

In terms of birds (Thiollay, in press), diversity in the agroforest is reduced to about 60 per cent of that in primary forest. Plantations have only five per cent of the diversity in primary forest (Table 13). About 41 per cent of bird species found in the forest have not been encountered in the agro-forest, whereas 25 per cent of the agro-forest species were not present in the forest surveys. It is interesting to note that the three surveyed areas are significatively different. The rubber agro-forest is the closest to natural forest in terms of bird species richness, while diversity levels are lowest in the durian agro-forest. This could be explained by both the composition of plant species and the influence of villages and constant human disturbance, which is much higher here than in the other agro-forests.

Large birds (weighing more than 80 grams) are significatively more abundant in primary forests; more than 50 per cent of species of this group do not appear in the agro-forests. The cause of this can be related to biological factors (simplification of composition and vertical structure from forest to agro-forest), but is probably due mostly to hunting pressures. Birds are shot for sport or food; in addition, bird keeping is extremely popular in Indonesia, and birds are often caught to be kept in cages in villages.

As far as mammals (Sibuea and Herdimansyah, 1993) are concerned, almost all forest mammals are present in the agro-forest (Table 14), but population densities have still to be studied. Results available for primates (macaques, leaf monkeys, gibbons and siamang) show that densities in the agro-forest are quite similar to those observed for natural forests. An interesting fact to note is the record of Sumatran rhino footprints in the damar agro-forest, less than two kilometres from villages. This represents the first record of rhino in this part of Sumatra and suggests that the conservation of endangered animals might possibly be an important adjunct to the use of agro-forests.

Table 14. Mammal families and species in three agro-forests

	agro-forests					
	Mn (durian)		Mb (hevea)		Kr (damar)	
	Sp.	Fam.	Sp.	Fam.	Sp.	Fam.
Insectivora	0	0	0	0	1	1
Dermoptera	0	0	1	1	1	1
Chiroptera	6	2	3	2	9	5
Primata	5	4	7	4	7	4
Pholidota	1	1	1	1	1	1
Rodentia	7	3	11	3	14	3
Carnivora	9	4	9	4	6	4
Perissodactyla	1	1	1	1	1	1
Artiodactyla	4	4	6	3	6	4
Total	33	19	39	19	46	24
Protected by Indonesian law (Ordinance no. 5, 1990)	14		15		17	
IUCN red list	9		6		7	
CITES	4		3		4	

Results of flora studies (de Foresta, Bompard, Molino, Michon) are taken from exhaustive observations along several 100-metre transect lines, completed by random collection in each of the three locations. For each location, more than 1000 herbarium samples are being analyzed. Global diversity is reduced to approximately 50 per cent in the agro-forest, and to 0.5 per cent in plantations. However, results have to be categorized by biological type, as they can be very different from one group to another. The biggest loss of diversity occurs for trees (30 per cent of the original diversity levels for agro-forests, 0 per cent for plantations). This is quite understandable since economic requirements, and therefore selection, relate mainly to trees.

Diversity of epiphytes in the agro-forest should be at least 50 per cent of the forest diversity in agro-forests (one to five per cent for plantations). Analyses of orchids (92 identified species, representing 50 per cent of the collected orchid matter) include seven new records for Sumatra, whereas 42 species are reported exclusively from old-growth forests. Diversity in undergrowth plants in agro-forests is twice as high as in natural forest, which is related to the richness of this group in old secondary forests compared to primary forests. Diversity for lianas is close to 95 per cent in rubber agro-forests, but is much lower in the damar agro-forests.

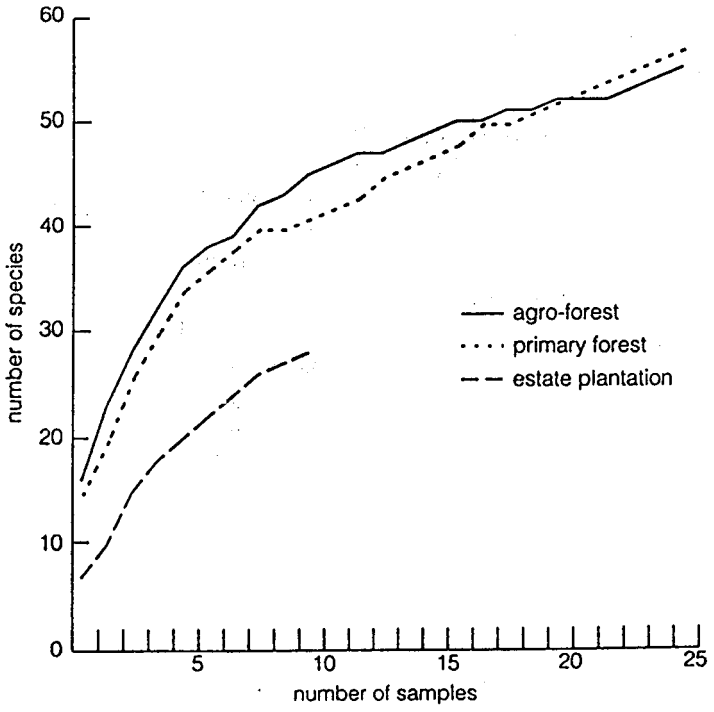
A critical analysis of biodiversity levels

The sample technique used for plant surveys (comparative quantitative collections on transects of a given length) does not provide definitive data on the overall presence or absence of a given species. Many relatively rare forest species in the agro-forest would not be revealed by this technique, which emphasizes numerically important species. The mammal census, which made use of observations as well as discussions with farmers, revealed a great diversity of mammals, but provided very little information about the frequency or abundance of individual species.

A wider census for useful plants in the agro-forests (plants with a positive selection pressure from the farmers) has revealed important numbers of species producing fruits and nuts, spices and flavourings, exudates, fibers, etc. Observations have shown the low density of many of these resources, which means that they are probably not included in our quantitative surveys. The same is probably true for plants which have no harvesting value and which are not affected by positive selection.

Figure 13. Comparison: Collembola diversity

Comparison of diversity in the soil of primary forest, rubber agro-forest and rubber estate plantation, Rantau Pandan area, Kabupaten Muara Bungo, Jambi Province (from Deharveng, 1992)



It should be stressed that biodiversity in the agro-forest does not result from a deliberate choice of farmers to conserve biodiversity *per se*. Rather, it is the logical consequence of structural features of the agro-forest and of associated management practices. The main incentive for establishing an agro-forest is economic, and is closely linked to the market economy. The search for marketable tree products is not a new trend. However, commercial tree gardening is not conceived as an exclusive enterprise, but is combined with other functions, for example subsistence. In so doing, farmers are following an age-old model of multi-purpose forest use.

Biodiversity results, therefore, from two types of dynamics. One is semi-intentional and exclusively concerns plants, combining the planting of useful species — which recreates the frame of a forest system — with selection of spontaneously occuring resources. The other is accidental, resulting from the establishment of a diversified flora and fauna as in any silvigenetic process, and shaping the forest aspect of an agro-forest. This accidental component is not a neutral one; it determines not only the diversified structure of the agro-forest, but its function. As an example, if a selection reduces minor fruit trees in a damar or a rubber agro-forest, there will probably be a reduction in the number of fruit-eating birds, squirrels and bats. There will therefore be a reduction in the number of natural pollinators and dispersors. This could possibly endanger the reproduction of many species, a trend which human intervention may not be able to reverse.

Changing the habits of farmers through education or agricultural extension can bring about important changes in biodiversity levels. One farmer in the durian/cinnamon agro-forest recently chose to use herbicides in his garden to get rid of weeds (an exogenous concept in indigenous farmers' societies). This will have an effect on animal populations and soil fauna as well as on the higher plants and seedlings that are killed in the process.

Managing biodiversity and its economic consequences

Agro-forests are more than a collection of forest resources. They also represent an admirable system of resource management, entirely developed and administered by indigenous populations.

The Indonesian examples show the value of ecological and technical control of resources as well as the socio-cultural control over these resources. This is accomplished not through the conventional domestication of species, which usually involves modification of plant characteristics to adapt to the cultivated ecosystem, but through total reconstruction of the original ecosystem.

Exclusive and homogenized management of stands, characteristic of conventional silvicultures and tree plantations, is not found in indigenous agro-forests. Agro-forests cannot be used for a single purpose. They are characterized by multiple use of resources, multiple use of individual species, an individualized manipulation of plants and maximal use of natural processes of production and reproduction. Agro-forest management achieves truly integrated management of a complex ecosystem.

The integrity of agro-forest structures is ensured through a dominant private tenure system complemented by an overall control by enlarged families or clans. Radical transformations, clear-felling and sale of individual agro-forest plots have to be approved by these superior councils, who ensure a respect for tradition as well as for future generations.

The success of agro-forests lies in their proven ecological reproductive capacity over the long term as well as in their immediate economic benefits. They provide the main source of monetary income for families, contributing to reasonable levels of life quality (including schooling of children), and are an important and valuable heritage. They also contribute to the nation's welfare through the production of important goods, including export crops, fruits, material and firewood.

Table 15. Comparison: species richness and abundance

	number of species			frequency		
	rubber estate	rubber agro-forest	primary forest	rubber estate	rubber agro-forest	primary forest
trees	1	92	171	28	247	258
lianas	1	97	89	5	228	219
tree seedlings	0	26	45	0	170	72
epiphytes	2	28	63	2	51	261
herbs	2	23	12	* 2000	217	84
total	6	266	382	2035	913	897
trees (except rubber)	0	91	171	0	189	258
total (except rubber)	5	265	382	2007	855	897

samples: 100 m transect-line; all plants past seedling stage recorded

* estimated number of herbs: about 1000 individuals for each species

The future of indigenous agro-forests

It is more and more apparent that sustainable management and protection of natural forests, usually exclusively administrated by national institutions, would benefit from the integration of local populations able to use and manage resources in an optimal way. Instead of displacing local people from forest areas, it would be judicious to give more forest land to those shifting cultivators who have mastered the techniques and strategies of a true integrated agro-silviculture. Agro-forests in Sumatra and Kalimantan achieve much more sustainable management of forest resources, together with conservation of biodiversity, than most of the forest plantations developed by the government as the solution to exhaustion of timber resoures.

On the other hand, the future of agriculture in forest areas will have to integrate forest components into food producing systems in order to achieve both ecological sustainability and economic viability. Small-scale agriculture has evolved with the forest and should not depart from it.

Why not agro-forests?

Preliminary study results reveal the importance of agro-forests in the conservation of biodiversity. This importance has to be considered in the context of forest transformation for agriculture or timber plantation: global levels of 50 per cent of preserved diversity could be considered low by conservationists. But statistics have to be compared with biodiversity levels in other types of agricultural/silvicultural systems. Agro-forests are not devised for conservation, but for production; biodiversity conservation is just a derived benefit, not an aim *per se*. Many areas of forest land will have to be transformed to give way to intensive production, and the current agro-forest strategy apparently allows the highest levels of biodiversity conservation.

In Sumatra, deforestation rates between 1982 and 1989 have reached 300,000 hectares per year. Most of the lowland dryland forests (between 15 and 150 metres elevation) have been logged; much of this logged-over forest has been replaced by estates, either oil palm plantations, accacia forests or monocrop rubber plantations. In 1985, intact lowland forest covered less than 1.5 million hectares. This means that, by 1994, only a few hundred thousand hectares of this forest were left. With some two million hectares of rubber agro-forests in the eastern lowlands of Sumatra, approximately 1.5 million hectares of fruit agro-forests in the alluvial lowlands, and about 10,000 hectares of productive damar agro-forest in the western lowlands; agro-forests, and not natural forests, are presently the widest reservoir of forest biodiversity at low elevations in Sumatra.

A threatened future

Agro-forests have survived until now thanks to the constant integration of technical and strategic innovations, agro-forests and societies evolving in parallel ways. But a gap is widening between peasant societies, which modernize through uniformity, and an agro-forestry model that is perceived by both agricultural and forestry authorities — and often by the farmers themselves — as backward and inefficient. Farmers' access to development is perceived exclusively through the extension of plantations. Agro-forests are probably the most endangered agro-ecosystem in Indonesia.

All over Indonesia many beautiful examples of age-old agro-forests are being drastically modified or even destroyed. This happens for many reasons, ranging from institutional, legislative and administrative impediments to socio-economic mutations occuring in production systems and changes in rural societies. Agro-forests are viable only so far as they can meet peasants' needs. They are sustainable only in a well-structured and coherent social context.

Biodiversity within agro-forests is directly threatened by the emergence of new elements in the peasant world. Fulfilling short-term monetary needs leads to the replacement of slow growth or secondary species by fast-growing, high yielding species. Uncertainty about the future restrains long-term investment, and agricultural extensionists and agricultural information through television promotes monocropping, the weed concept in tree gardening, and an increase in gross yields per unit of land for individual crops. Agro-forests can be affected by the same range of factors if they do not provide enough immediate income; this can be due to lack of inadequate marketing channels for the products.

This was the case in the Tembawang system in west Kalimantan, where local markets for tengkawang nuts are so undeveloped and monopolistic that people prefer to sell their trees for timber, at the derisory price of US $3-5 per tree. The trees are not prized by local people, who prefer — and are pushed by agricultural extensionists — to adopt more modern agricultural systems, mainly monocrop and input-consuming plantations. Agro-forests are also threatened by non-economic factors, such as the weakening of traditional regulators (family or clan heads, custom representatives). This places more importance on individual initiatives, which are often unsuccessful.

Last, as agro-forests are seen as being natural formations and are found in territories that are not officially acknowledged as agricultural lands, they fall under the chainsaws of timber companies. This happened to damar agro-forests in Bengkulu and is happening to lembo in east Kalimantan. Agro-forests are cleared for transmigration projects, as in Ipuh, Bengkulu, or they are felled to

give way to fast-growing timber estates, as illustrated by the loss of the sophisticated rattan agro-forests in east Kalimantan. The unfavourable administrative and legal framework is the first thing that must be changed to provide better prospects for the future.

The role of scientists

Indonesian agro-forests can indeed provide the base for a totally original model of sustainable development. This could benefit not only Indonesia, but many forest lands all over the humid tropics. The value of the agro-forest still has to be acknowledged to balance the commonly negative perception. Strengthening the agro-forest model needs several types of action, including further experimentations and improvements to existing models as well as extension through integration of new systems in future development programs.

But what the agro-forest model needs most urgently is innovation able to carry it into the 21st century. It might otherwise disappear in the same modernization movement that fells natural forests and assimilates indigenous forest societies. Outside institutions, and above all scientific institutions, have to support vanishing local institutions to ensure a bright future for an age-old model of original resource management.

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