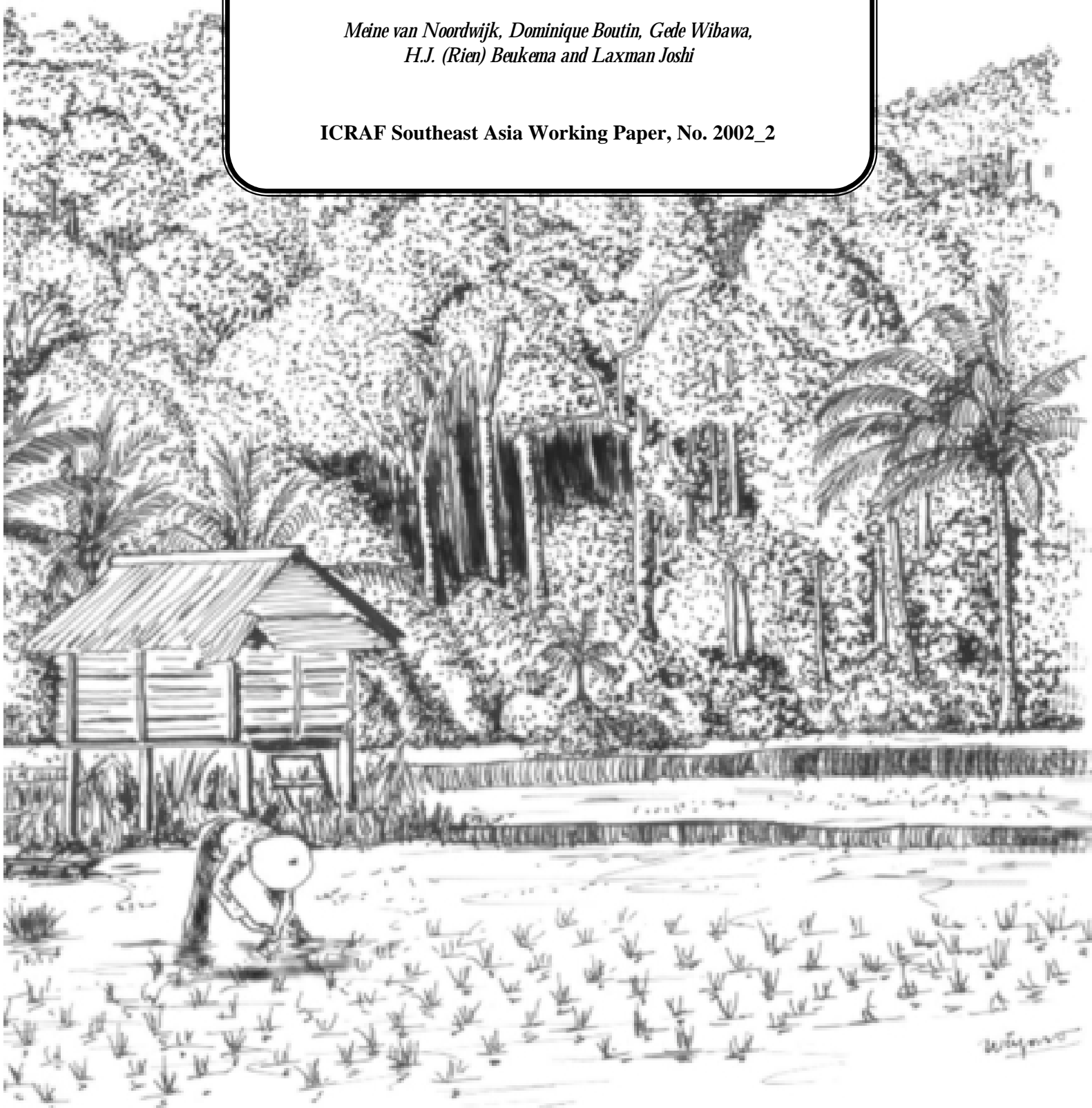


**Options for smallholder rubber producers
to increase productivity while maintaining
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Options for smallholder rubber producers to increase productivity while maintaining 'forest functions'*

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*. Based on presentation made at the ASIA RUBBER MARKETS CONFERENCE, 28-29 October 2002, KUALA LUMPUR

Summary

In this paper we discuss rubber agroforestry in Indonesia in the context of 'integrated natural resource management' (van Noordwijk et al., 2001):

1) Characterization and diagnosis

- 1a) Rubber production in Indonesia differs substantially from the pattern elsewhere in SE Asia -- basic characteristics, areal extent, production
- 1b) Views on smallholder rubber AF in Indonesia, in contrast to monocultural plantations common elsewhere
 - a) Backward or low-cost, low-risk, multifunctional land use?
 - b) Lost opportunity & low quality, or Threat to increased overproduction?
 - c) Safety-valve on the global production system due to high elasticity

2) Intensification & development pathways:

- a) SRDP style projects for monocultural plantations -- despite heavy WB & ADB investment only 10% may have been reached, with very limited spontaneous adoption of the clone-based technology outside of project areas
- b) Robust clones (such as PB260) used in SRAP with reduced weeding & fertilizer compared to current technical recommendations
- c) Sisipan -- gap-level interplanting of rubber (& other trees), in-situ grafting etc.
- d) Intensified on non-rubber components of rubber agroforests for higher timber output
- e) Shift towards oil palm

3) Productivity, sustainability, quality

4) Farmer knowledge, HH decision making, returns to land and labour

5) Environmental impacts

- a) Watershed functions
- b) Biodiversity
- c) C stocks

6) Trade-offs between private and public benefits; is there a role for 'environmental service payments'?

7) Scenarios, likely trends -- relevant policy response, priorities for research and development

1. Introduction

In South East Asia rubber is mainly grown by smallholders and tapped with family labour or through a 'share tapping' system, which means that the sale of rubber products provide the main income for millions of poor rural families. Rubber production in Indonesia differs substantially from the pattern elsewhere in SE Asia. In Thailand and Malaysia, farmers adopted the techniques utilized in rubber estates: planting of high yielding clonal rubber, application of fertilizers and agro-products and utilization of legume cover crops. Governments provided cheap credits and encourage farmers to establish new rubber plantations. In Indonesia, a limited number of smallholders obtained government assistance through various schemes but the wide majority still continued to manage rubber in an extensive way, using the "jungle rubber approach".

Dominant views from government and research levels on smallholder rubber AF in Indonesia still see it in contrast to monocultural plantations common elsewhere, as:

- A lost economic opportunity, maintaining rural poverty,
- A backward way of producing low quality bulk product,

Over the last decade an alternative view has emerged in which this agroforest is:

- A low-cost, low-risk, multifunctional land use?
- Which maintains essential 'forest functions' while providing employment up to population densities of 50 persons km⁻²

In the current efforts to regulate latex supply to the world market to a level that can provide acceptable rewards for the producers, the extensive production systems can be seen as:

- A threat to increased overproduction once the technology gap is closed? Or as
- A 'safety-valve' on the global production system due to its high elasticity, which means production responds faster to fluctuating prices than the plantation sector.

With the current consumer interest in the European (and other...) markets on 'green production', the rubber agroforest option may qualify for forms of 'ecolabelling' and thus target a separate part of the overall market.

ICRAF, the world agroforestry centre, is working in partnership with Indonesian and Thai national research and development partners, as well as international partners, to explore these questions and contribute to new perspectives and opportunities for the smallholders involved.

In this presentation we will apply a generic 'Integrated Natural Resource Management' (INRM) framework (Van Noordwijk et al., 2002) to the analysis of rubber production systems. It starts with identifying perspectives on problems and opportunities in the current situation, specifying land use options that can then be compared in their impacts on productivity, socio-economic consequences and environmental impacts. The next step in the analysis is focussed on the tradeoffs between the multiple functions identified, and the discussion of policy options for modifying incentives that will induce land users to take decisions that support public goods as well as their direct interests.

2. Intensification & development pathways for smallholder rubber producers

Tomich et al. (2001) and Murdiyarso et al. (2002) compared the overall productivity and environmental impacts of rubber agroforest, rubber plantations and a number of other land use systems for Jambi and concluded that rubber was losing out from oil palm under current price regimes, and that specific efforts are needed to keep rubber systems competitive.

A number of 'intensification' pathways exist for current rubber agroforest owners:

- a) 'Smallholder Rubber Development Project' (SRDP) style projects for *monocultural plantations* -- despite heavy WB & ADB investment only 10% of the target farmers may have been reached, with very limited spontaneous adoption of the clone-based technology outside of project areas,
- b) *Clear-and-replant* based on the introduction of robust, productive clones (such as PB260), as in the Smallholder Rubber Agroforestry Project (SRAP of CIRAD/ ICRAF/ Gapkindo/ Sembawa), that can be used with reduced weeding & fertilizer compared to current technical recommendations, intercropped with fruit or timber trees, or while allowing secondary forest development in the interrows,
- c) '*Sisipan*' (Joshi et al., 2002)-- gap-level interplanting of rubber and enrichment planting of other trees into existing rubber gardens, potentially using in-situ grafting techniques to reduce the non-productive period associated with a clear-and-replant.
- d) Intensified management efforts on the *non-rubber components* of rubber agroforests for higher timber or fruit output
- e) Shift towards *oil palm*

3. Productivity, sustainability, quality issues

In 1994 ICRAF in association with Cirad-France and Sembawa research center established a network of trials to study rubber agroforestry systems and test different approaches suitable for different conditions under SRAP (Smallholder Rubber Agroforestry Project). Three different systems suitable in most conditions were tested in trial with active participation of farmers:

Rubber agroforestry system-type 1 (RAS1). In this system natural vegetation is left in the interrow and minimum weeding is performed on the rubber planting row only. The aim is to reduce maintenance cost and to recreate an environment similar to jungle rubber.

Rubber agroforestry system-type 2 (RAS 2). Clonal rubber is associated with food crops and tree crops (fruit trees and timber trees) in order to optimize land use and generate additional incomes.

Rubber agroforestry system-type 3 (RAS 3). In imperata grass lands rubber is associated with legume shrubs and fast growing trees in order to control imperata by shading. The system aims at reducing investment cost (limited use of herbicides, no legume cover crops)

In 2002, at the end of the immature stage, results showed that RAS systems are very well adapted to local constraints. There is a considerable demand from surrounding farmers who want to join the project or develop similar systems on their own. Impact analysis carried out in 2000 shows that 60 % of SRAP farmers have replanted in the last 5 years using agroforestry techniques. The low availability of improved rubber planting material in villages is considered as the major limitation for new field development.

Box 1. Experimental forms of Rubber Agroforestry Systems: RAS 1-3

The first system (RAS 1) is similar to the current jungle rubber system, in which unselected rubber seedlings are replaced by clones selected for their potential capacity for adaptation¹. These clones must be able to compete with the natural secondary forest growth. Various planting densities (550 and 750 trees/ha) and weeding protocols are being tested to identify the minimum amount of management needed for the system. This is a key factor for farmers whose main concern is to maintain or increase labour productivity. The biodiversity is presumed to be very similar to that of jungle rubber, which is quite high and relatively close to that of secondary forest at the same age. This system is probably the closest to the concept of fallow enrichment and suits a vast number of farmers because of its simplicity.

The second, RAS 2, is a complex agroforestry system in which rubber trees (550/ha) and perennial timber and fruit trees (92 to 270/ha) are planted after slashing and burning. It is very intensive, with annual crops being intercropped during the first 3 or 4 years, with emphasis on improved upland rice, and with various rates of fertilization as well as dry-season cropping with groundnuts, for instance. Several variations of crop combinations are being tested including food crops or cash crop such as cinnamon. Several planting densities of selected species are being tested according to a pre-established tree typology, in particular with the following species: rambutan, durian, petai and tengkawang. Biodiversity is limited to the planted species (between 5 and 10) and those that will regenerate naturally and will thus be selected by farmers.

The third system, RAS 3, is also a complex agroforestry system with rubber and other trees planted in a similar way to RAS 2; the difference being that this system is used on degraded lands covered by *Imperata cylindrica*, or in areas where *Imperata* is a major threat. Labour or cash (for herbicides) for controlling *Imperata* are the main constraints. In RAS 3, annual crops, generally rice, are grown in the first year only, with non-vine cover crops planted immediately after the rice harvest (*Mucuna spp*, *Flemingia congesta*, *Crotalaria spp*, *Setaria* and *Chromolaena odorata*), multipurpose trees (*Psophocarpus* (wingbean), *Gliricidia sepium*), or fast growing trees for use as pulpwood (*Paraserianthes falcataria*, *Acacia mangium* and *Gmelina arborea*) can be planted (several combinations are currently being tested). The objective here is to eliminate the weeding requirement by providing a favourable environment for rubber and the associated trees to grow, thus preventing the growth of *Imperata* with limited labour requirements. The association of non-vine cover crops and MPT²s for shade is aimed at controlling *Imperata*. Biodiversity is expected to be similar to that of RAS 2.

¹ The selected clones are PB 260, RRIC 100, BPM 1 and RRIM 600.

² MPT : multi purpose tree.

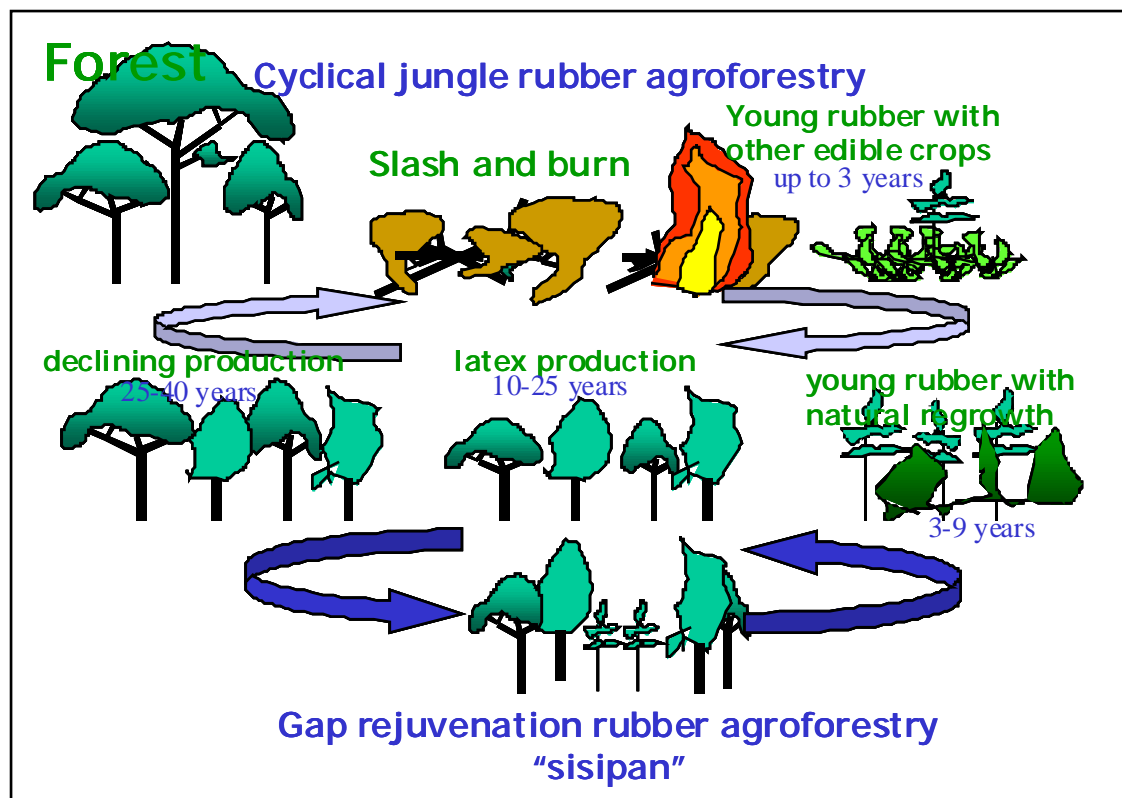


Figure 1. Two options for rejuvenation of rubber production systems: a rotational system and one based on 'sisipan' or gap-level interplanting (after Laxman, 2002)

During the research on the RAS 1-3 systems, we realized that all three of these systems rely on a clear-and-plant ('tanam') approach, with the 'clear' often in the form of 'slash-and-burn'. In fact Indonesian farmers use a different strategy as well: *sisipan* or interplanting into existing vegetation.

Our current understanding that *sisipan* techniques have been the response of smallholders who do not have resources to invest in a 'clear and replant' operation, and who want to maintain the options of deriving continuous income, even at a low level, from the garden during the immature period of the newly planted trees. Financial profitability calculations (Wibawa et al., 2002) suggest that as long as yield levels can be maintained above 700 kg DRC ha⁻¹ year⁻¹ and for the high discount rates that smallholders face, the *sisipan* system is superior.

4. Farmer knowledge, HH decision making, returns to land and labour

A comprehensive assessment of profitability for land use alternatives in lowland Sumatra was reported by Tomich et al. (2001). Rubber agroforests in their current or intensified form can provide employment opportunity for population densities up to 60 – 80 persons km⁻² at a 'return to labour' that is just about competitive with urban wage rates (at the official 'minimum wage rate' that may reflect a 'target' rather than the real 'minimum'). Oil palm in this calculation offers about double the returns to labour – still below what legal/illegal logging can provide...

Table 1. Returns to labour, labour requirements for establishment of the various land use type and average annual labour requirements in the operational phase and the human population density that can be supported assuming 150 work days per year per average person and 80% of the land area available for productive land use (Modified from: Tomich *et al.*, 2001)

Land- use type	Returns to labour, relative to minimum wage rate		Labour requirement (Person-days ha ⁻¹)			Equivalent population density, people km ⁻²
	Private prices	Social prices	Establishment phase	Operation phase	Total	
<i>Community forestry</i>	2.9	2.8	Na	0.2 - 0.4	0.2 - 0.4	0.2
<i>Logging,</i>	-4.3 - 0.5	2.0 - 7.8	15 - 100	17 - 41	31	17
<i>Rubber agroforest</i>	1.0	1.0	271	157	111	59
<i>Rubber agroforest_intensified</i>	1.0 - 1.7	1.1 - 1.9	444	74	150	80
<i>Rubber plantations</i>	1.7	0.7	344	166	133	71
<i>Oil palm plantations</i>	1.5	2.5	532	83	108	58
<i>Sh.Cult. upland rice</i>	0.75	0.95	Na	15 - 25	15 - 25	11
<i>Cassava,</i>	1.05	1.05	Na	98 - 104	98 - 104	54

The data show that the historical switch from upland food crops to tree crops has allowed a substantial increase in rural population density – and has during peak prices for rubber actually attracted the migrant flows to reach close to the potential population densities in much of the range.

5. Environmental impacts

5a. Watershed functions

The main concerns about rubber effects on watershed functions relate to erosion in the initial land clearing from forest, as well as in subsequent clear-and-replant cycles. Recent measurements in Jambi have shown that the combination of rubber and upland rice can provide sufficient ‘filter functions’ that prevent sediment transfer to streams. Water use of rubber agroforests is probably less than that of oil palm plantations. Overall the issue of watershed functions does not differentiate strongly between the various alternatives.

5b. Biodiversity conservation: rubber agroforests as last reservoir of lowland forest species

Since the early 1970s forests in the Sumatran lowlands are being rapidly transformed by large-scale logging and estate development (oil palm, trees for pulp and paper factories), turning the extremely species-rich lowland rainforest into large,

monotonous monoculture plantations. In terms of forest biodiversity, not much can be expected from such plantations, while on the other hand strict conservation of sufficiently large areas of protected lowland rainforest has not been a realistic option in the process of rapid land use change. The ongoing development is changing the role of rubber agroforests in the landscape: from adding anthropogenic vegetation types to the overall natural forest diversity, rubber agroforests are probably becoming the most important forest-like vegetation that we can find covering substantially large areas in the lowlands. It has become a major reservoir of forest species itself and provides connectivity between forest remnants for animals that need larger ranges than the forest remnants provide.

While ecologists are aware that jungle rubber cannot replace natural forest in terms of conservation value, the question whether such a production system could contribute to the conservation of forest species in a generally impoverished landscape is very relevant. However, jungle rubber farmers are not interested in biodiversity in the sense conservationists are. They make a living by selectively using species richness and ecosystem functions, and base their management decisions on maximizing profitability and minimizing ecological and economical risks. Michon and De Foresta (1990) were the first to draw attention to this issue, including the need for researchers to take both the farmers perspective and the ecologist's perspective into account. They started the discussion on complex agroforestry systems and the conservation of biological diversity in Indonesia, and pleaded for "assessment of existing and potential capacity of agricultural ecosystems to preserve biological diversity".

As part of a research programme on complex agroforestry systems, researchers from Orstom and Biotrop started working on biodiversity in rubber systems in the Sumatra lowlands (De Foresta and Michon 1994). Vegetation profiles were drawn of four jungle rubber plots in Jambi province (Kheowvongsri 1990) and one in South Sumatra province (De Foresta 1997), including lists of tree species and analysis of structure. In addition, a 100 meter transect line was sampled for all plant species in a natural forest and a jungle rubber garden in Jambi and a rubber plantation in South Sumatra. Bird species (Thiollay 1995) and soil fauna were compared between natural forest and jungle rubber, and an inventory was done to document the presence of mammal species in jungle rubber. In an overview paper presenting the results, Michon and De Foresta (1995) conclude that different groups are affected differently by human interference. Levels of soil fauna diversity are quite similar between forest and agroforest, while bird diversity in the agroforest is reduced to about 60 percent of that in primary forest, with a shift from typical forest birds (including ground dwellers) to birds of more open vegetation. Danielsen and Heegaard (1994 and 2000) confirmed the results of Thiollay (1995) that different groups of birds were affected differently by changes in vegetation structure, floristic richness and associated variety of food resources. Some groups were drastically reduced while others were thriving in agroforests.

Almost all forest mammals were found to be present in the agroforest, but population densities were not studied yet, and occasional recordings of rhinoceros or elephant do not indicate that agroforests are in themselves a suitable habitat for 'charismatic megafauna'. For vegetation Michon and de Foresta (1995) concluded that overall diversity is reduced to approximately 50 percent in the agroforest and 0.5 percent in plantations. These statements on relative diversity, however, apply to plot-level assessments only and cannot be extrapolated to larger scales, until we have data on the scaling relations beyond the plot for forest as well as agroforests. Another

multi-taxa study (including plants, birds, mammals, canopy insects and soil fauna) was reported by Gillison et al (1999) and covered a wider range of land use types, from forest to *Imperata* grassland, with similar results for the relative diversity of agroforest. From these studies it is clear that jungle rubber is an interesting system potentially combining biodiversity conservation and sustainable production, but some questions remain. Apart from signalling changes in overall species richness, understanding the ecological significance of differences in species composition between forest, jungle rubber and rubber plantations is necessary to be able to judge the value of jungle rubber for the conservation of forest species. Another problem to be solved is the problem of scale. Results from studies based on few plots or relatively small plots in a limited area cannot be safely extrapolated, as some land use types are more repetitive in species composition than others (alpha versus beta diversity).

Studying terrestrial pteridophytes, Beukema and van Noordwijk (in press / 2002) found that average plot level species richness was not significantly different amongst forest, jungle rubber and rubber plantations, however at the landscape level the species-area curve for jungle rubber had a significantly higher slope parameter, indicating a higher beta diversity. When pteridophytes were grouped according to their ecological requirements, the species-area curves based on 'forest species' alone were far apart, showing that jungle rubber supports intermediate numbers of forest species as compared to natural forest (much higher) and rubber plantations (much lower).

We can conclude from all these studies that jungle rubber is indeed diverse, but also that it is different from forest as a habitat that has more gaps and open spaces, and in scaling relations. The percentages of forest species conserved in complex agroforestry systems such as jungle rubber are not easily estimated from the relative richness at plot-level, as they depend on taxonomic or functional group, and on the scale of evaluation.

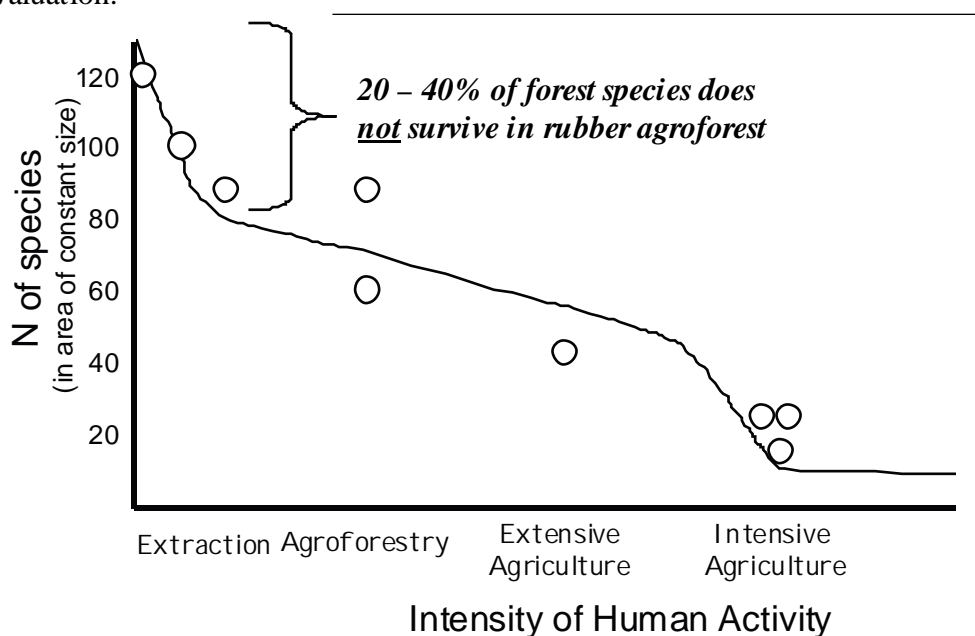


Figure 2. Plant species richness across a land use intensity gradient in Jambi (Murdiyarto et al., in press); the accolade indicates species that go locally extinct when humans are active: they are either exploited or sensitive to disturbance (Van Schaik and van Noordwijk, 2002)

Biodiversity studies in jungle rubber have been integrated with socio-economic and agronomic studies from the beginning (Gouyon et al 1993). To optimally use limited research capacity, further biodiversity studies should ideally be targeted at taxonomic groups that are either of direct interest to farmers, such as timber trees and other secondary products (Hardiwinoto et al 1999, Philippe 2000), or that are important to ecosystem functioning (soil fauna, pollinators, seed dispersers). There is also an important role for biological research in studying effects of the secondary forest component such as competition for light and nutrients (Williams, 2000), or the ecology of vertebrate consumers of rubber seeds and seedlings (pigs) or young leaves (monkey) (Gauthier 1998) and fungal diseases of rubber.

5c) C stocks

Tomich et al. (2002) compared data for the ‘time-averaged C stocks’ for the different land use systems. Whereas natural forest will have C stocks of 250 Mg C ha⁻¹ for sustainably logged forest the time-averaged C stock will be around 150 Mg C ha⁻¹, and that of the cassava/Imperata cycle would bring this down to around 40 Mg C ha⁻¹, the values for rubber plantations and agroforests will be 100 – 120 Mg C ha⁻¹, the sisipan technique can increase this to say 120 – 140 Mg C ha⁻¹, and oil palm plantations operate at about 90 Mg C ha⁻¹.

6. Trade-offs between private and public benefits; is there a role for ‘environmental service payments’? – ecolabelling??

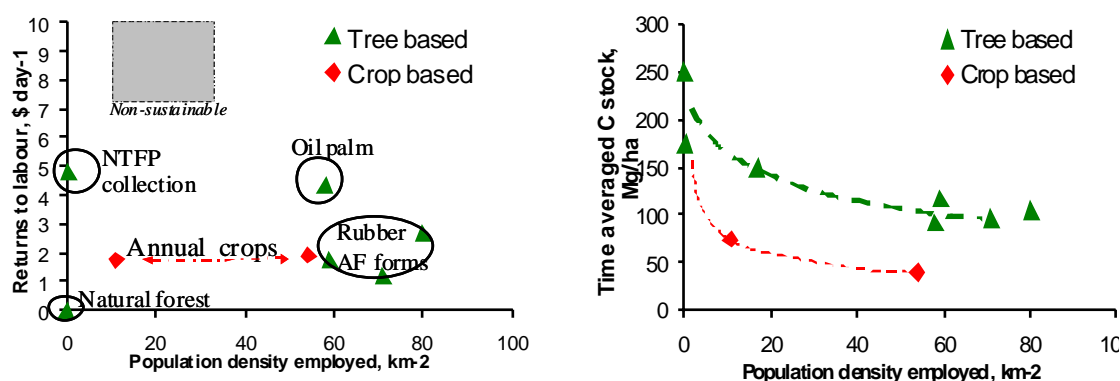


Figure 3 Tradeoffs between population density, returns to labour and time-averaged C stock for land use alternatives in Jambi

Overall, the tree crop systems are ‘win win’ solutions from a environment & development perspective, as they allow for higher population densities, income as well as C stocks when compared to food crop production. Within the tree crops, however, there is a negative tradeoff between environmental attributes and income.

By far the most distinguishing element in comparisons between tree crop systems is the ‘biodiversity’ issue – with the extensive rubber agroforests indeed in a very special position. Although 20 – 40% of forest species does not survive in rubber agroforest, the other 60 – 80% can and in the absence of effectively conserved lowland forest in Sumatra, makes the current rubber agroforests a major reservoir of biodiversity..

ICRAF and partners are currently interested in the options of an ‘ecolabelling’ type approach to capture a higher price for these extensive forms of rubber production. A full analysis of this issue is beyond the scope of the current presentation.

7. Scenarios, likely trends -- relevant policy response, priorities for research and development

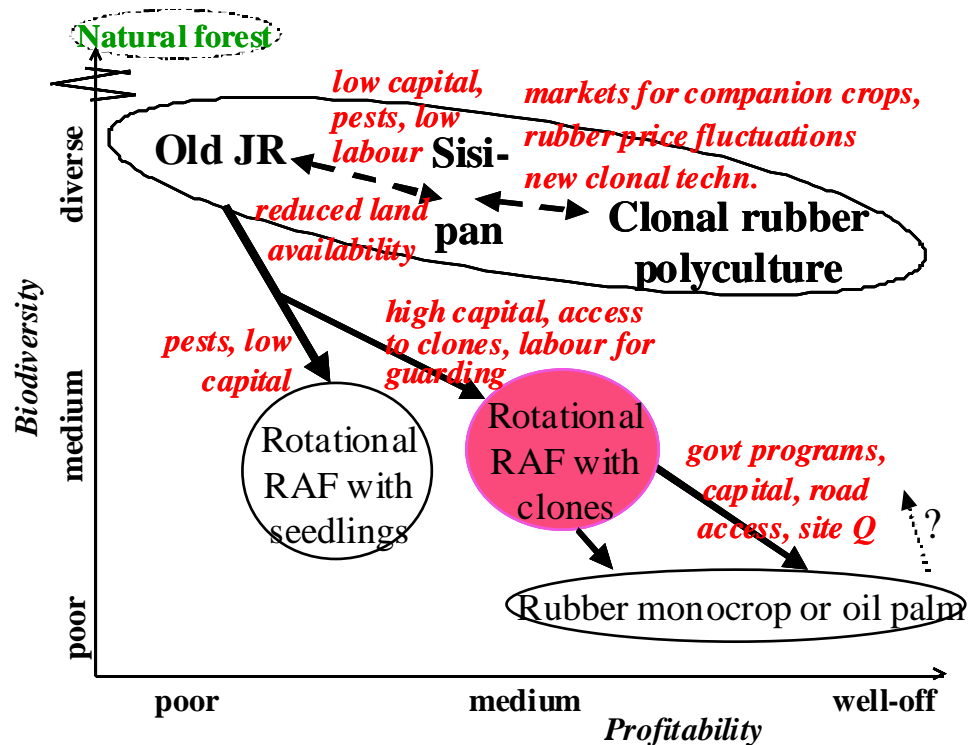


Figure 4. Current understanding of the driving forces that influence farmer decisions in the tree crop domain, and their consequences for profitability and biodiversity.

Although still rather sketchy, our current understanding of the farmer decisions in Jambi that have led to the current ‘old jungle rubber’ situation and the options available, points to access (roads) and specific subsidies or cheap credit still being the major drivers towards oil palm conversion (along with expansion of local processing capacity), while improving markets for farmer-grown timber and fruits being the main incentive to the enrichment planting strategies and ‘clonal rubber polyculture’ as idealized target.

It seems likely, however, that the current ‘environmental service’ provided by jungle rubber farmers in the form of biodiversity conservation will not last – unless there are specific incentives that reward for this service. This reward may have to be ‘areas based’ (paying farmers for not-intensifying in part of the domain), based on higher value of the rubber (‘green rubber’) or on the direct value of other products from these extensive systems. The latter will be the most sustainable, but may need help in a transition period. The main challenge thus is (Fig. 5): can we connect the ‘bottom end’ of the rubber producers (in terms of technology and status) to the ‘top end’ (most environmentally conscious) of the consumers?

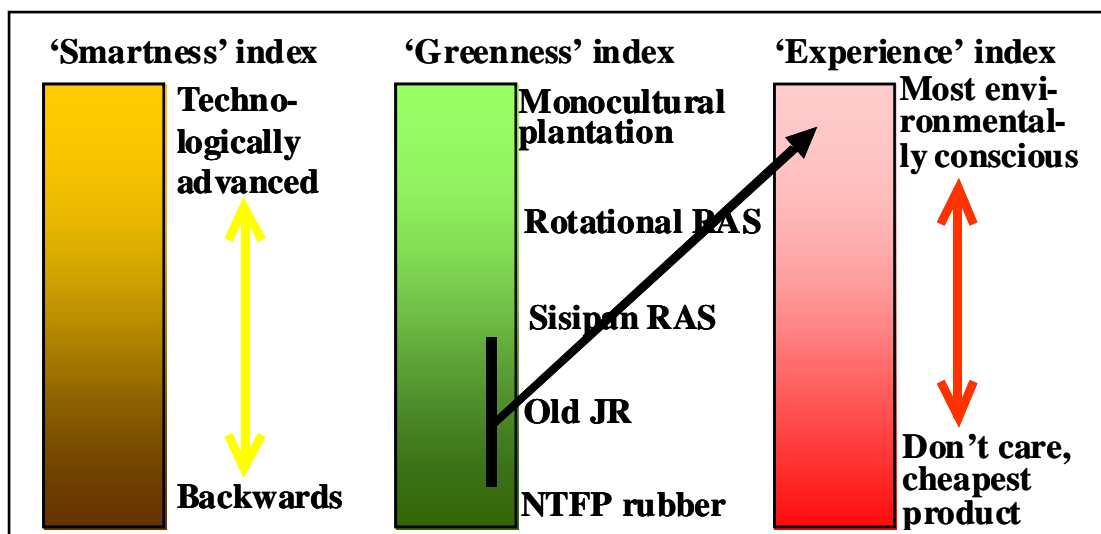


Figure 5. Key question on any form of ‘ecolabelling’ of rubber: “Is it possible to link the ‘most green’ part of the natural rubber (NR) production spectrum to the most ‘environmentally conscious’ consumers -- and obtain better prices for the farmers involved?”

References on ICRAF’s research on rubber agroforestry in Jambi:

- Beukema H and van Noordwijk M, (in press) Terrestrial pteridophytes as indicators of a forest-like environment in rubber production systems in the lowlands of Jambi, Sumatra. *Agriculture, Ecosystems and Environment*, *in press*
- Joshi, L., Wibawa, G., Beukema, H.J., Williams, S.E. and Van-Noordwijk, M., 2002. Technological change and biodiversity in the rubber agroecosystem in J. Vandermeer (Ed.) *Tropical Agroecosystems: New Directions for Research*. CRC Press, Baton Rouge, FL
- Ketterings, Q.M., Wibowo, T.T., Van Noordwijk, M.N. and Penot, E., 1999 Slash-and-burn as a land clearing method for small-scale rubber producers in Sepunggur, Jambi Province, Sumatra, Indonesia. *Forest Ecology and Management* 120: 157-169
- Ketterings Q.M., Van Noordwijk, M. and Bigham, J.M., 2002. Soil phosphorus availability after slash-and-burn fires of different intensities in rubber agroforests in Sumatra, Indonesia. *Agriculture, Ecosystems and Environment* 92: 37-48.
- Murdiyarto D., Van Noordwijk M., Wasrin, U. R., Tomich T.P. and Gillison A.N., 2002. Environmental benefits and sustainable land-use options in the Jambi transect, Sumatra, Indonesia. *Journal of Vegetation Science* 13: 429-438
- Tomich, T.P., Van Noordwijk, M., Budidarseno, S., Gillison, A., Kusumanto T., Murdiyarto, D. Stolle, F. and Fagi, A.M., 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*. CAB-International, Wallingford pp 221-244
- Tomich, T.P., de Foresta, H., Dennis, R., Ketterings, Q.M., Murdiyarto, D., Palm, C.A., Stolle, F., Suyanto, S. and Van Noordwijk, M., 2002. Carbon offsets for conservation and development in Indonesia? *American Journal of Alternative Agriculture* 17: 125-137

- Van Noordwijk, M, Williams, S.E. and Verbist, B. (Eds.) 2001. Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from:
<http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm>
- Van Schaik, C.P. and van Noordwijk M., 2002. Agroforestry and biodiversity: are they compatible? In: S.M. Sitompul and S.R. Utami (Eds.) *Akar Pertanian Sehat*. Proc. Seminar Ilmiah, 28 June 2002, Brawijaya University, Malang. pp 147-156.
- Wibawa G., Hendratno, S. and Van Noordwijk, M. 2002 Permanent smallholder rubber agroforestry systems in Sumatra, Indonesia: environmental benefits and reasons for smallholder interest. In : Sanchez P et al (eds.) *American Society of Agronomy*, Madison (W, USA) in press
- Williams, S. E. van Noordwijk, M., Penot, E., Healey, J. R., Sinclair, F. L. and Wibawa, G., 2001. On-farm evaluation of the establishment of clonal rubber in multistrata agroforests in Jambi, Indonesia. *Agroforestry Systems* 53 (2001): 227-237

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