Characterisation of biodiversity in improved rubber agroforests in West-Kalimantan, Indonesia. Real and Potential uses for spontaneous plants

Stéphanie Diaz-Novellon[1], Eric Penot[2], Michel ARNAUD[3].

[1]Centre National d'Etudes Agronomiques des Régions Chaudes (CNEARC), 1101 avenue Agropolis - BP 5098 34033 - MONTPELLIER cedex 01, diaz-novellon@wanadoo.fr

[2]Cirad-Tera, programme TH, Montpellier, France : Penot@cirad.fr

[3]Cirad-Tera, programme ERR, Montpellier, France, Arnaud@cirad.fr

1 Introduction : the improvement of jungle rubber.

Since the introduction of rubber at the turn of the 20th century smallholders have developed an original complex agroforestry system called jungle rubber in which non selected young rubber trees (seedlings) are managed extensively alongside secondary forest re-growth.

The issue of improving smallholder rubber productivity at affordable capital investments and levels of inputs while maintaining the environmental benefits of jungle rubber has been addressed by the Smallholder Rubber Agroforestry Project (SRAP: a joint project run by ICRAF, GAPKINDO and CIRAD). In 1995-1996, 27 trials (with a total of 100 plots) were set up in three provinces in Indonesia to assess the possibility of associating clonal rubber with agroforestry practices under smallholder conditions (Penot, 1997). Two RAS types were selected for this study: RAS n° 1 and n° 3. RAS n° 1 is basically improved jungle rubber using clonal planting material (see a description of RAS types in annexe 1). The rubber trees are in competition with spontaneous vegetation in the inter-row but results show that there are no negative consequences for rubber growth during the immature period. RAS n° 3 was designed for areas infested by *Imperata cylindrica*, with the establishment of shrubby leguminous cover crops and fast-growing tree species in the inter-rows with the aim of shading out weeds. The other type, RAS n° 2, is based on intercropping clonal rubber with various annual and perennial crops, including fruit and timber trees (Penot et al, 1994). In all cases, RAS have a planting density of 550 clonal rubber trees/ha and a variable number of associated fruit, timber or fast growing shade trees (from 92 to 256/ha).

In addition to the RAS experimental plots, "RAS sendiri" (or "endogenous RAS") are rubber agroforests improved by farmers without outside assistance.

The district of Sanggau in the province of West Kalimantan was identified by SRAP as representative of traditional jungle-rubber-based local farming systems that have developed over the last 90 years. The district of Sanggau is located in the central area of the Kapuas river basin, between 1° N and 0°6' S and 09°8' W and 11°33' E. The district covers 18 302 km2, i.e. 13 % of the province. The trial plots described in this study are located in the villages of Embaong, Engkayu, Kopar, and Trimulia (the last being in the transmigration area).

Most soils in the province of West-Kalimantan are acrisoils associated with ferralitic soils. Such soils have relatively good physical characteristics but poor chemical value and become acid. Rubber is widely grown in this area as it can grow in poor soils. The landscape is dominated by logged-over forest, secondary forest and a mosaic of jungle rubber and fallow with secondary forest re-growth. Large scale logging activities took place from 1950s to the 1980s at the expense of primary forest. At present, forested areas are located in hilly or remote areas and are very limited in extent. Oil palm and *Acacia mangium* plantations developed exponentially in the 1990s increasing the conversion of degraded forest areas into Estates that cultivate perennial crops.

The main objective of this study is to assess existing plant biodiversity in RAS systems compared to that of jungle rubber. The second objective is to review the current uses of certain plants and their market potential.

2 Methodology

The data presented in this paper was collected between August and October 2001 in 4 villages in the West-Kalimantan provinces and included 23 rubber agroforests plots. The nature of the previous vegetation, neighbouring vegetation and soil characteristics were recorded in addition to classical data collected from plots used for on-farm trials (rubber growth. etc).

2.1. Transect method

In order to qualify existing biodiversity, the "transects" method was used with a sampling size per transect of 1 m x 0,2 m, and 15 replications for each treatment. The measurement criteria for floristic analysis classically used with agroforestry systems are: i) abundance, ii) density, iii) frequency and iv) dominance. In addition, in our study data were collected on the number of species and identity.

This method was implemented to try and cover a wide range of situations. However, the results obtained with this method do not allow a direct comparison of biodiversity between cropping systems (between RAS and jungle rubber) because the initial plots (the transects) are too small. Further analysis merging replications into larger transects should provide information that will enable comparison of systems. Further research is therefore required, both in the field to cover a wider range of situations and in data processing to complete the picture. This paper presents the preliminary results.

2.2. Statistical analysis : the use of correspondence analysis

Statistical analyses (correspondence analysis)[1] was implemented using "Winstat", a software developed by CIRAD. This analysis allowed us to focus on different effects that influence plant biodiversity in rubber inter-rows under the different systems. The five first axes were taken into account for each analysis. Data were collected in RAS systems as well as in selected fallow plots with different densities of existing vegetation. The plotting was as follows: 23 RAS plots, fallow plots respectively 1,2,3,4 and 5 years old, 6-year-old jungle rubber plots (the same age as RAS plots), some *tembawang* plots *(Tembawang* are fruit and timber agroforestry systems developed by Dayak people) and some secondary forest plots near the study villages. Complete detailed results are available in Diaz Novellon's MSc. Thesis (2001)

The S-Plus software[2] allowed us to implement discriminating analyses to explain variations in variables of diversity as a function of different explanatory variables (a "TREE function"). The selected variables of diversity were i) the number of species per replication, ii) the number of individuals in a replication (all species included) and iii) the ratios of individuals/number of species (N). These variables of diversity were correlated with different explanatory variables such as:

- The village: Kopar, Engkayu, Embaong, Trimulya;
- The farmer (21);
- The type of RAS (RAS 1 or RAS 3);
- The sub-type of RAS (RAS1.1/1.2/3.1/ 3.2/ 3.3/ 3.4)[3];
- The treatment (A, B, C, D, E, F, G, H, I, J);

[1] In French : AFC = analyse factorielle des correspondances.

[2] This software is available on the web and is usually used for botanical analysis.

[3] RAS trials are subdivided to study one component per trial in order to keep the procedure very simple and useable by farmers. Treatments are planting density, type of clones, weeding intensity and so on

- The surrounding plot environment (forest, fallow, jungle rubber, oil palm, etc.);
- The type of crop or vegetation before rubber (annual crops, *Imperata cylindrica*, Jungle Rubber, fallow, secondary forest, etc.)

3. Assessment of the biodiversity under rubber agroforestry systems: a comparison between jungle rubber and RAS n°1 & 3.

Specific diversity, i.e. the number of species, appears to be higher in jungle rubber than in improved rubber agroforests (RAS).

Graph 1 and 2 show the main results of the effect of environmental factors and previous vegetation on the biodiversity of each system (graph 2) and a comparison of the density (number of species and replications) between RAS and jungle rubber of the same age (graph 3).

However, in RAS n° 3.4 in which fruit and timber trees are planted in the inter-rows, the biodiversity of a number of species per transect is comparable to that of jungle rubber. A similar result was observed with "RAS sendiri". It thus appears that the different cultivation methods can directly influence the spontaneous diversity of plants in the inter-rows, and in fact, experimental RAS, RAS sendiri and jungle rubber are managed differently resulting in a significant "farmer effect" .

According to trial protocols discussed each year with project farmers the number of weedings in the inter-rows is higher in the case of RAS. In practice in RAS, weeding is limited to the selective cutting of trees and shrubs that grow taller than young rubber trees, as compared to jungle rubber, where there is no weeding at all during the first few years. Weeding appears to be the main factor that influences plants diversity. When the cutting of spontaneous vegetation of the inter-row is spread out over time, the number of species is higher. On the other hand, the type of rubber trees (clonal or seedlings) does not influence the type, the diversity and the quantity of vegetation. Inter-row biodiversity is therefore more influenced by the farming practices and in particular by the frequency of selective cutting or the number of weedings.

The distribution and biodiversity of RAS plots is shown in table 1.

Table 1: Distribution of plants per biological type for all plots

	Trees	Herbaceous	Lianas on the ground	Lianas on trees	Bamboo rattan	Shrubs
Number of plants	113 8	2480	368	128	54	231
Number of spe- cies	55	24	7	6	1	3

One important question concerning the comparison between RAS and jungle rubber is whether jungle rubber has a higher specific plant density, i.e. the number of plants per unit area, than that of improved rubber agroforests.

Our results show that jungle rubber does indeed have more individual plants in inter-rows than RAS, although the density of plants is very similar to that of "RAS sendiri". The different agroforestry practices (and in particular the frequency of selective cuttings) explain this difference. In comparison to biodiversity in secondary forest or *tembawang*, the number of species appears to be similar to that of RAS when the ground-level density of specie*s* is considerably lower (see further tables). In other words, the difference is mainly quantitative.

What are the most significant factors that explain the variation in biodiversity? Discriminating analyses showed that previous farming practices are a significant factor. An area that had been cultivated for at least 3 years showed higher specific biodiversity than fallow. A possible explanation for this result is that cultivated areas as "open systems" have a more significant seed bank and can collect seeds from surrounding forests or agroforests. Environmental factors probably also influence biodiversity. The presence of jungle rubber in the immediate vicinity induces greater biodiversity. 1 to 5 years of fallow around plots probably also increases diversity. As far as agricultural practices are concerned, the number of selective cuttings per year appears to be the most significant factor influencing plant biodiversity in the inter-row[4].

Previous results on jungle rubber biodiversity that were available to the author (Werner 97, De foresta, 97) as well as a guide book on plant uses (Levang & al, 1991) provided very useful preliminary studies for this paper.

Smallholders' perception of plant biodiversity.

It was immediately clear that local populations know the plant species in their fields and their specific uses perfectly well. During field surveys as well as during interviews with farmers, more than 300 species had to be indexed. The most

[4] Detailed results are available in the MSc Thesis by the author, see bibliography (Diaz Novellon, 2001).

common uses of spontaneous biodiversity (in forest and agroforests) are in order of importance: health (medicinal plants) food (fruit, vegetables), construction (wood and timber), firewood and others (see **table 2**).

Table 2: potential uses of biodiversity by the Dayak population

Uses	Number of species
Timber for construction, housing	83
Firewood	40
Timber for sale or furniture	2
Fruits	112
Vegetables	68
Medicinal plants	179
Animal food	24
Pulp (for paper)	1
Cosmetics	1
Colouring properties	2
Use as paper	9
Weed control	14
Insecticide	6
Handicraft	66
Latex	4
Oil	7
Fertilisation	14
Spices	55
Others	8

However most spontaneous vegetation is not yet used by the local population and is thus available other for "potential uses". Medicinal plants have considerable potential (see **table 3**), as they are not widely used as farmers prefer "modern" drugs, which are considered to be far more effective against malaria, diarrhoea and other illnesses.

Table 3: Uses of medicinal plants.

Diseases cured by local plants	Number of identified species
Coughs	12
Fever	23
Itching	15
Tiredness	11
Malaria	2
Dysentery	1
Throat	13
Toothache	1
Bellyache Belly sickness	44
Burns	9
Headaches	11
Others	11

In the case of timber and wood, the most valuable species (see **table 4)** are becoming scarce in the vicinity (in local forests) in the study area**.**

Table 4: Timber species that are becoming scarce in remaining forests

0Local names	Latin names	Village
Belian	Eusideroxylon zwageri	All villages
Tapang	Koompassia excelsa	Embaong, Kopar
Tekam		All villages
Benkirai	Shorea sp	Embaong
Meranti	Shorea spp	Engkayu, Trimulya
Terenak		All villages
Jeluntung	Dyera costulata	Trimulya
Kayu Raya	Shorea sp.	Kopar
Majau	Shorea palembanica	Embaong
Omang	Hopea dryobalanoides	Sanjan, Engkayu
Medang	Litsea elliptica	Kopar, Engkayu
Tunam	Shorea lamellata	Kopar
Nyatuh	Palaquium spp	Engkayu
Owan		Engkayu
Ubah	Glochidion sp	Sanjan, Engkayu
Taba	0Aquilaria malaccensis	Kopar
Keladan	1Dryobalanops beccarii	Engkayu
Tengkawang	Shorea macrophylla	Kopar

Most farmers are interested in integrating certain timber species see **table 5)** in their agroforests for both housing (construction) and sale.

Table 5: Timber species preferred by farmers.

Local names	Latin names
Belian	0Eusideroxylon zwageri
Keladan	Dryobalanops beccarii
Tekam	
Ketuat	
Meranti	Shorea spp
Terindak	Shorea senimis
Tengkawang	Shorea macrophylla
Mengkirai	
	1Trema orientalis
Mentibu	
Medang	Litsea elliptica

Nyatuh	Palaquium spp
Oman	Hopea dryobalanoides
Owan	
Jonger	Ploiarium alternifolium
Taba	Aquilaria malaccensis
Tantang	Buchania sessifolia

Prices vary considerably with the timber species, showing that this market is already well developed (**table 6).**

Table 6: Prices for local timber species

Timber species	Latin name	Price in rupiah
Belian		50 000 Rp / board
	0Eusideroxylon zwageri	
Raya		3 500 Rp / board
Jonger	Ploiarium alternifolium	4 000 Rp / board
Owan		8 000 Rp / board
Medang	Litsea elliptica	8 000 Rp / board
Paku		5 000 Rp / board
Tapang		20 000 Rp / board
Tengkawang	Shorea macrophylla	4000 to 10 000 Rp / board
Tantang	Buchania sessifolia	200 000 Rp / m2

Note : 1 US $ = 10500 Rp in July 2001.

Some local species are maintained or preserved by replanting or favouring regeneration from natural re-growth in the different types of agroforests (**table 7**) and have a range of different uses.

Table 7: Spontaneous timber species maintained in local agroforests and their uses.

Local names	Latin names	Uses
Leban	Vitex pinnata	Timber, wood, spice, medicinal
Medang	Litsea elliptica	Timber, latex
Ramboutan	Nephelium lappaceum	Fruits, timber
Jengkol	Pithecellobium jiringa	Fruits, vegetable, timber, medicinal
Durian	Durio zibethinus	Fruits, timber
Pingam	Artocarpus sp	Fruits, timber, vegetable
Cempedak	Artocarpus integra	Fruits, medicinal, vegetable
Lengsat	Lansium domesticum	Fruits, medicinal, handicrafts
Pekawai	Durio c.f. dulcis	Fruits
Mentawa	Artocarpus c.f. anisophyllus	Fruits
Nyatuh	Palaquium spp	Timber, latex
Owan		Timber, handicrafts

Bungkang	Polyalthia rumpfii	Timber, spice
Belian	Eusideroxylon zwageri	Timber
Ubah	Glochidion sp	Timber
Kemenyan	Styrax benzoin	Timber, latex, animal food
Tantang	Buchania sessifolia	Timber
Bidara	Nephelium maingayi	Fruits

Some of these species have been re-introduced in agroforests (see **table 8**), in particular in "*tembawang*", or are protected when they emerge in natural regrowth in jungle rubber and RAS systems.

Table 8: Local species reintroduced in agroforest

Local names	Latin names	Uses
Jengkol	1Pithecellobium jiringa	Fruits, vegetable, timber, medicinal
Mangga	Mangifera indica	Fruits
Ramboutan	Nephelium lappaceum	Fruits, timber
Manggis	Garcinia mangostana	Fruits
Durian	Durio zibethinus	Fruits, timber
Cempedak	Artocarpus integra	Fruits, medicinal, vegetable
Coklat		Cocoa
Kopi		Coffee
Petai	Parkia speciosa	Fruits, vegetable
Lengsat	Lansium domesticum	Fruits, medicinal, handicraft
Kedupai	Mischocarpus pentapetalus	Fruits
Sibau	Xerospermum norotanum	Fruits
Mentawa	Artocarpus anisophyllus	Fruits
Pekawai	Durio c.f. dulcis	Fruits
Melinjo	Gnetum gnemon	Fruits, vegetable
Nangka	Artocarpus heterophyllus	Fruits
Tengkawang	Shorea macrophylla	Fruits, oil, timber
Tekam		Timber, handicraft
Ketuat		Fruits, timber
Tempuih	Baccaurea sp	Fruits
Pisang	Musa spp	Fruits, vegetable, medicinal

Some other species that farmers do not consider suitable in RAS inter-rows were also identified (**table 9**). These species are in fact still used in that their products are still collected in true forests, but are not specifically selected in agroforests due to the fact that – at least in the farmers' opinions - they may have a negative effect on rubber growth or production.in the farmers' opinions For example, after 20 years of growth the number of durian trees per hectare has to be limited to less than 20 to reduce shading when the durian's canopy begins to outgrow that of rubber. Another example is "tengkawang" (Illipe nut tree) which is considered to "dry" soils and therefore limit rubber trees growth (although this observation has not been scientifically confirmed).

Table 9: List of species not chosen for agroforests and their uses

Local names	Latin names	Uses
Belangai	Eurya nitida	Timber, medicinal, handicraft
Tucet	Alstonia angustifolia	Timber
Plaik	Alstonia scholaris	Timber, latex, medicinal, handicraft
Bamboo		Housing, handycraft , various uses
Todoh	Phrynium capitatum	Wrapping
Ringkan	Ficus grossularoides	Fruits, wrapping, timber
Resak	Melastoma malabathricum	Timber, fruits, vegetable, medicinal
Pakis		
Semolang	Euodia aromatica	Medicinal, timber
Siyet	Sceria prupurescens	Medicinal
Entiup	Artocarpus sericicarpus	Fruits, oil, handicraft
Leban	Vitex pinnata	Timber, spices, medicinal
Jambu america	Bellucia axinanthera	Fruits, wrapping, timber
Alang-Alang	Imperata cylindrica	Medicinal
Marade		Timber

Certain species (see **table 10**) may be selected to limit invasion of *Imperata cylindrica* in young agroforests.

Table 10: Species used to limit Imperata cylindrica (alang²) in young agroforests.

Local names	Latin names	Type of action
Semenput		Shading
Beringing		
Melastoma	*Melastoma malabathricum*	Cover cropping
Coklat		Cover cropping
Nenas	*Ananas comosus*	Root competition
Gmelina	*Gmelina arborea*	Shading
Orok-Orok	*Crotolaria mucronata*	Competition with alang²
Gamal	*Gliricidia sepium*	Shading (limited)
Akacia	*Acacia* mangium	Shading
Albizia	*Albizia sp*	Shading

Table 11 summarises the different species in agroforests, *"tembawang"* and jungle rubber, RAS sendiri, RAS1 and RAS 3 as well as in "house gardens" of the local population (*pekarangan)* used and sold on local markets. It gives an idea of the wide variety of products that have an impact on both the household food supply and on the economy.

Conclusion: Market potential

Some forest products are of obvious economic interest (see **table 11**). Smallholders try to domesticate some of these species in the inter-rows of their agroforest (RAS and Jungle rubber), by replanting or favouring regeneration from natural re-growth, which has the advantage of involving almost no cost.

Timber species and fruit trees are particularly appreciated when they emerge from forest re-growth as they require no cost for plantation and very little additional labour to maintain. They are also replanted in order to enrich the vegetation in inter-rows.

Fruit trees have the most obvious potential market value , in particular durian (Durio zibethinus) which is already sold everywhere in Indonesia as well as in other countries in Southeast Asia (e.g. Thailand & Malaysia), rambutan and dukus, the latter profiting from a keen demand on the Indonesian market. National markets do not yet appear to be saturated but export would provide the best market for smallholders, particular in the case of durian, which could easily be exported to neighbouring Malaysia, and north Borneo. The lack of larger organised marketing channels other than the traditional Sino-Indonesian one is a severe obstacle to the expansion of fruit markets and exports.

As a result of the keen demand for timber and wood products such as plywood in consumer countries (Japan, USA, and Europe), a timber shortage may already be expected in the very near future. Smallholders in West-Kalimantan would be well advised to anticipate this trend and include in their agroforests inter-rows species that can be used to supply the demand of the the plywood industry. Some species (Nyatoh in particular /*Palaquium spp*.) have a life-span similar to that of rubber (30 to 40 years). The ultimate life cycle of rubber agroforestry systems might then completed with the exploitation of timber trees such as Belian (*Eusideroxylon zwageri*),(lifespan 60 years) or meranti (up to 90 years). In this way, old rubber-based agroforests may develop into "*tembawang*". Finally, at the end of rubber life-span, rattan might prove to be a useful crop as indicated by the strong demand for furniture for export.

One important obstacle is the Indonesian legislation on land and tree tenure that needs to be re-examined and adapted to the context of smallholder production whose future potential could be highly significant. At present regulations concerning timber exploitation practically precludes trade in timber from forest or agroforest by smallholders.

Other forest products with future potential are without any doubt medicinal plants. Local sales of these products although limited, has also gradually declined due to the effectiveness and availability of pharmaceutical products. However, pharmaceutical firms could be interested in several forest and agroforest species from Borneo and perhaps develop research projects that could indirectly benefit local populations. Examples of this type have been already been observed in other countries in Amazonia, as well as in Côte d'Ivoire where a product to control hypertension was discovered under rubber

Irrespective of how great the future potential of agroforest products is, and even if it is high for fruit, timber, rattan and medicinal plants, most products still remain under-exploited and this represents a great challenge for the very near future. Several contraints remain in terms of market organisation as well also as in terms of official regulations.

References

Diaz-Novellon S., Boutin D. Flora of rubber agroforests in the West Kalimantan Province. CD rom, SRAP, ICRAF-CIRAD Bogor, September 2001.

Diaz Novellon, S. (2001). Caractérisation de la biodiversité spontanée des agroforêts à hévéa en Indonésie : utilisation et potentialités des espèces utiles. CNEARC, Master of Sciences « Agronomie et Innovations en milieu rural ». Montpellier, CNEARC: 113 p.

De Foresta, H. (1997). Smallholder rubber plantations viewed through forest ecologist glassess. An example from South Sumatra. ICRAF/SRAP workshop on RAS (Rubber Agroforetsry Systems), Bogor.

Levang, P. and H. d. Foresta (1991). Economic plants of Indonesia : a Latin, Indonesian, French and English dictionary of 728 species. Bogor, Orstom - Seameo/Biotrop.

Penot, E. (1997). Introduction to SRAP methodology and concepts: summary of the preliminary results. The ICRAF/SRAP Workshop on RAS (Rubber Agroforestry Systems), September 1997, ICRAF, Bogor.

Penot, E. (1999). "Rubber Agroforestry Systems (R.A.S.) methodology and main results : technical report." CIRAD/ICRAF, project paper. Montpellier , February 1999.

Werner, S. (1997). Biodiversity of jungle rubber in West-Kalimantan. ICRAF/SRAP workshop on RAS (Rubber Agoforestry Systems), Bogor.

Annexe 1: description of the various RAS cropping system

RAS 1: an improved jungle rubber.

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 promising adaptation. These clones must be able to compete with the natural secondary forest growth; various planting densities and weeding protocols are tested. The biodiversity is very similar to that of jungle rubber, being itself close to that of secondary forest of the same age. (H. de Foresta, 1997). This system is similar to that originally tested by the dutch in the 1930' and called "jungle weeding" (Dijkman, 1950) after estates planters recognize that with the same unselected planting material, yields of jungle rubber were very comparable to that of estates with high weeding and intensive management. This prove that rubber, at least unselected rubber (seedlings), could grow and produce well in a complex agroforestry system with no major incidence on production. Clonal rubber requires definitely more weeding and maintenance that seedlings. The idea of RAS 1 is to reintroduce clones in a jungle rubber environment and to assess the minimum maintenance required for rubber to grow well. The main hypotheses derives from the precedent statement : rubber production, to a certain extend, is not affected by associated trees. In RAS 1, associated trees are not selected. These trees are those than grow naturally, however, farmers do a selection at opening (between 8 and 15 years after planting).

One main question might be the following " With an early opening (at 5/6 years old compared to 8/15 years with jungle rubber)), and consequently an earlier canopy closure : is biodiversity composition and evolution will be different ?, can we therefore expect the same type of biodiversity ?

RAS 2 : an intensified rubber agroforest with intercrops.

The second, RAS 2, is a complex agroforestry system in which rubber (550/ha) and perennial timber and fruit trees (92 to 152 trees/ha) are established 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 varieties of rice, with various amounts of fertilization as well as dry season cropping such as groundnut.

In that case, the number and type of trees associated to rubber are deliberately chosen at planting time.

Several combination of planting densities (92, 140 and 250 trees/ha) and of selected species are being tested according to a tree typology, in particular : rambutan, durian, petai and tengkawang. Biodiversity is limited to the planted species as well as those which naturally regenerate and are eventually selected by farmers.

The various types of RAS 2

In RAS 2.1 : Each field is divided in 5 plots (rubber + X) : rubber alone, Durian, Rambutan, Durian + Rambutan, farmer 's Mix (a combination of various fruit and timber trees)

In RAS 2.2 : fruit and timber trees are planted at 3 planting densities : 92, 140 and 150 trees/ha with rubber 550 trees/ha with a maximum of 30 big trees such Durian or timber trees. These planting density are within the range of what farmers already do in Sanjan for instance , without noticeable change in rubber production.

In RAS 2.5, rubber is combined with cinnamon (in the Jambi province) Cinnamon is collected at the 8th year. Cinnamon at 1000 trees /ha is planted with rubber 550 trees/ha in RAS 2.5.

RAS 3: a rubber agroforest adapted *to Imperata* grassland

The third system, RAS 3, is a complex agroforestry system with rubber and other trees planted with a frame similar to that of RAS 2; the difference is that it is established on degraded lands covered by *Imperata cylindrica,* or in area where *Imperata* is a major threat.

Imperata increase rubber immature up to 8/9 years (G Wibawa, 1995). Labour or cash for controlling *Imperata* with herbicide are the main constraints. In RAS 3, annual crops, generally rice, are grown the first year only, with non vine cover crops grown immediately after rice harvesting *(Mucuna, Flemingia, Crotalaria, Setaria and Chromolaena*) with a selection of trees : fruit and timber trees, multipurpose trees *(wingbean, Gliricidia..*) and fast growing trees as pulpwood for shading *(Paraserianthes falcataria, Acacia mangium or crassicarpa and Gmelina arborea* have been selected in West Kalimantan. The objective here is to eliminate the weeding constraint after the first year by providing a favourable environment for rubber and associated trees and consequently suppressing *Imperata* with low labour requirements. Several design and combination have been tried in RAS 3 in West Kalimantan.

The various types of RAS 3

RAS 3.1 (planting in 1995) : a preliminary test.

The different treatments where based on the use of the following trees (1 per treatment): Leucena leucocephala, Gliricidia sepium, Caliandra callothyrsus, Ceasalpinia sappam, Chromolena odorata and Flemingia congesta with classical LCC (legume cover crops) as a control. In addition , 250 fruit and timber trees are combined with 550 rubber/ha

RAS 3.2 (planting in December 1996) : confirmation test.

This trial was established according to the results of RAS 1 trial with the following trees : *Gliricidia s., Gmelina a.,* and the following cover crops: *Chromolena odorata, Crotalaria and Mucuna spp*.

The first control is rubber in monoculture + LCC. The second control is rubber monoculture + *Imperata.* In addition , 250 fruit and timber trees are combined with 550 rubber/ha

RAS 3.3 : no associated fruit/timber trees : pulp trees only

A first set of 4 replications has been planted in January 1996. The selected trees have been the following: Paraserianthes falcatarian Acacia mangium and Gmelina arborea. Rubber is at 550 trees/ha as well as pulp trees in the interrow (3 meters between tres on the pul tree line and 3 meters apart from the rubber line) . The covercrop is Flemingia.

RAS 3.4 : pulp trees + associated trees.

Same structure as RAS 3.3 with 1 pulp tree out of 3 replaced by associated fruit/timber trees: in that case : the planting densities are for rubber : 550/ha, for pulp trees : 460/ha and for associated trees : 92/ha

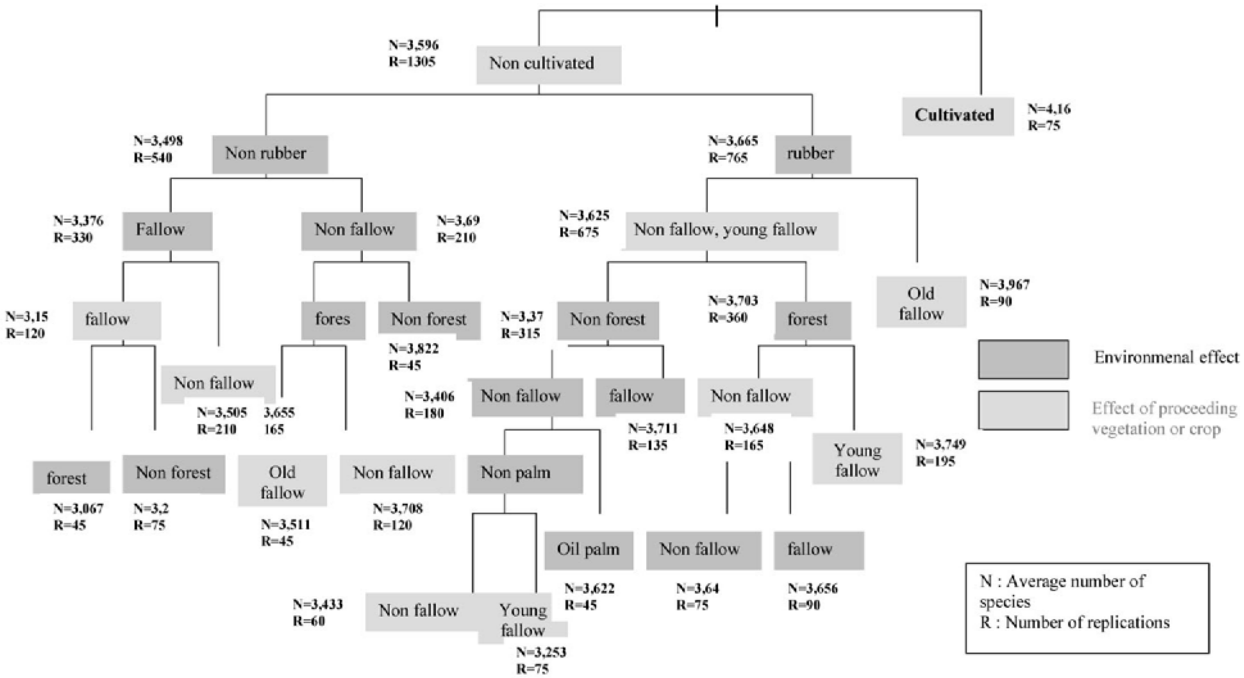
Table 11: Species and products already sold on local

Indonesian/local names	Latin names	Sale price	Origin
Pisang / Banana	Musa spp.	1 500 Rp /lot	Agroforêst
Pakis piding / ferns		500 Rp / lot	Agroforêst
Kangkong	2Ipomea aquatica	500 Rp / lot	
Cangkok manis		500 Rp / lot	Agroforêst
Daun kacang/bean leaves		500 Rp / lot	Home garden
Daun ubi / cassava leaves	Gnetum gnemon	500 Rp / lot	Agroforest
Bunga pisang/banana flower	Musa spp	1 000 Rp / fleur	Agroforêst
Jengkol	Archidendron pauciflo-rum	1 000 Rp / Kg	Agroforeesêt
Maram	Eleiodoxa conferta	2 000 Rp / Kg	Agroforest
Kacang panjang/bean	Vigna unguiculata	2000 Rp / Kg	Home garden
Timun /cumcumber	Cucumis sativus	2000 Rp / Kg	Home garden
Bunga jagung/maize flower	Zea sp	500 Rp / fleur	Pontianak
Bayam	Amaranthus hybridus	500 Rp / lot	Home garden
Petai	Parkia speciosa	2 500 Rp / Kg	Agroforest
Labu air / pumpkin	Lagenaria siceraria	2 500 Rp / Kg	Home garden
Jahe / gingember	Zingiber officinale	2 500 Rp / Kg	Home garden
Kelapa / coco nuts	Cocos nucifera	1 000 Rp / fruit	Home garden
Peringgi		4 500 Rp / Kg	Home garden
Kecambah		1 000Rp/portion	
Ubi / cassava	Manihot esculenta	2 500 Rp / Kg	Agroforest
Kedondong	Spondias pinnata	500 Rp / lot	
Pekawai	Durio c.f. dulcis	10 000 Rp /lot	Agroforest
Terong	Solanum melongens	5 000 Rp / Kg	Home garden
Cabe / pepper	Capsicum annuum	20 000 Rp / Kg	Pontianak
Buncis	Phaseolus vulgaris	3 500 Rp / Kg	
Gambas	Luffa acutangula	2 000 Rp / Kg	
Jeruk / lemon	Citrus sp	3 000 Rp / Kg	Home garden
Nangka / Jacqj fruit	Artocarpus heterophyllus	2 500 Rp / Kg	Agroforêst
Kencur	Kaempferia galanga	10 000 Rp / Kg	
Kunyit	Curcuma longa	5 000 Rp / Kg	Agroforest
Serai	Cymbopogon nardus	500 Rp / lot	Agroforest
Keladi	Colocasia esculenta	1 000 Rp / lot	Agroforest
Kundur	Benincasa hispida	2 500 Rp / Kg	
Asam	Tamarindus indica	500 Rp / fruit	Agroforest
Labu siam	Sechium edule	2 500 Rp / Kg	Home garden
Pane	Momordica charantia	5 000 Rp / Kg	Pontianak
Wartel / carott	Daucus carota	9 000 Rp / Kg	Pontianak
Jeruk nipis / lemon	Citrus aurantifolia	4 000 Rp / Kg	Pontianak
Kol / cabbage	Brassica oleraceae	5 000 Rp / Kg	Pontianak
Kentang / potato	Solanum tuberosum	4 500 Rp / Kg	Pontianak
Tomat / tomato	Lycopersicon esculentum	6 000 Rp / Kg	Pontianak
Bawang merah/red onion	Allium cepa	7 000 Rp / Kg	Pontianak

Bawang putih/white onion	Allium sativum	7 000 Rp / Kg	Pontianak
Kayu manis/cinnamon	Cinnamomum burmanii	2 000 Rp / lot	Agroforest
Nenas / pinepale	Ananas comosus	2 000 Rp / fruit	Agroforest
Sawih / cabbage	Brassica rugosa	5 000 Rp / Kg	Pontianak
Jambu air	Syzygium aquaeum	1 500 Rp / Kg	Home garden
Pepaya / papaya	Carica papaya	2 500 Rp / Kg	Home garden
Kenikir	Cosmos caudatus	500 Rp / lot	
Lengkuas	Alpinia galanga	1 000 Rp / lot	Agroforest
Daun salam / leaves	Eugenia polyantha	500 Rp / lot	Agroforest
Daun sop /celery leaves	Apium graveolens	1 000 Rp / lot	Home garden
Daun pepaya/ papaya leaves	Carica pepaya	500 Rp / lot	Home garden
Mangga	Mangifera indica	8 000 Rp / Kg	Agroforest
Petai	Parkia speciosa	2 000 Rp / lot	Agroforest
Kacang tanah/peanut		3 000 Rp / Kg	Home garden
Cempedak hutan	Artocarpus integra	500 Rp / fruit	Agroforest
Kumis kucing	Orthosiphon aristatus	1000 Rp / lot	Home garden

NB : These species ‘s latin names should be utilized cautiously because of the difficulties of identification and correspondence between vernacular names and scientific names

Graph 1: Effect of environmental factors and previous vegetation on agroforest biodiversity

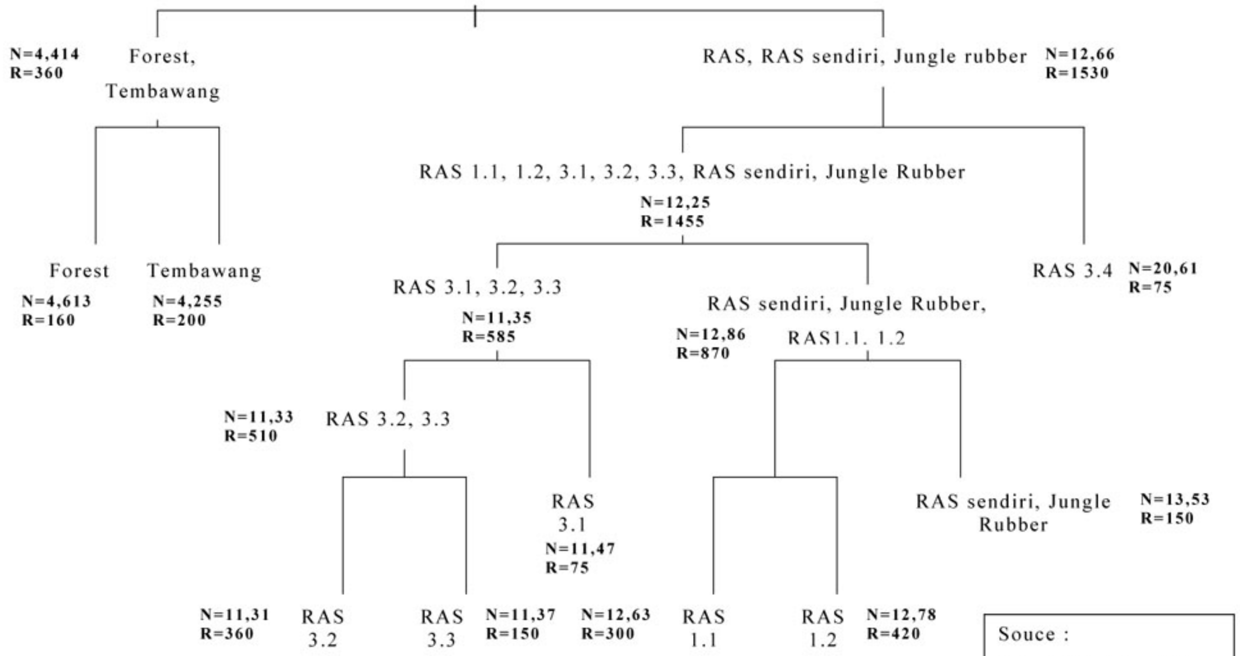


Source : Diaz - Novellon, 2001

Graph 2: Comparison of density in RAS and jungle rubber at the same age

N : number of species

R : number of replications



Souce :

Diaz-Novellon, 2001