densities of selected species are being tested according to a tree typology, in particular : rambutan, durian, petai and tengkawang.

The third system, RAS 3, is also 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 "alang-alang" grass or in area where Imperara is a major threat. Labour or cash for controlling Imperata with herbicide are the main contraints. In RAS 3, annual crops, generally rice, are grown the first year only, with non viny cover crops grown immediately after rice harvesting (Mucuna, Flemingia, Crotalaria, Setaria and Chromolaena) or multipurpose trees (Calliandra, Gliricidia..) or fast growing trees as pulpwood (Paraserianthes falcataria, Acacia mangium and Gmelina) are established (several combinations are being tested) . The objective here is to eliminate the weeding protocol by providing a favourable environment for rubber and the associated trees to grow, consequently suppressing Imperata growth with low labour requirements. The association of non-viny cover crops and MPT[6]'s for shading is aimed to control Imperata.

A network of farmer-managed trials is underway in Jambi and West-Sumatra provinces, Sumatra, and in West Kalimantan province, Borneo. By mid 1996, approximately 34 hectares of trials involving 62 farmers have begun and eventually this will be expanded (see table 3)

These experiments take into account the limited resources of smallholders; labour is one the main factors being considered in assessments of a system's suitability as well as cash for inputs investment (in particular planting material, herbicides and fertilizes). The range of trees that can be grown in association with rubber in agroforestry associations and the market potential of their products are being examined—tekam, meranti, belian (ironwood), nyatoh and keram trees for timber, durian, rambutan, duku, , cempedak, petai and jengkol for fruit.

Most rubber development projects to increase rubber production for smallholders have been based on a monoculture technological package for rubber, comparable to that used by the large estates, and these projects are relatively expensive to implement, involving credit, clonal material and labour-intensive management of the rubber plots. These projects have reached only about 13% of the smallholder rubber producers in the country (Tomish, 1992). That leaves the majority of farmers still farming jungle rubber. Improved agroforestry systems such as RAS may eventually be able to produce up to three fold rubber as they do now, without losing any of the other advantages of these diverse agroforestry systems that generate income for so many of Indonesia's smallholders. The objective is to find the right balance between the farmers' needs and the specific requirements for rubber clones, without destroying the very nature of this agroforestry system (Penot 1994), in particular their environmental benefits as well as their biodiversity.

This on farm experimentation is developed through a farming system research where understanding farming strategies and the process of adoption of innovations are key issues. Surveys should lead to a typology of farmers linked with the conditions of adoptions of one or another RAS cropping systems. Innovations adoption process is analysed in light of constraints and opportunities of local farming systems.

The key issue is to conserve the advantages of agroforestry practices ; income diversification, limitation of risks...as well as environmental advantages ; water and soil conservation, rehabilitation of degraded lands with Imperata and maintainance of a certain level of biodiversity and to provide to farmers an affordable low to medium input

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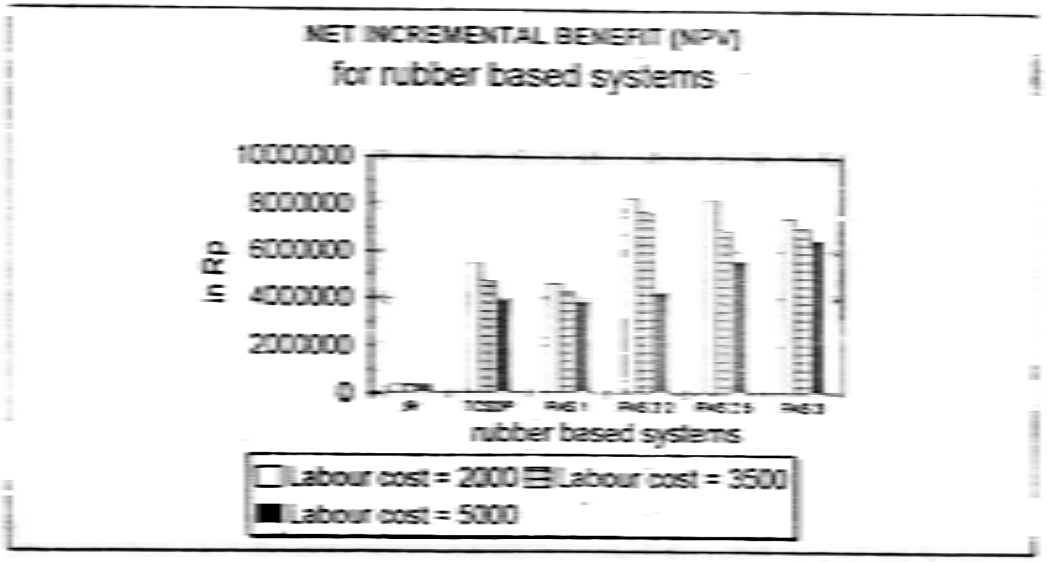
[6]MPT : multi purpose tree.

1

INCREMENTAL NET BENEFIT ANALYSIS (NPV)
FOR RUBBER BASED AGROFORESTRY SYSTEMS

SCENARIO	LABOUR COST per day in rp	Jungle rubber clonal seedlings traditionnal close to estates	TCSDP like clonal plantation Development projects	RAS 1 Rubber clone in traditionnal conditions	RAS 2.2 rice inter-crop Rubber clones + associated trees +rice interrows	RAS 2.5 Cinnamon inter-cropping Rubber clone + cinnamon	RAS 3 with FGT (*) Rubber clones + associated trees + rice interrows + FGT
Opportunity cost of labour similar to upland rice	2.000	334,606	5.505,405	4,620,264	8,215,011	8,169,207	7,394,031
Wage offered by estates	3.500	333,139	4.706,841	4,236,782	7,634,937	6,900,726	6,949,357
Opportunity cost of labour for bag due system	5.000	331,571	3.908,278	3,853,279	4,236,782	5 602,244	6,504,683
Opportunity cost of labour for NPV =0	LR/Seedlings 5,790	6,828	9,893	12,157	6,900	10,057	16,000

NOTE *discount rate = 15 % (real interest rate)*



and labour rubber based cropping system with a high productivity, in order to secure both income and sustainability.

THE ECONOMICAL RATIONALE OF RAS COMPARED WITH OTHER RUBBER CROPPING SYSTEMS

Introduction of the 7 rubber based cropping systems

We suggest a preliminary financial analysis of 7 rubber based systems ranging from the least intensified, but the most used and traditionnal in Indonesia - jungle rubber - to the most intensified, RAS 2.2 with annual and perennial intercropping.
The 7 systems are the following :

- 1 - **traditional jungle rubber with unselected rubber seedlings** (actual existing system): this system has no cost other than labour in term of inputs and is very extensive. The biodiversity of jungle rubber in term of species has been estimated as very high (relatively close to that of primary forest in Jambi for example) (De foresta, 1995).
- 2 - **Jungle rubber with clonal seedlings (GT1)** (existing system, in particular in areas close to estates, but not yet well developped) : this system is using a planting material available in all zones where estates have been established with clones. The cost of establishment is limited to the cost of the seeds or seedlings.
- 3 - **TCSDP like monoclonal rubber plot** (existing as development schemes): this system is based on the traditional project technological package developed by TCSDP[7] including clones and a high investment of weeding and maintenance,. This system requires a high level of input and labour and is ,so far, considered the 'modern and intensified' rubber cropping pattern. Costs are TCSDP estimates (TCSDP reports), adapted with 1996 prices. In 1995, TCSDP has introduced upland rice intercropping in its technological package, so we did (for the first 3 years with improved rice and fertilization).
- 4 - **RAS 1**[8] (experimental): this is basically a jungle rubber system using clones and a minimum of inputs (TCDSP like fertilization for the first 2 years) and labour (weeding is limited on the row). The inter-row is not weeded and secondary forest is allowed to grow replacing the traditional LCC covercrops used in TCSDP system. This is a low input/medium labour system. The challenge here in terms of research is to see if clones can compete and grow well in an agroforestry environment at a given level of inputs (basic fertilization) and labour (minimum number of weedings per year). Emphasis is put on return to labour optimization. Biodiversity is expected to be similar to that of jungle

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TCSDP = Tree Crop Smallholder Development Project/World Bank

[8]All Rubber Agroforestry Systems have the following characteristics :
- rubber is planted at 550 trees/ha (6 x 3 meters). The selected clones are PB 260, RRIC 100, RRIM 600 and BPM 1.
- associated trees (if any) are fruits (local and improved rambutan) and local timber trees at 92 trees/ha (9 x 12 meters).
- FGT (Fast Growing pulp Trees) are planted at 3 x 3 in between rubber and associated trees (400 trees/ha). They are harvested the 5th year after planting.
- cinnamon is planted at 3 x 3 in the inter-row and harvested the 7th year.
- fertilization follows TCSDP recommendations for the first 2 years.

TABLE 2

COMPARISON BETWEEN RUBBER BASED AGROFORESTRY SYSTEMS

DISTRIBUTION OF PRODUCTION VALUE (NPV) IN RUBBER BASED SYSTEMS

PRODUCTION VALUE	Jungle rubber unselected seedlings traditionnal		Jungle rubber clonal seedlings traditionnal		TCSDP like clonal plantation Development projects		RAS 1 Rubber clone in traditionnal conditions	
	rp		rp		rp		rp	
TOTAL OUTPUT VALUE OF ALL PRODUCTIONS	1,859,979		2,226,786		10,070,267		7,464,373	
PRODUCTION VALUE OF RUBBER	1,592,717	86%	1,959,524	88%	9,046,062	90%	7,178,502	96%
PRODUCTION VALUE OF RICE	264,650	14%	264,650	12%	1,011,146	10%	264,650	4%
PRODUCTION VALUE OF FRUITS								
PRODUCTION VALUE OF CINNAMON								
PRODUCTION VALUE OF PULP TREES								
PRODUCTION VALUE OF TIMBER	2,612	0.14%	2,612	0.12%	13,059	0.13%	24,404	0.33%

NOTE : discount rate = 15 % (real interest rate)

PRODUCTION VALUE	RAS 2.2 rice inter-crop Rubber clones + associated trees +rice intercrops		RAS 2.5 Cinnamon inter-cropping Rubber clone + cinnamon		RAS 3 with FGT (*) Rubber clones + associated trees + rice intercrops + FGT	
	rp		rp		rp	
	10,837,300		12,197,378		11,075,776	
PRODUCTION VALUE OF RUBBER	8,682,644	80%	9,046,062	74%	8,682,644	78%
PRODUCTION VALUE OF RICE	1,011,146	9%			453,686	4%
PRODUCTION VALUE OF FRUITS	1,126,371	10%			1,126,371	10%
PRODUCTION VALUE OF CINNAMON			3,138,257	26%		
PRODUCTION VALUE OF PULP TREES					795,935	7%
PRODUCTION VALUE OF TIMBER	17,140	0.16%	17,140	0.14%	13,059	0.12%

rubber. The target is the farmers in pionner or remote areas, as well as those with limited labour ressources.
- 5 - **RAS 2.2** (experimental) : rubber + associated trees + rice intercropping the first 3 years. Associated fruits and timber trees are planted at a density of 92 trees/ha. Improved or 4 months local rice (with fertilization) is grown during the immature period. The system is intensive with a medium level of input/labour requirement. Income is diversified with rubber, rice, fruit and timber production.
- 6 - **RAS 2.5** (experimental) : rubber + cinnamon : this system is specifically developed for the Jambi province where cinnamon is a recent opportunity for local farmers. A cinnamon planting density of 3 x 3 meters results in 1100 cinnamon trees/ha intercropped with rubber.
- 7 - **RAS 3.3** (experimental) : rubber + associated trees + FGT (fast growing pulp trees) : this system is designed for degraded lands where Imperata is a major risk. The first year is cropped with rice; immediately after the harvest non climbing covercrops such as Flemingia or Crotalaria are planted in order to limit the level of weeding. Associated trees and FGT are planted in the inter-row. FGT are harvested in the 5th year. This system is specifically developed for West-Kalimantan (Sanggau area) where pulpwood species can be sold to the planned pulp factory.

The main difference between RAS 1 and RAS 2/3 is that RAS 1 requires a specific environment to be set up with surrounding vegetation being forest, jungle rubber or tembawang with no Imperata. The associated trees are those which naturaly growing and subsequently selected by the farmer. In RAS 2/3, associated trees are directly planted by the farmers who can choose the species among those which are adapated and are not too competitive with rubber. In RAS 2/3, tree diversity is limited to the cropped species, however farmers may select among the naturally growing species those which have an economic output.
All systems except RAS 2.5 have rice intercropping the first year.

RAS recommendation domains

In all cases, rubber is the main economic driving force of each system. Income diversification enable farmers to profit from market opportunities for fruits, timber, rattan and other non-timber products.
RAS 1 and RAS 2.5 are designed for farmers in remote or pioneer areas with low cash availability and without land shortage. RAS 2.5 is targeted especially for piedmont zones close to the Barisan mountains in Sumatra.
RAS 2.2 is the most intensive system aimed at farmers with severe land limitation such as transmigrants.
Farmers in degraded areas with Imperata (in West-Kalimantan for instance where the risk is high) are targeted for RAS 3.
The further promotion of such systems, linked with a typology of farmers, raises the question of the type of development schemes that should be adopted : partial approach or complete approach such as TCSDP ? A partial approch seems to be more adapted to such development. Certified improved planting material supply to farmers is a key issue.

3

COMPARISON BETWEEN RUBBER BASED AGROFORESTRY SYSTEMS
LABOUR REQUIREMENT AND RETURN TO LABOUR

LABOUR		Upland rice slash and burn system (shifting cultivation)	Jungle rubber unselected seedlings traditionnal	Jungle rubber clonal seedlings traditionnal close to estates	TCSDP like clonal plantation Development projects	RAS 1 Rubber clone in traditionnal conditions	RAS 2.2 rice inter-crop Rubber clones + associated trees +rice intercrops	RAS 2.5 Cinnamon inter-cropping Rubber clone + cinnamon	RAS 3 with FGT (*) Rubber clones + associated trees + rice intercrops + FGT
TOTAL LABOUR REQUIRED during system lifetime	manday	1,370	3,414	3,534	3,016	2,454	3,558	2,764	3,588
% of TCSDP total labour requirement			113%	117%	100%	81%	118%	92%	119%
tapping system			D/1, D/2	D/1, D/2	D/3	D/3	D/3	D/3	D/3
FOR RUBBER ONLY									
Labour during immature period for rubber only	manday	0	54	54	597	434			514
% of TCSDP total labour requirement			9%	9%	100%	73%			86%
Labour during mature period for rubber only	manday	0	3260	3,380	2,119	1,900			1,910
RETURN TO LABOUR (full production)									
RUBBER return to labour : YEAR 15	Rubber/15	0	8,979	12,210	50,839	45,714	51,246	51,246	51,246
Average RICE return to labour (1 or 3 years)	Rice	1,992	3,500	3,500	5,000	2,917	5,000		6,000
FRUIT return to labour : YEAR 15	Fruit/12-15						12,861		12,861
CINNAMON return to labour (year 7)	Cinnamon/7							38,400	
FGT return to labour (year 8)	FGT/8								18,667

Table 4

COMPARISON BETWEEN RUBBER BASED AGROFORESTRY SYSTEMS
INITIAL INVESTMENT during immature period

	Remark	Upland rice slash and burn system (shifting cultivation)	Jungle rubber unselected seedlings traditionnal	Jungle rubber clonal seedlings traditionnal close to estates	TCSDP like clonal plantation Development projects	RAS 1 Rubber clone in traditionnal conditions	RAS 2.2 rice inter-crop Rubber clones + associated trees +rice intercrops	RAS 2.5 Cinnamon inter-cropping Rubber clone + cinnamon	RAS 3 with FGT (*) Rubber clones + associated trees + rice intercrops + FGT
LEVEL OF INTENSIFICATION		---		--	+++	+	+++	++	++
INITIAL INVESTMENT during immature period	NPV in rp		0	34,783	1,470,116	482,359	1,143,293	474,261	817,304
% of TCSDP cost			0%	2%	100%	33%	78%	32%	56%
Number of days of work for initial investment (*1)	mandays			10	420	138	327	136	234
INITIAL INVESTMENT during immature period with TCSDP project cost included					2,344,706 Rice included		Rice included		

NOTE : discount rate = 15 % (real interest rate)

Financial analysis of rubber based cropping systems : a preliminary comparison between systems.

In this first financial analysis, there is no depreciation of initial investment during the immature period. It is assumed that farmers do not use credit in order to simplify the assessment of rubber systems performances. To provide a contact for this initial investment, we present the number of days of work at local opportunity cost (generally in a estate nearby for a daily wage of 3 500 rp[9], that is the case in West-Kalimantan) that are required to cover costs of investment. As farmers generally do not have sufficient initial cash for investment, part time work[10] in estate may be one of the existing opportunity to raise the necessary funds. A further analysis should include a credit scheme. Acreditsheme will not significantly change the long term financial analysis.

Costs and benefits are in calculated in net present value (NPV) with value at the end of the period (1 year) with a rate of interest at 15 %, equivalent to the current real interest rate in Indonesia. The total net benefit includes that of rubber, rice, fruits, cinnamon and timber for the overall lifestime of each system, voluntary limited to 35 years. In fact the expected lifespan of rubber based systems such as jungle rubber may have a longer rubber lifetime up to 40/50 years. RAS 2.2 and 3 systems with associated trees may also evolve, beyond the rubber lifespan, into fruit and timber based agroforestry systems (such as 'Tembawang' or 'pulau buah' up to 50 or 60 years after planting). Rubber wood from seedlings is counted only as fuelwood with a limited value but may be sold later as a valuable product (for particul board or pulp for instance). Clonal rubber wood is expected to be sold as a valuable timber product in particular for furniture industry. In all case, rubber wood harvets is contracted.

Costs are effective costs observed in current on-farm experimentation of SRAP. Prices are those observed in February 1996. Production and labour requirements are assupmtions based on previous surveys (Gouyon, Barlow....) or farmers interviews.

The table 1, 2 and 3 represent the situation in West-Kalimantan with no fencing cost (except for RAS 2.5 system, based on rubber and cinnamon in Jambi only). In the Jambi province where herbivory wild animals is a major contraint (among them monkeys and wild pigs), rubber plots require fencing, leading to an increase of costs at establishment. A calculation including this cost does not affect significantly our analysis in the long term except the impact of initial cost of establishement (cost of fencing is assumed to be 150 00 rp/ha). This analysis refers mianly to West-Kalimantan situation except if noted and for RAS 2.5 (Jambi).

In RAS 2.2 and 3, timber trees are harvested 35 years after planting yielding a modest benefit. Fruit production is annual for petai and jengkol and durian, duku and rambutan are assumed to fruit every 3 years. We also assume that yields are low and only 50 % of the production is actually sold for 40 producing trees/ha. Distribution between trees is the following : fruit trees : 75 % (70 trees/ha with 60 producing trees) and timber trees : 25 % (22 trees/ha).

Labour for tapping is limited in RAS systems to 120 tapping days (1 tapping day is 0,5 manday) as PB 260 and other selected clones allow a D/3 tapping system (tapping every 3 days) without any decrease in production. Jungle rubber is tapped more frequently (

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[9]However official minimum daily wage is 4600 rp in March 1996 in Indonesia, the daily wage observed in West-Kalimantan and Jambi provinces is generally close to 3500 rp.

[10] On the other hand, part time activities may be a future potential constraint for the development of plantations in zones where work opportunities are developing.

TABLE 5

COMPARISON BETWEEN RUBBER BASED AGROFORESTRY SYSTEMS

RETURN TO LABOUR

RETURN TO LABOUR (full production)		Upland rice (shifting cultivation)	Jungle rubber unselected seedlings	Jungle rubber clonal seedlings	TCSDP like clonal plantation	RAS 1	RAS 2.2 rice inter-crop	RAS 2.5 Cinnamon inter-cropping	RAS 3 with FGT (*)
RUBBER return to labour : YEAR 15	Rubber/15	0	8,979	12,210	50,839	45,714	51,246	51,246	51,246
Average RICE return to labour (1 or 3 years)	Rice	1,992	3,500	3,500	5,000	2,917	5,000		6,000
FRUIT return to labour : YEAR 15	Fruit/12-15						12,861		12,861
CINNAMON return to labour (year 7)	Cinnamon/7							38,400	
FGT return to labour (year 8)	FGT/8								18,667
Opportunity cost of labour for NPV =0	JR/Seedlin		**5,790**	**6,828**	**9,893**	**12,157**	**6,900**	**10,057**	**16,000**
NOTE : discount rate = 15 % (real interest rate)									