ECONOMIC ANALYSIS OF IMPROVED SMALLHOLDER RUBBER AGROFORESTRY SYSTEMS IN WEST KALIMANTAN, INDONESIA - IMPLICATIONS FOR RUBBER DEVELOPMENT

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Abstract

Farm budget analysis is a tool to understand economic performance of agriculture practice - to assess impact of technology intervention and price and policy changes. This helps better understand strengths and weaknesses of various farm operations. As a type of farm budget analysis, the farming system modeling software "Olympe" developed by a consortium of INRA/CIRAD/IAMM, is an efficient software to analyze and model farming systems performance. Olympe enables a comprehensive overview of farmer situation and links to technical innovations and practices. A range of analyses can be carried out such as the economic impact of technical choice, effect of climatic or economic uncertainty as well as the environmental impact of land use options.

The Olympe application was used to analyze the impact of new Rubber Agroforestry Systems (RAS technology) in Sanggau, West Kalimantan, Indonesia. RAS technologies are developed for adoption by smallholder farmers with limited resources. The results show that while the RAS technology requires more capital input, both return to labor and return to land are higher compared to farmers' traditional system. The return to labor of RAS technologies can be higher than that of intensive monoculture rubber. The economic and environmental advantages of diversified RAS technologies over monoculture rubber and oil palm are evident.

Paper prepared for the international conference on
"SSLWM: Linking research to strengthen upland policies and practices"
Luang Prabang, Laos. 12-15 December 2006.
Day 2, Parallel Session B, Paper 11

1 Introduction

Natural rubber is an important export commodity for Indonesia where approximately 1.3 million farm households rely on rubber cultivation and provide 75% of the national production (DGE 2002). The most common, the traditional complex, rubber system, known as 'jungle rubber', has two characteristics of interest. First, jungle rubber is owned by smallholder farmers (2-5 ha plots) and it is a result of local farmers adapting rubber as a cash crop into their crop fallow system ation since the early 20th century (van Noordwijk et al., 1995; Penot and Sunario 1997; Joshi et al. 2002). In addition to rubber, a range of other products can be harvested for self consumption or sale. The system provides regular income for farmers, mostly from rubber, and temporarily from food and cash crops in the initial years, fruits, timber and other products the latter years. Secondly, from a conservation point of view, jungle rubber provides environmental benefits. Being essentially a secondary forest, it performs functions of biodiversity conservation, carbon sequestration, watershed protection and soil conservation (Joshi et al. 2003).

The inherent production characteristics of jungle rubber, however, are not at par with the environmental services they provide. Compared to a monoculture plantation, the latex yield from a jungle rubber is very low. Jungle rubber normally produces 500-600 kg/ha/year, that is far below the normal production of over 1200 kg /ha/year in estate plantations. Because of the low quality of rubber from jungle rubber, extensive processing is needed to produce a low grade product for the international market (Barlow *et. al*., 1988).

Deleted: One of the underlying causes of forest degradation in Indonesia is the conversion of natural forest to tree crop plantation. The area of tree crop plantations in Indonesia, both large-and small scale, has tended to increase from year to year. Among the main plantation commodities (rubber, coffee, tea, coconut, cacao, sugarcane and oil palm), the largest area is planted to rubber and oil palm. ¶

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Many projects have been implemented in Indonesia over the last several decades to improve rubber production and productivity by introducing more intensive monoculture systems - *Pola Perkebunan Inti Rakyat,* (Nucleus Estate and Smallholder, NES); *Proyek Rehabilitasi, Peremajaan dan Perluasan Tanaman Ekspor, PRPTE* (Project of Rehabilitation and Replanting for Export Commodities), Smallholder Rubber Development Project (SRDP), Tree Crops Smallholder Development Project (TCSDP) and Tree Crops Smallholder Sector Project (TCSSP). Outside government project areas, most smallholders cannot implement recommended technologies that are not less appropriate for smallholder farmers with limited capital and resources. Beginning in 1994 ICRAF in collaboration with CIRAD-France and Indonesian Rubber Research Institute (Sembawa Research Station) established a network of on-farm trial-cum-demonstration plots in Jambi, West Sumatra and West Kalimantan in Indonesia to assess rubber agroforestry systems designed considering smallholder farmers' limitations. This led to three types of improved Rubber Agroforestry Systems (or RAS, see

Box 1) that are less intensive than intensive monoculture systems but more appropriate for smallholder farmers.

Box 1. Rubber Agroforestry Systems adapted for smallholder farmers (Source: Joshi et al. 2006).

The first system **RAS-1** is similar to traditional jungle rubber system, but recommended clones are used instead of unselected rubber seedlings. The clones used must be able to compete with the natural secondary forest growth. Various planting densities (550 and 750 trees/ha) and weeding protocols were tested to ascertain the minimum management necessary for optimum production. Intensive weeding is limited to the two-meter strip of rubber rows; the space between rubber rows is less intensively weeded. This is important for smallholder farmers who need to maintain or increase labour productivity. The system is very much in line with the fallow enrichment concept and suits a large number of smallholders because of its simplicity.

The second, **RAS-2**, is a more complex agroforestry system. Rubber trees at normal density (550 stems/ha) and perennial timber and fruit trees (92 to 270/ha) are planted after slashing and burning. Annual crops, mainly upland rice, are intercropped in the first 3 or 4 years, under various rates of fertilization. Planting densities of selected species were tested according to pre-established tree typology. Tree species such as rambutan, durian, petai and tengkawang were included. Natural regeneration is allowed in the inter-rows, and farmers decide on what naturally regenerating species to maintain.

The third **RAS-3** is also a complex agroforestry system with rubber and other trees similar to RAS-2; the difference being that this is adapted for establishing rubber agroforestry on degraded *Imperata cylindrica* grassland where labour or cash for herbicides are limited. In RAS-3, annual crops, mainly rice, are grown in the first year only, with legume crops such as *Mucuna, Pueraria* and *Flemingia* are planted immediately after rice harvest. Fast growing multipurpose trees *(such as Paraserianthes falcataria, Acacia mangium and Gmelina arborea*) can also be used. These trees can shade Imperata in the early years of rubber establishment while after 7-8 years; these can be harvested and sold to pulp industry providing farmers with extra income.

While technologies and options for now available for smallholder farmers to choose from, detailed economic assessments of costs and returns of these alternatives are still not available. Farm budget analysis is a commonly used economic tool to assess performance of agriculture practices. This type of analysis can also assess impact of technology intervention as wells as that of price and policy changes. Using on-farm trial information and additional data from Sanggau district of West Kalimantan, an economic analysis of the improved RAS was carried out.

2 Data collection and analysis

Data collected during the 10-year on-farm trial-cum-demonstration plots were compiled. Recent data on rubber tree growth, management practices, input materials and rubber production were also collected. New socio-economic information from total 80 RAS on-farm trial participants and non-participants were collected from seven villages in Sanggau District - Embaong, Engkayu, Kopar, Pana, Sanjan, Sibau Mulya and Tukang Jaya.

The farming system modeling software "Olympe" was used for the farm budget analysis. The software, developed by a consortium of INRA/CIRAD/IAMM in France, facilitates a comprehensive overview of farmer situation and links to technical innovations and practices. A range of analyses can be carried out such as the economic impact of technical choice, effect of climatic or economic uncertainty as well as the environmental impact of land use options.

Three group ‘systems' are included in Olympe software for all input and output data: cropping systems (annual and perennial agricultural crops), livestock and off-farm activities. P**roduction systems** data at the farm level includes agricultural undertaking and strategy for combination of production factors as well as non-operational costs.

3 Study site

3.1 Site description

Sanggau is the largest district of West Kalimantan Province, covering 12,858 km^2 and a population density of 29 people per km^2. Annual rainfall varies between 2500 mm to 3500 mm (155 rainy days per year). The dry season occurs from April/May to September. January is the wettest month (196 mm rain) and July is the driest (54 mm rain). Annual average temperature is 26^o Celsius. The landscape is dominated by logged-over forests, secondary forests and mosaics of smallholder rubber with secondary forest regrowth. Little forests exist and only in hilly areas. Sanggau is the leading rubber district in West Kalimantan, with twice the number of small farmers cultivating rubber as oil palm.

3.2 Socio-economic attributes

Dayak forms the single largest ethnic group in Sanggau District, with a small proportion of Javanese transmigrants in few places. The average household size in Sanggua was 4.7 individuals of whom 3.4 individuals per household belong to the economically active group (age between 16 and 55 years). For farm activities each household has 2.7 individuals or 709 person-days/year are available. Labour shortage for farm activites is commong. Many farmers practised *gotong royong* (labour contribution) to cultivate their land. However, in the peak season some farmers need to hire labour at cost (Rp 15.000 - Rp30.000 per day).

On average, each household has 4.8 ha land, of which more than half (55%) is rubber. Nearly 38% farmers have land from 1 - 3 ha; 45% with 4 – 7 ha and 17% farmers with more than 7 ha. Javanese farmers have smaller land (2 ha) compared to local Dayaks (over 7 ha). Dayak farmers also have access to communal land for upland agriculture and fruit collection with the permission from the village head.

3.3 Farming systems and household income

Both irrigated paddy cultivation at lower altitudes (sawah) and upland rice (lading) at higher slopes are important systems in the district. The mixed fruit garden system (Tembawang), that is often an evolution from old secondary forests and rubber cultivation, are also maintained by nearly quarter of the farmers the surveyed villages. Rubber cultivation is probably the most important income generating activity for most farmers in the district. While monoculture system is practiced by some farmers, the complex multi-strata rubber systems are more common. In general a household is involved in numerous activities of sawah, ladang and rubber cultivation.

For RAS practicing households in the surveyed villages in Sanggau, farming activities on average provided 87% of total household income (Table 1); 91% of farm income is from rubber cultivation.

Table 1. On-Farm and Off-Income of RAS Participant

	All Farm Income	Off Farm Income	Family Income
Average	15,921	632	16,553
Max	60,624	2,350	62,974
Min	1,684	20	1,704

4 Rubber based farming

4.1 General

Traditional jungle rubber, an extensive yet complex agroforestry system, is dominant in Sanggau, with 55% of respondents owning jungle rubber. Unselected seedlings are used, compared to high yielding clones used in more intensive monoculture plantations, The system in low-input and low-out; almost no fertilizer and other agro-chemicals are used, Jungle rubber covers 52% of total rubber area or 29% of total cultivated land.

Jungle rubber is essentially a secondary forest regrowth enriched with economically valuable rubber trees (Joshi et al. 2003), Following land clearing, normally through ‘slash and burn’, farmers plant rubber seedlings. In the initial one to three years, upland rice and other annual crops may be grown. After rubber trees and other natural regeneration begin to affect the annual crops, farmers abandon the plots. While the rubber trees continue to grow until time of tapping, farmers return to the plots occasionally for minor weeding and to keep the rubber trees free from competing vegetation, climbers and lianas. The rubber trees are normally ready for tapping usually 10 years after planting. This compares with the pre-tapping period of five to six years for the improved RAS, that can be longer or shorter depending on management intensity.

4.2 Tapping and labour

Sixty percent rubber farmers tap about one hectare of rubber plantation per day. The RAS farmers tapped 60-200 rubber trees while in traditional system farmers can tap 200 to 300 trees in the same period - 5-7 hours a day (early morning to mid morning). Farmers normally tap 5 or 6 times a week but they do not tap throughout the year or with the same intensity. The tapping frequency is less during periods of intense agricultural activities (such as planting or harvesting), social or religious functions. Compared to more intensive system, traditional system requires less labour, particularly during the tree establishment phase immature period. Share-tapping (yield devided between tapper and owner) is not common in Sanggau. The V-shaped tapping panels are most common in the jungle rubber and the ½ S is used for clonal rubber.

RAS-1 required low labor due to limited weeding (2-meter strip of rubber rows). Farmers using RAS-1 Medium intensity applied four weedings per year in the first two years, with preference of chemical weeding to manual weeding. Some farmers weeded only twice a year, and this is referred to RAS-1 Low Maintenance. More resourceful farmers prefer weed control with chemical herbicides (*Round-up* or *Spark*) to reduce labor cost as the chemical control is more effective and economical (Penot 1996).

RAS-2 with associated trees, among three systems, needed highest labor (444 person-days/year during establishment phase) and 334 person days/ha/year for management thereafter. This system is more intensive as additional labour is required for the intercrops. Many Javanese farmers, known to be hard working, selected RAS-2 to make most of their limited land resources.

Labor required for different rubber systems for up to year 10 is presented in Figure 1 and details of relevant information are included in Table 2.

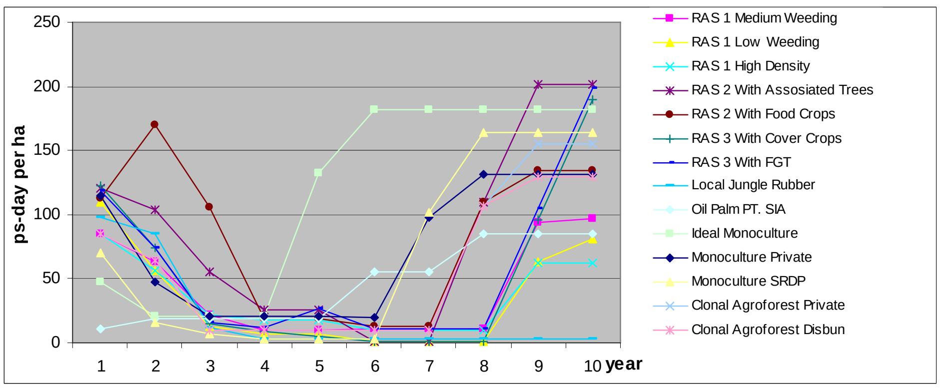

Figure 1. Labor required for rubber and oil palm cultivation in Sanggau, West Kalimantan.

Table 2. Economic data on rubber and oil palm cultivation in Sanggau, West Kalimantan.

Systems	Life Span years	Years to Positive Cash Flow	Labor requirement*		
			Establishment (ps-day/ha)	Operation (ps-day/ha/ year)	Total (ps-day/ha)
Jungle Rubber	40	-	2,986		73
RAS SYSTEMS					
1. RAS 1 Low Weeding	28	13	582	76	62
2. RAS 1 Medium Weeding	28	14	828	91	76
3. RAS 1 High Density	28	10	552	62	55
4. RAS 2 with Food Crops	28	18	1,525	84	84
5. RAS 2 with associated trees	28	10	729	85	81
6. RAS 3 With Cover Crops	28	13	1,649	175	135
7. RAS 3 With FGT	28	14	1,377	154	127

Rubber Monoculture					
1. Monoculture SRDP	30	14	1,263	124	109
2. Monoculture Private	30	13	1,239	155	130
3. Ideal Monoculture	30	10	1,085	165	147
Clonal Rubber Agroforest	28	15	2,272	145	128

4.3 Rubber productivity

Olympe simulation requires a good understanding of the cultural practices and yield data on various products in the system. Related to tapping in rubber systems, numerous factors influence production and productivity: tappable trees, tapping quality, tapping days, seasonality, labor availability and even market price of rubber. Figure 3 shows data monitoring on latex production in different RAS technologies. The data beyond year 3 are estimates based on other research results of Gouyon (1992) and Wibawa (1997) as well as literature review.

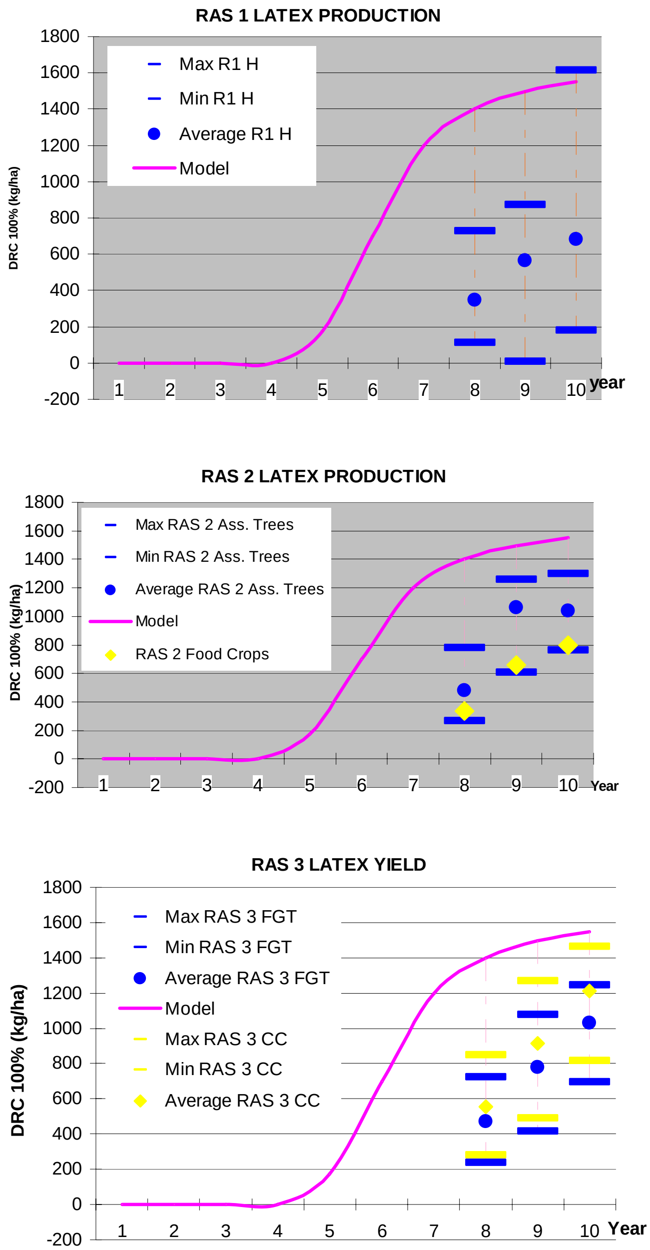

Figure 2. Latex production vs. Model on Rubber Monoculture Latex Yield

Gouyon (1992) estimated the latex yield to rise over the first few years after tapping starts, then plateau, and later gradually decline. The BEAM Model specifies a plateau interval of approximately five years; this is not unreasonable for smallholders. While Gede (1997 described the latex production under different systems as in Figure 4.

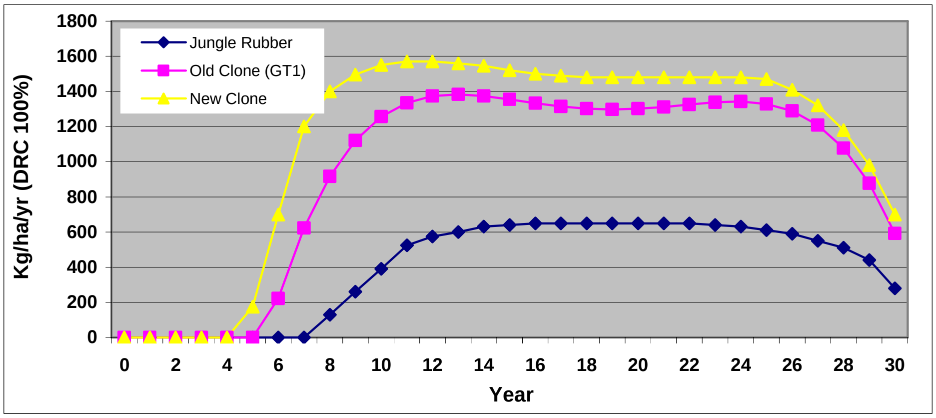

Figure 3. Latex yield prediction in three systems (source: Wibawa 1997).

The productivity of rubber in the study areas was 35% higher than the national average for smallholders (Ditjenbun 1997), but much lower than the productivity of clonal rubber in plantations (1500 kg of dry rubber ha per year) (Hendratno *et al.* 1997). For RAS plots, the yield varied from 865 – 1131 kg dry rubber/ha/year; this is significantly higher than jungle rubber system output of 441 kg/ha year. The difference in yield between clones and wildlings is well known (Ririn and Cacho, 1998).

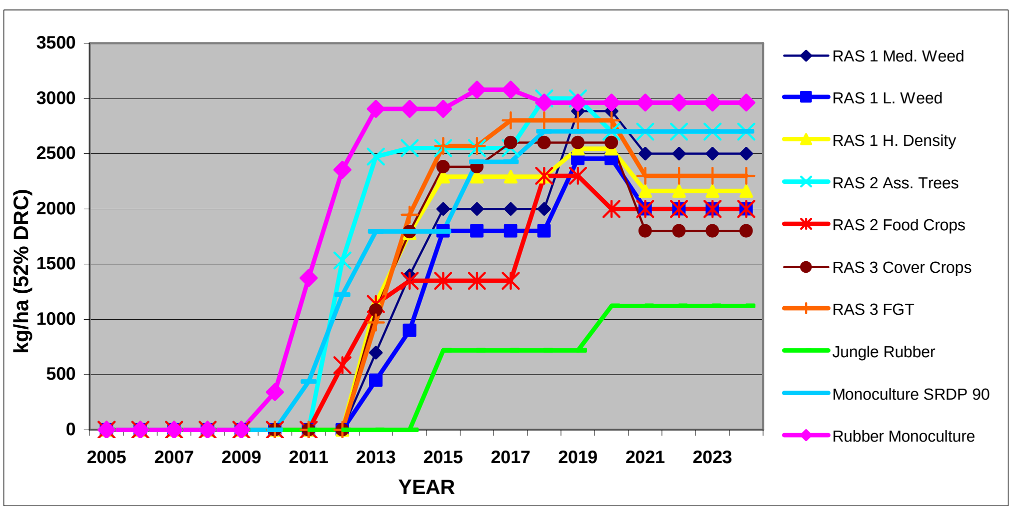

Figure **4** Latex yield of different rubber systems in Sanggau.

Table 3. Average rubber production from different rubber systems

	FARMING SYSTEMS	Average Yield DRC 100% (Kg/ha/year)
1.	Jungle Rubber	441
2.	RAS 1 Low Maintenance	917

3.	RAS 1 Medium	1,080
4.	RAS 1 High Density	1,052
5.	RAS 2 With Food Crops	865
6.	RAS 2 Associated Trees	1,131
7.	RAS 3 With Cover Crops	950
8.	RAS 3 With FGT	1,119
9.	Monoculture SRDP	1,174
10.	Monoculture Private	971
11.	Monoculture Ideal	1,342
12.	Private Clonal Agroforest	901

In the first years, RAS-1 High Density produces more latex because of more-than-normal number of tappable trees - 750 trees/ha compared to 550 trees/ha in other RAS-1. Later yield in the high density plot goes down because of high mortality. The negative effect of too high tree density on latex productivity per tree has been explained by Grist *et al.* (1998).

4.4 Non Rubber Products

In the first few years after planting rubber trees, annual crops such as paddy, maize, cassava and vegetables can be planted. In later years farmers can also benefit from medicinal plants, fruits and timber. In Sanggau District local fruits such as Durian, Pekawai, Petai, Jengkol and Tengkawang are valuable (Martin 2005) and Terindak and Nyatu are valuable timber species. In the RAS demonstration plots, fruit trees and timber species have not reached harvestable stage, hence data for Sanggau context are still unavailable. The use of Acacia as a combination species was inappropriate as when planted together at the same time with rubber, it grew very fast and severely affected rubber tree growth. Plot owners, therefore, removed Acacia within three year after planting.

4.5 Economic performance of various rubber systems

The results of coupling the Olympe with Net Present Value (NPV) measurements are used to assess the ‘discount factor’ consequence of long investment. The NPV is a measure of estimate returns to land and internal rate of returns (IRR) are alternative measures of estimates of discount rates that bring the NPV to zero. The following graphs show the margin of various rubber based farming systems during the 20 years.

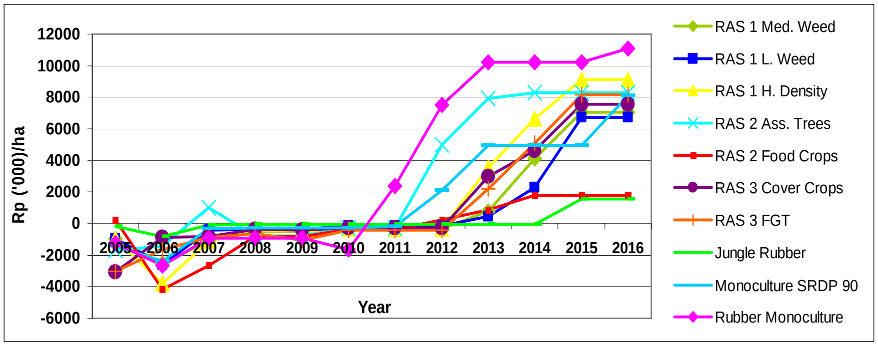

Figure 5. Profit margin in twenty years of different rubber systems.

The economic assessment of various rubber based farming systems shows at Table 11. The results show that the traditional system (local jungle rubber) is not profitable, indicated by negative values for return to land (negative Rp.1,073,000 ha^{-1}) and the system also not attractive as return to labor lower than the real average wage rate in the study area (Rp.17,907 compare to Rp. 20,000). All RAS technologies are profitable, indicated by positive values for return to land (varied between Rp.2,864,000 – Rp. 18,316,000) while value of return to land of monoculture system with new clonal rubber is Rp. 18,567,000.

RAS technologies also provide attractive return to labor and some of them is higher than the monoculture systems.

Table 4. Economic performance of various rubber systems (at discount rate 11%)

FARMING SYSTEMS	NPV (Rp'000/ha)	IRR (%)	EST. COST (Rp'000/ha)	Return to Labor (Rp /Ps-days)
Local Jungle Rubber	(1,073)	9.15	13,629	17,907
RAS 1 Low Maintenance	10,087	21.01	10,874	40,838
RAS 1 Medium	11,197	20.20	14,318	47,629
RAS 1 High Density	13,496	21.91	12,657	47,629
RAS 2 With Food Crops	4,116	14.16	21,834	25,113
RAS 2 Associated Trees	18,316	26.32	15,373	42,749
RAS 3 With Cover Crops	2,864	14.33	19,427	23,189
RAS 3 With FGT	7,127	17.47	18,513	27,683
Monoculture SRDP	8,045	17.84	20,192	29,477
Monoculture Private	11,307	20.06	17,217	32,415
Monoculture Ideal	18,567	24.18	19,035	35,683
Clonal Agroforest (Private)	5,514	13.81	27,341	25,189

5 Non-rubber systems

5.1 Food crops systems

This rice based system is an important system in Sanggau for subsistence and local economy. Upland field (Ladang) is a traditional shifting cultivation practice producing relatively low rice production (500 kg/ha/year) compared to irrigated rice system (1,200-2,600 kg/ha/year). The migrant Javanese farmers prefer sawah to ladang, while the local Dayak farmers have a preference for ladang (upland rice) for growing glutinous rice mainly used for local alcoholic drink tuak that is an essential item for traditional functions. Relevant information of food crop system is provided in Table 5.

Table 5. Food crops systems

Typology	Sawah Intensive	Sawah Extensive	Ladang Paddy
Main Product	Rice	Rice	Rice/Glutinous Rice
Other Products	No other products	No other products	Maize, Cassava, Vegetables
Rice production (kg)	2,600	1,200	500
Total Cost (Rp ‘000)	4,590	2,000	3,060
Labor Requirement (ps-days)	139	90	153
Margin (Rp ‘000)	1,910	1,000	140
Return to Labor (Rp/ps-days)	13.76	11.12	0.88
Constraint	High Input	Low production	Low productivity, unpredictable rainfall

5.2 Tembawang

Tembawang or mixed fruit garden is a famous traditional complex agroforest in West Kalimantan. All local people recognize that Tembawang provide many items for household subsistence from timber for house building, to mushroom and medicinal herbs. Products such as Durian and Tengkawang or illipe nut (*Shorea species*) are saleable, but harvests are variable and unpredictable. The forest gardens are at best supplementary source income, although windfall harvests are highly appreciated. Once individually owned rubber trees are no longer productive, the land may either be cleared and replanted, or left fifty years to become a new tembawang.

5.3 Oil Palm

Oil palm is one of land use options in Sanggau as in other parts of Kalimantan and Sumatra, and it is considered by many farmers as more profitable and consistent as price of rubber fluctuates unpredictably. A large oil palm company exists in Sanggaul; it is a private company built in 1995 and started planting in 1997. Its activities are focused in northwest Sanggau including Kopar and Engkayu, two villages where ICRAF has activities.

In the early credit scheme farmers had to provide 7.5 hectares land to join the scheme. The company established the oil palm plantation. When the plantations reach harvest stage, farmers receive only two hectares; each farmer also has pay back his “loan" of up to Rp28 million to the company from each harvest. The remaining 5.5 ha land was managed by the company and the plans are that this land will later become state land (HGU=Hak Guna Usaha). Credit reimbursement should be repayed from years 5 to 15 as much as 15% of each harvest. Farmers also have to pay the company for the input materials (such as fertilizer, pesticides and chemicals). This payment amount is around 26% of the oil palm harvested.

6 Scenario prospecting for rubber price fluctuation

The objective of scenarios building is to asses the strengths or resilience of technologies. Results of Olympe prospecting of scenario with 50% dip in price of rubber, but maintaining price of palm oil constant are shown in Figure 6. The results indicate that the margin of rubber monoculture system declines under the margin of RAS-2, because of the buffering by diversified products such as fruits and timber.

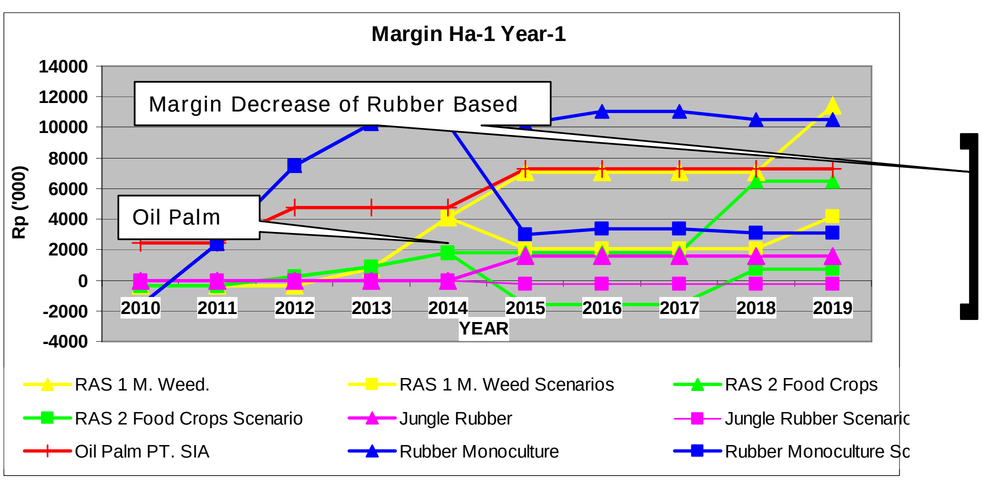

Figure 6. Simulating rubber price drop by 50% in 2015 and 2016.

A second scenario of rubber price increasing by 50% in 2018, and price of oil palm decreasing 40% gives the results in Figure 7.

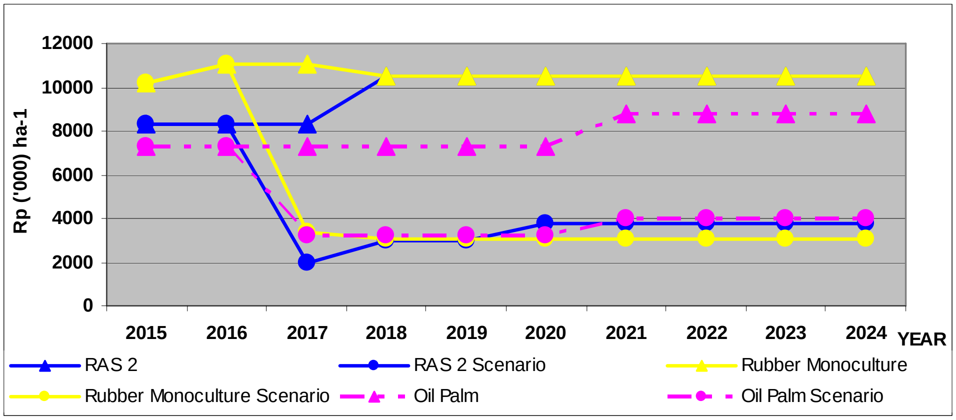

Figure 7. Scenario of rubber price doubling and price of oil palm decreasing by 40%.

Basically farmers considered rubber as a "refuge", a valuable, flexible and sustainable crop, even when prices are low, as was the case in the period from 1997 to 2002. The importance of diversified systems become obvious at times of low rubber price or other problems.

7 Summary conclusions

1. The average household size in Sanggau was 4.7 individuals, with 3.4 members per household economically active. Household labor available for farming was about 2.7 individuals, equivalent to 709 person-days/year.
2. The results show, compared to traditional jungle rubber, RAS technology requires more capital input, but both returns to labor and return to land are much higher.
3. While more intensive monoculture rubber offers better rubber productivity (yield and profitability), it also requires much higher capital and input that is beyond reach for most smallholder farmers especially during the immature period.
4. Rubber agroforestry systems, including RAS technology, can provide smallholder farmers with diversified income and a range of NTFPs.
5. Tools for simulating possible changes such as price fluctuation can inform farmers and policy makers to make better decisions on land use systems. Various possibilities can be tested and their economic performances assessed.
6. Olympe software is informative and useful, customisable outputs of important economic analysis.
7. Although we use the tools in rubber context, the software is applicable for any farming practice.

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