Economic Analysis of Improved Smallholder Rubber Agroforestry Systems in West Kalimantan, Indonesia - Implications For Rubber Development

Y. C. Wulan, S. Budidarsono and L. Joshi
ICRAF, Bogor, Indonesia

Abstract

Farm budget analysis is a tool for understanding the economic performance of agricultural practices - to assess the impact of technology interventions, price and policy changes. This helps provide better comprehension of the strengths and weaknesses of various farm operations. As a type of farm budget analysis, the farming system modelling software *Olympe* developed by a consortium of L'Institut National de la Recherche Agronomique (INRA), Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) and Institut Agronomique Méditerranéen de Montpellier (IAMM), is an efficient piece of software for analysing and modelling farming systems performance. Olympe gives a comprehensive overview of farmers' situations and links to technical innovations and practices. A range of analyses can be carried out including economic impact of technical choices, effects of climatic or economic uncertainties, and the environmental impacts of land use options. The Olympe application was used to analyse 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 labour return and land return are higher than in farmers' traditional systems. The labour return 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.

Keywords: farming systems performance, farm budget analysis, Rubber Agroforestry Systems (RAS), West Kalimantan.

1. Introduction

Natural rubber is an important export commodity for Indonesia with approximately 1.3 million farm households relying on rubber cultivation, which accounts for 75% of national production (DGE, 2002). The predominant traditional complex rubber system, known as 'jungle rubber', has two characteristics of interest: firstly the crop is owned by smallholder farmers (with 2-5 ha plots on average) and secondly it is a result of local farmers adapting rubber as a cash crop into their crop fallow system rotation from the early 20th century (van Noordwijk et al, 1995; Penot and Sunario, 1997; Joshi et al, 2002). In this system, a range of products additional to rubber can be harvested for self consumption or sale. The system provides regular income for farmers, mostly from the rubber, plus the temporary benefits of food and cash crops in the initial years and fruit, timber and other products in later years. Secondly, jungle rubber provides environmental benefits from a conservation point of view. Being essentially secondary forest, such plantations perform functions of biodiversity conservation, carbon sequestration, watershed protection and soil conservation (Joshi et al, 2003). The inherent production characteristics of jungle rubber, however, do not benefit from the environmental services provided: the latex yield from jungle rubber is very low when compared with that of monoculture plantations. Jungle rubber normally produces 500-600 kg/ha per year, which is far below the normal production of over 1,200 kg/ha per year in estate plantations. In addition, 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).

Many projects have been implemented in Indonesia in recent decades to improve rubber productivity by introducing more intensive monoculture systems. These include *Pola Perkebunan Inti Rakyat*, (the Nucleus Estate and Smallholder project); *Proyek Rehabilitasi, Peremajaan dan Perluasan Tanaman Ekspor*, (the Rehabilitation and Replanting for Export Commodities project); the Smallholder Rubber Development Project (SRDP), the Tree Crops Smallholder Development project and the Tree Crops Smallholder Sector project. Outside government project areas, most smallholders cannot use recommended technologies that are not less appropriate for smallholder farmers with limited capital and resources. Beginning in 1994, the World Agroforestry Centre (ICRAF), in collaboration with CIRAD-France and the Indonesian Rubber Research Institute, established a network of improved Rubber Agroforestry Systems (RAS) on-farm demonstration plots in Jambi, West Sumatra and West Kalimantan. These RAS (box 1) are less intensive than intensive monoculture systems but more appropriate for smallholder farmers.

While technologies and options are now available for smallholder farmers to choose from, detailed economic assessments of the costs and returns of these alternatives are still not available. Farm budget analysis is a commonly used economic tool for assessing performance of agriculture practices. This type of analysis can also assess the impact of technology interventions as well 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 was collected and compiled during ten years of the on-farm trial/demonstration plots. Recent data on rubber tree growth, management practices, input materials and rubber production was also collected. New socio-economic information from a total of 80 RAS on-farm trial participants and non-participants was sourced from seven villages in Sanggau District - Embaong, Engkayu, Kopar, Pana, Sanjan, Sibau Mulya and Tukang Jaya in 2005 and 2006.

Box 1: Rubber Agroforestry Systems adapted for smallholder farmers

*The first system, **RAS-1**, is similar to the traditional jungle rubber system, but recommended clones are used instead of unselected rubber seedlings. The clones 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-metre 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 system, **RAS-2**, is a more complex agroforestry system. Rubber trees are planted at normal density (550 stems/ha) along with perennial timber and fruit trees (92 to 270 trees/ha) after slashing and burning. Annual crops, mainly upland rice, are intercropped for the first two or three years, under various rates of fertilisation. 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 between rubber rows and farmers decide which naturally regenerating species to maintain.*

*The third system, **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 *planted immediately after the 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 seven to eight years; these can be harvested and sold to the pulp industry to provide farmers with extra income.*

Source: Joshi et al. 2006

The farming system modelling 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 situations and links to technical innovations and practices. A range of analyses can be carried out on topics such as the economic impact of technical choices, the effects of climatic or economic uncertainties, or the environmental impacts of land-use options. Three group 'systems' are included in the Olympe software for all input and output data: i) cropping systems (annual and perennial agricultural crops), ii) livestock and iii) off-farm activities. **Production systems** data at the farm level includes agricultural undertakings and strategies 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 with a population density of 29 people per km^2. Annual rainfall varies between 2,500 mm-3,500 mm (155 rainy days per year). The dry season occurs from April/May to September. January is the wettest month (196 mm of rain) and July the driest (54 mm of rain). The annual average temperature is 26°C. The landscape is dominated by logged-over forests, secondary forests and mosaics of smallholder rubber with secondary forest re-growth. Sanggau is the leading rubber district in West Kalimantan, with the amount of small farmers cultivating rubber outnumbering those growing oil palm by two to one.

3.2 Socio-economic attributes

The Dayaks form the single largest ethnic group in Sanggau District, alongside small populations of Javanese transmigrants in areas. The average household size in Sanggau consists of 4.7 individuals, of whom 3.4 individuals per household are economically active (aged between 16 and 55 years). An average household has 2.7 individuals or 709 person-days/year available for farm activities. Labour shortage for farm activities is common. Many farmers practise *gotong royong* (labour contribution) to cultivate their land. However, in the peak season some farmers need to hire extra labour at a cost of 15,000-30,000 Indonesian rupiahs (Rp) per day. On average, each household has 4.8 ha of land, of which more than half (55%) is rubber. Nearly 38% of farmers have 1-3 ha of land; 45% have 4–7 ha and 17% of farmers have more than 7 ha. Javanese farmers tend to own smaller land areas (2 ha on average) than local Dayaks (over 7 ha on average). Dayak farmers with permission from the village head also have access to communal land for upland agriculture and fruit collection.

3.3 Farming systems and household income

Both irrigated paddy cultivation at lower altitudes (*sawah*) and upland rice (*lading*) on 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, is also maintained by nearly a quarter of the farmers in the surveyed villages. Rubber cultivation is probably the most important income generating activity for most farmers in the district. While a monoculture system is practised by some farmers, complex multi-strata rubber systems are more common. In general, each household is involved in numerous activities of *sawah*, *ladang* and rubber cultivation. For RAS-practising households in the surveyed villages in Sanggau, farming activities provided an average of 87% of total household income (table 1); 91% of farm income is from rubber cultivation.

Table 1: On-Farm and off-farm income (Rp) of RAS participants (US$1=Rp9,000)

	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 in this system, whereas high yielding clones are used in more intensive monoculture plantations. The system is low-input and low-output: almost no fertiliser or other agro-chemicals are used. Jungle rubber covers 52% of the total rubber area, or 29% of the total cultivated land.

Jungle rubber is essentially a secondary forest re-growth enriched with economically valuable rubber trees (Joshi et al, 2003). Farmers plant rubber seedlings following land clearing, normally through slash-and-burn. In the initial one to three years, upland rice and other annual crops may be grown. After the rubber trees and other natural regeneration begin to affect the annual crops, farmers abandon these plots. While the rubber trees continue to grow until tapping time, 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 ten years after planting. This compares with the pre-tapping period of five to six years for the improved RAS, which can be longer or shorter depending on management intensity.

4.2 Tapping and labour

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

RAS-1 requires little labour as few weeds can grow on the two-metre strip of rubber rows. Farmers using RAS-1 'medium intensity' apply four weedings per year in the first two years, with a preference for chemical use over manual weeding. Some farmers weed only twice a year, and this system is referred to as 'low maintenance' RAS-1. More resourceful farmers prefer to control weeds with chemical herbicides (Round-up or Spark) to reduce labour cost as the chemical control is more effective and economical (Penot, 1996).

Among the three systems RAS-2 with associated trees requires the most labour (444 person days/year during establishment phase) and 334 person days/ha per 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 the most of their limited land resources. Labour required for different rubber systems in the first ten years is presented in figure 1 and more relevant details are included in table 2.

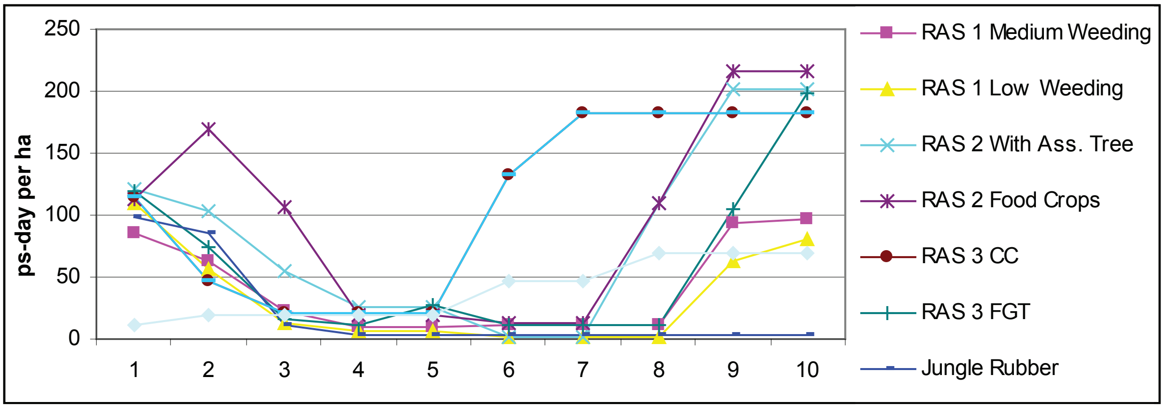

Figure 1: Labour required for rubber and oil palm cultivation in Sanggau, West Kalimantan

4.3 Rubber productivity

Olympe simulation requires good understanding of the farming practices, plus yield data for the various products in the system. Numerous factors related to tapping influence rubber production and productivity: tappable trees, tapping quality and days, seasonality, labour availability and even market price. Figure 2 shows data monitoring of latex production in different RAS technologies. Data beyond year three is estimated, based on other research results from Gouyon (1992), Wibawa (unpublished) and other literature. According to Gouyon, latex yield rises over the first few years of tapping, then reaches a plateau which is followed by gradual decline. The BEAM Model (Bio-Economics of Agroforestry Modelling) specifies a plateau interval of about five years, which is not unreasonable for smallholders. Figure 3 shows latex production under various different systems, as described by Wibawa (unpublished).

Table 2: Economic data on rubber and oil palm cultivation in Sanggau

Systems	Life span (years)	Years to positive cash flow	Labour requirement*		
			Establishment (days/ha)	Operation (days/ha/yr)	Total (days/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 fast growing trees (FGT)	28	14	1,377	154	127
Rubber monoculture					
1. SRDP	30	14	1,263	124	109
2. Private monoculture	30	13	1,239	155	130
3. Ideal monoculture	30	10	1,085	165	147
Clonal rubber agroforest	28	15	2,272	145	128

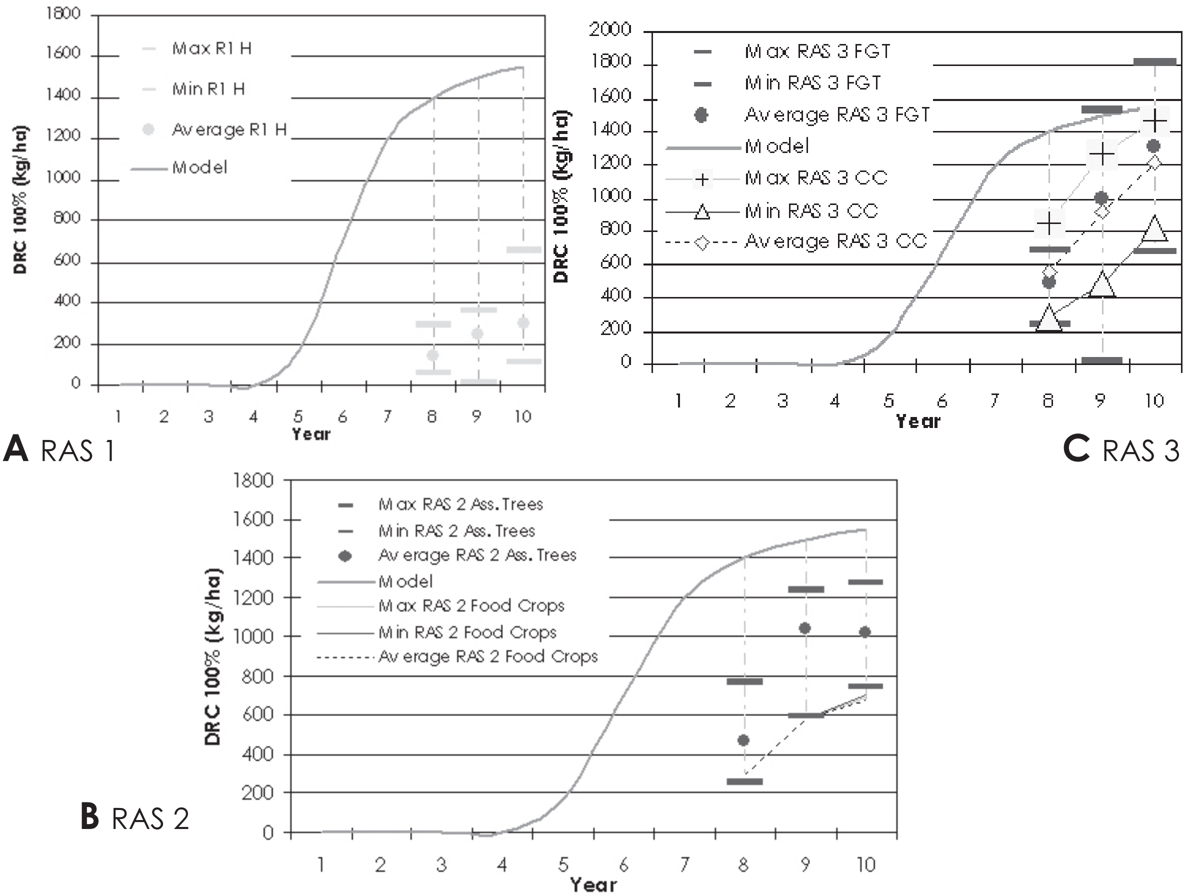

Figure 2: Latex production versus model on rubber monoculture latex yield

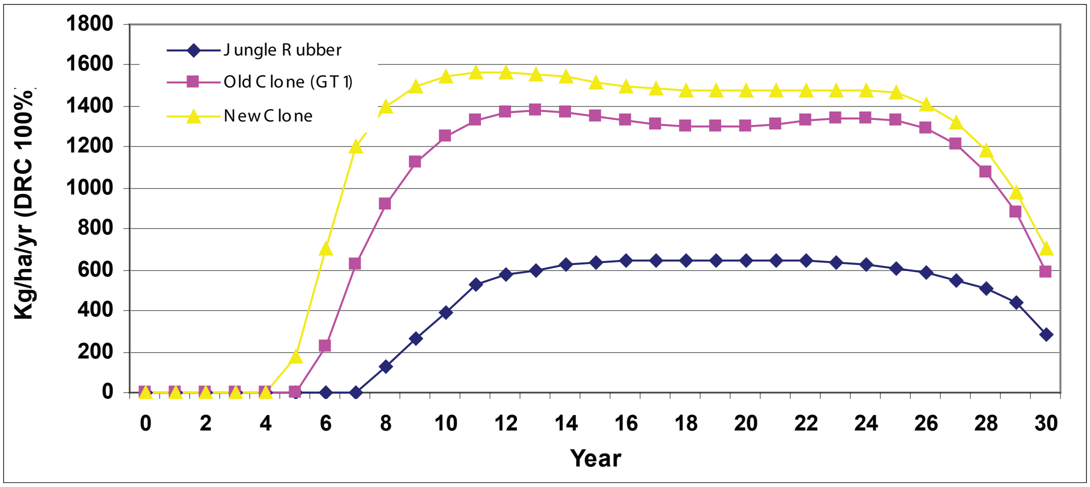

Figure 3: Latex yield prediction in three systems

Source: Wibawa, unpublished.

The productivity of rubber in the study areas was 35% higher than the national average for smallholders (DGE, 2002), but much lower than the productivity of clonal rubber in plantations (1,500 kg of dry rubber/ha per year; Hendratno et al, 1997). For RAS plots, the yields varied from 865–1,131 kg dry rubber/ha per year. This is significantly higher than the jungle rubber system output of 441 kg/ha per year. The difference in yields between clones and wildlings is well documented (Purnamasari et al, 1999).

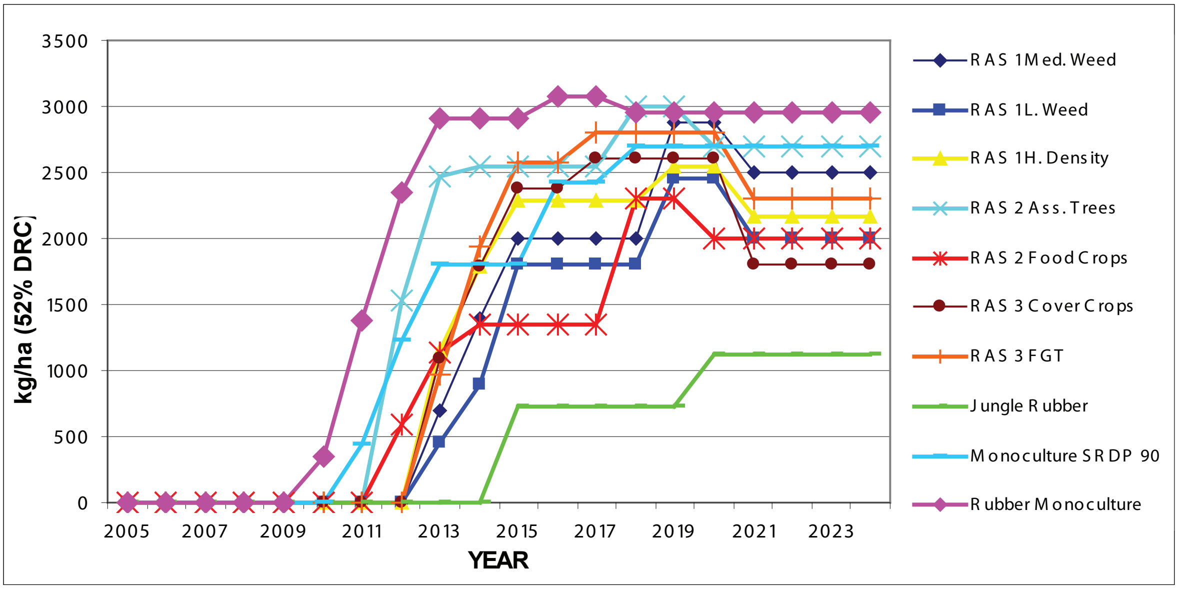

Figure 4: Latex yields of different rubber systems in Sanggau

Table 3: Average rubber production from different rubber systems

Farming systems	Average yield dry rubber content or DRC 100% (kg/ha/year)
Jungle rubber	441
RAS-1 low maintenance	917
RAS-1 medium	1,080
RAS-1 high density	1,052
RAS-2 with food crops	865
RAS-2 associated trees	1,131
RAS-3 with cover crops	950
RAS-3 FGT	1,119
SRDP	1,174
Monoculture private	971
Monoculture ideal	1,342
Private clonal agroforest	901

During the initial years RAS-1 high density produces more latex because of higher number of tappable trees - 750 trees/ha compared to 550 trees/ha in other RAS-1 systems. Later, yields in the high density plots decrease because of high mortality. The negative effects of excess 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, fruit and timber. In Sanggau district, local fruits such as durian, *pekawai*, *petai*, *jengkol* and *tengkawang* are valuable crops (Laure, 2005) while *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 these from Sanggau is still unavailable. The use of acacia as a combination species with rubber was inappropriate: it grew very fast and severely affected rubber tree growth. Plot owners therefore removed acacia within three years of 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 estimated returns to land and internal rates of returns (IRR) are alternative measures of estimates of discount rates that bring the NPV to zero. The following graph shows the margin of various rubber-based farming systems over 20 years (figure 5).

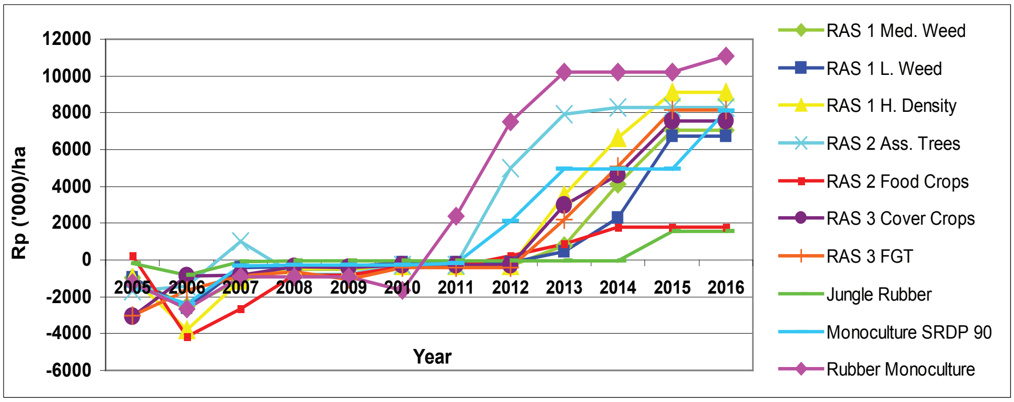

Figure 5: Profit margin over twenty years of different rubber systems

The economic assessments of various rubber-based farming systems are presented in table 4. The results show that the traditional system (local jungle rubber) is not profitable, as indicated by negative values for land return (negative Rp1,073,000/ha) and a labour return rate that is lower than the real average wage rate in the study area (Rp17,907 against Rp20,000). All RAS technologies are profitable, indicated by positive values for land return (between Rp2,864,000–18,316,000) while the value of land return for the monoculture system with new clonal rubber is Rp18,567,000. RAS technologies also provide attractive labour returns, some of which are higher than in monoculture systems.

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

Farming systems	NPV (Rp'000/ha)	IRR (%)	Estimated cost (Rp'000/ha)	Labour return (Rp/day)
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 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 crop systems

The rice-based system is important in Sanggau for subsistence and the local economy (Courbet et al, 1997). Traditional upland shifting cultivation (*ladang*) produces relatively low yields (500 kg/ha per year) compared to the irrigated rice system (1,200-2,600 kg/ha per year). Migrant Javanese farmers prefer *sawah* to *ladang*, while the local Dayak farmers have a preference for *ladang* for growing glutinous rice, which is mainly used for the local alcoholic drink (*tuak*), an essential item for traditional functions. Relevant details for food crop systems are provided in table 5.

Table 5: Basic input and output data for food crops systems in West Kalimantan

Typology	Sawah intensive	Sawah extensive	Ladang (upland non-irrigated rice)
Main Product	Rice	Rice	Rice/glutinous rice
Other Products	None	None	Maize, cassava, vegetables
Rice production (kg)	2,600	1,200	500
Total cost (Rp'000)	4,590	2,000	3,060
Labour requirement (days)	139	90	153
Margin (Rp'000)	1,910	1,000	140
Labour return (Rp/day)	13.76	11.12	0.88
Constraints	High input	Low production	Low productivity, unpredictable rainfall

5.2 Tembawang

The *tembawang*, or mixed fruit garden, is a famous traditional complex agroforestry system in West Kalimantan. All local people recognise that *tembawang* provide many items for household subsistence such as timber for house building, foodstuffs like mushrooms, and medicinal herbs. Products such as durian and *tengkawang* or illipe nut (*Shorea* species) can be sold, but harvests are variable and unpredictable. The forest gardens are at best supplementary sources of 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* (Potter, 2004).

5.3 Oil palm

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

The company first set up a credit scheme, which farmers had to provide 7.5 ha of land to join. In this way the company established the oil palm plantation. When the plantations reached harvest stage, the farmers received only 2 ha back each and also had to pay back to the company their 'loans' of up to Rp28 million from each harvest. As much as 15% of each harvest should be repaid from years 5 to 15 as credit reimbursement. The remaining 5.5 ha of land was managed by the company and the plans are that this land will later become state land (*Hak Guna Usaha*). Farmers also have to pay the company for input materials such as fertilisers and pesticides. This cost represents around 26% of the oil palm harvested.

6. Scenarios for rubber price fluctuation

The objective of scenario building is to asses the strengths or resilience of technologies. Scenarios modelled through Olympe predict a 50% dip in the price of rubber but a constant price for palm oil, as shown in figure 6. The results indicate that the margin in the rubber monoculture system declines to under the margin for RAS-2, which is buffered by diversified products such as fruits and timber.

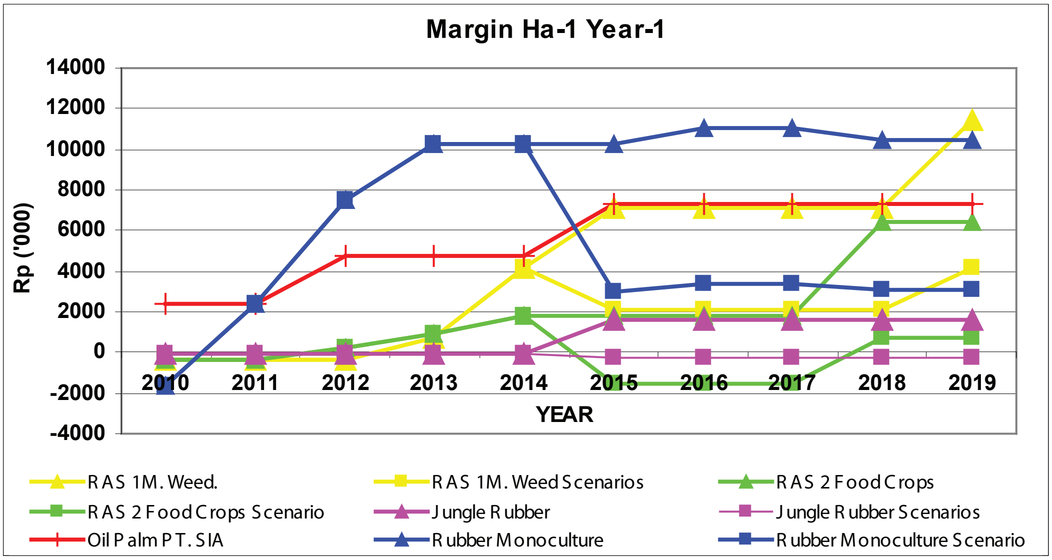

Figure 6: Simulating a rubber price drop by 50% in 2015 and 2016 (assuming constant palm oil price)

A second scenario, with the rubber price increasing by 50% by 2018 and price of oil palm decreasing by 40%, is presented in figure 7.

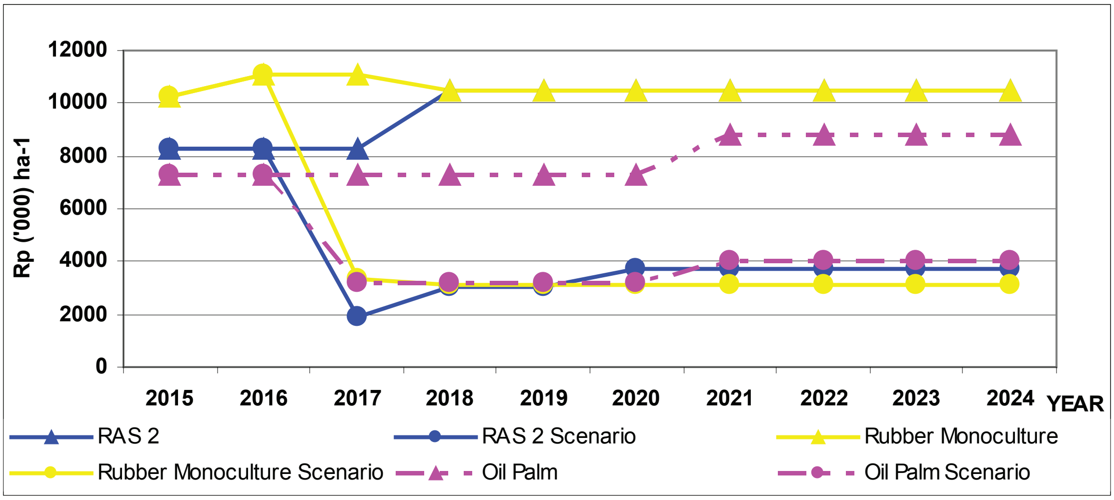

Figure 7: Simulation of rubber price doubling and price of oil palm decreasing by 40%

Basically, farmers consider rubber a 'refuge': a valuable, flexible and sustainable crop, even when prices are low, as was the case from 1997-2002. The importance of diversified systems becomes 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 economically active members per household. Household labour available for farming was about 2.7 individuals, equivalent to 709 person days/year.
2. The results show that compared to traditional jungle rubber, RAS technology requires more capital input, but returns for both labour and land are much higher.
3. While more intensive monoculture rubber offers better productivity (yield and profitability), it also requires much higher capital and input (labour, fertilisers, pesticides) which are beyond reach for most smallholder farmers, especially during the immature period.
4. Rubber agroforestry systems, including RAS technologies, can provide smallholder farmers with a diversified income and a range of non-timber forest products.
5. Tools for simulating possible changes such as price fluctuations can inform farmers and policy makers before they make better decisions on land-use systems. Various possibilities can be tested and their economic performances assessed.
6. The Olympe software is informative, useful, and provides customisable outputs of important economic analysis.
7. Although this study used the tools in a rubber context, the software is applicable for any farming practice.

References

Barlow, C., Shearing C. and Dereinda R. 1988. *Alternatives Approaches to Smallholder Development*. Centre for Policy and Implementation Studies.

Courbet, P., Penot E, and Ilahang. 1997. Farming Systems Characterization and The Adoption of Innovations in West Kalimantan. Proceedings of SRAP, Bogor, September 1997. ICRAF.

Directorate of General Estate (DGE). 2002. *Statistik karet* (Rubber statistics). Jakarta: Ministry of Agriculture.

Gouyon, A. 1992. Economic evaluation of technologies for smallholders: methodology and examples. Proceedings of the Symposium on Technology Transfer, The International Rubber Research and Development Board.

Grist, P., Menz, K. and Thomas. 1998. "Modified BEAM Rubber Agroforestry Models: RRYIELD and RRECON". ACIAR *Technical Reports Series* (42).

Joshi, L., Wibawa, G., Vincent, G., Boutin, D., Akiefnawati, R., Manurung, G., van Noordwijk, M. and Williams, S.E. 2002. *Jungle rubber: a traditional agroforestry system under pressure*. ICRAF SEA.

Joshi L., Wibawa, G., Beukema, H., Williams, S. and van Noordwijk, M. 2003. Technological change and biodiversity in the rubber agroecosystem of Sumatra. In Vandermeer, J. (ed.) *Tropical Agroecosystems*, CRC Press, FL. USA: 133-157.

Joshi, L., Wibawa, G., Ilahang, Akiefnawati, R., Mulyoutami, E., Wulandari, D. and Penot, E. 2006. Diversified rubber agroforestry for smallholder farmers – a better alternative to monoculture. Paper presented at the workshop "Rubber Development in Lao PDR: Exploring Improved Systems for Smallholder Rubber Production", Vientiane 9-11 May 2006.

Martin, L. 2005. Analysis and Characterization of Farming Systems in West Kalimantan. Institute National Agronomic. Paris. MSc Thesis.

Penot, E. 1996. Introduction to SRAP methodology and RAS concepts: summary of the preliminary results. Internal draft.

Penot, E. and Sunario. 1997. RAS on-farm experimentation in West Kalimantan: Preliminary results of on-farm rice trials in cropping seasons 1994/95, 1995/96 and 1996/97. Internal Research Report. World Agroforestry Centre. South East Asia. Bogor. Indonesia.

Potter, L. 2004. Can Indonesia's Complex Agroforests Survive Globalisation and Decentralisation? A Study in Sanggau District, West Kalimantan. The 15th Biennial Conference of The Asian Studies Association of Australian. Canberra.

PPPS. 1997. *Laporan Tahunan* Annual Report. Pusat Penelitian Perkebunan Smebawa. Palembang.

Purnamasari, R., Cacho, O. and Simmons, P. 1999. Management strategies for Indonesian smallholder rubber production in South Sumatra: a bioeconomic analysis. Working Paper Series in Agricultural and Resource Economics.

Van Noordwijk, M., Tomich, T.P., Winahyu, R., Murdiyarso, D., Partoharjono, S. and Fagi, A.M. 1995. Alternatives to slash-and-burn in Indonesia, Summary Report of Phase 1. ASB-Indonesia Report Number 4. ICRAF, Bogor.

Wibawa, G. 1997. Unpublished. Internal data of *Pusat Penelitian Perkebunan Sembawa*. Palembang.