APPENDIX 1 A PROFITABILITY ASSESSMENT OF SMALLHOLDER RUBBER AGROFORESTRY SYSTEMS IN JAMBI, SUMATRA, INDONESIA

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INTRODUCTION

A literature review on traditional rubber agroforestry systems in Indonesia, or jungle rubber as it is referred to, reveals two main points of interest. First, jungle rubber that is mostly owned by smallholder farmers (2-5 ha) is a result of local farmers' efforts since the early 20th century to adopt rubber as a cash crop into their crop fallow system (van Noordwijk et al., 1995; Penot, 1997; Joshi et al., 2002). Rubber was adapted to the traditional upland rice fallow system leading to the development of complex rubber agroforests that are characterized by high diversity in native forest tree species and understory plants. These rubber agroforests represent the best example of 'domesticated forests' (Michon, 2005) that maintain basic forest ecological processes in a productive context.

From an economic perspective, this land use system provides a wide range of sources of income for farmers, their neighbours and the other agents in rubber marketing. Jungle rubber provides regular income for farmers, mostly from rubber, and temporarily from food and cash crops in the initial years, fruits and other commodities from other tree species that grow spontaneously in the later years.

Secondly, from a conservation point of view, jungle rubber provides environmental benefits; being essentially secondary forest, it harbours many wild plants and animals of the primary forest that is almost disappeared from Sumatra's lowland peneplains (Gouyon, et. al., 1993; de Jong et al., 2001). Ecological studies have clarified vegetation structure and composition of rubber agroforest in Jambi (Gouyon et al., 1993; Penot, 1995; Beukema and van Noordwijk, 2004; Michon, 2005) and local ecological knowledge and farmer management styles for regeneration in cyclical or semipermanent rubber agroforest have been analysed by Joshi et al. (2003, 2005), Ketterings et al. (1999) and Wibawa et al. (2005). In brief, 60-80% of plant species found in neighbouring forests are also found in traditional jungle rubber. The woody biomass in a typical old traditional rubber agroforests also represents a carbon stock substantially (some 20 Mg C ha^{-1}) above what rotational systems would achieve as time-averaged value (Tomich et al., 2004). In addition, the locations where the agroforest are found, which are in riparian areas, also provide important hydrological functions. Michon and de Foresta (1994) found that a sample plot of jungle rubber contained 92 tree species, 97 lianas, and 28 epiphytes compared to respectively 171, 89, and 63 in the primary forest. In addition, Thiollay (1985) estimates that jungle rubber supports about 137 bird species of which nearly half are associated with primary forest.

The inherent production characteristics of jungle rubber in Jambi, however, are not at par with the environmental services they provide, because of the problems faced by farmers. Compared to a monoculture plantation that is common in estate system, the latex yield of jungle rubber on a per unit area is very low and the quality of rubber output is also inferior. Extensive processing is needed to produce a low grade product for the international market (Barlow *et. al*., 1988).

In addition, the low quality weakens farmers' bargaining position in the rubber marketing systems. Although the Indonesian National Standard (SNI) of rubber quality was launched by the government at the end of 1999, to improve rubber quality and increase farmers' income, the continuity and the effectiveness of such regulation are still in question as long as the control system is not well managed.

The issue of economic feasibility of various rubber production systems has been raised many times. In this paper we address two research questions:

1. How profitable is jungle rubber; what are its returns to land and returns to labour?
2. How does jungle rubber compare with more intensive mono-species systems of clonal rubber and oil palm?

Other points explored in relation to the long-term agricultural investments in rubber agroforests are the cash flow constraints and labour requirements. Investing in rubber agroforests, a perennial cultivation system entails multi-year financing. Here analysis of multi-year cash flow is carried out to reveal investment barriers to farmer adoption. Assessing labour requirements is based on calculations of person-days required including, total labour required for establishment phase (refers to the period before positive cash flow), and the average person-days per hectare per year employed for the operational phase (period after positive cash flow begin).

Assessment Method

Current assessment is focused on three socio-economic variables of smallholder rubber cultivation: (1) profitability as an indicator of production incentives for smallholders and also an indicator of comparative advantage of such activity to society at large; (2) labour requirements as an indicator of labour constraint for smallholders and a measurement of rural employment opportunity provided by the systems; and (3) cost of establishment as an indicator of cash flow constraint in establishing such systems. To relate them with policy perspectives, the assessment employed Policy Analyses Matrix (PAM) technique (Monke and Pearson, 1995). Assessment starts with the PAM framework for estimating profitability indicators and proceeds with an analysis of labour requirement and cash flow

The PAM approach is designed to analyse the pattern of incentives at the microeconomic level and to provide quantitative estimates of the impact of policies on those incentives (Monke and Pearson, 1995). As a partial equilibrium static framework, the PAM provides a consistent framework to analyse the information regarding land use activities, and to relate the direct financial and economic incentives that smallholder farmers face to relevant government policy that influences these incentives. The PAM compares household production budgets for a given agricultural production valued at private and social prices. The private prices are the prices that households and firms actually face; they indicate the financial incentives for adoption and investment in a system by independent smallholder farmers. Social prices, or economic 'shadow prices,' are calculated to remove the impact of policy regulations and market imperfections; they indicate the potential profitability or comparative advantage of a particular land use activity, given the opportunity costs of inputs from the perspective of society. The basic structure of PAM is shown in Table 1.

Table 1 Structure of Policy Analysis Matrix

	Revenues	Cost		Profits
		Tradable Inputs	Domestic Factors	
Private prices	A	B	C	D[1]
Social prices	E	F	G	H[2]
Effect of divergences and Efficiency policy	I[3]	J[4]	K[5]	L[6]

[1] Private profit, D = A - B - C
[2] Social profit, H = E - F - G
[3] Output transfer, I = A - E
[4] Input transfer, J = B - F
[5] Factor transfer, K = C - G
[6] Net transfer, L = D – H = I - J - K

Ratio Indicators for Comparison of Unlike Outputs

Private cost ratio (PCR): C/(A – B)
Domestic resource cost ratio (DRC): G/(E – F)
Nominal protection coefficient (NPC)
on tradable outputs (NPCO): A/E
on tradable inputs (NPCI): B/F
Effective protection coefficient (EPC): (A – B)/(E – F)
Profitability coefficient (PC): (A – B – C)/(E – F – G) or D/H
Subsidy ratio to producers (SRP): L/E or (D – H)/E

(Source: Monke and Pearson 1995, Table II.1, page 19.)

The first row of the matrix shows the profitability of an activity from the perspective of the individual farmer as valued from the private perspective and in terms of prices the farmers are faced with. This row captures the production budget for a land use activity reflecting the actual market prices received and paid for by the farmers for revenues and costs, respectively. The second row captures the production budget for the same activity valued at social prices (shadow prices) in absence of policy distortions and market imperfections on the financial incentives. The third row shows the divergence between private and social profitability indicating how policies and market imperfections affect the financial incentives faced by smallholder farmers.

Two indicators are used for rubber agroforest profitability assessment: ***returns to land*** as measured by the Net Present Value (NPV)[2] – calculated as the 'surplus' remaining after accounting for labour, capital, and other materials costs, and ***returns to labour*** - measured as the wage rate that sets the NPV equal to zero. The appropriate measure of profitability for long term investment NPV, i.e. the present

[2] In areas where land is scarce, the NPV calculation over the 25-year period can be interpreted as the 'returns to land' for the selected land use activity unit under study (Tomich et al 1998, p 64). Although land abundance and labor scarcity historically prevailed in many areas of Sumatra, making it an attractive focus of government sponsored transmigration programs, this relationship seems to have been shifting in Sumatra. Because much of the erstwhile abundant land has been subsequently granted to industrial plantations or has been settled in by spontaneous migrants as observed in Jambi Province in the past two decades, land may now be considered as becoming scarce.

worth of benefits (revenues) minus the present worth of the cost of tradable inputs and domestic factors of productions (Gittinger, 1992). Mathematically, it is defined as:

$$NPV = \sum_{t=0}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

where B_t is benefit at year t, C_t cost at year t, t is time denoting year and i is the discount rate used in the assessment. An investment is appraised as profitable if NPV is greater than 0.

Calculating the wage rate until NPV goes to zero leads to a proxy for 'returns to labour', since this process converts the surplus to a wage rate (Vosti et al, 2000). The calculation of returns to labour converts the 'surplus' to a wage after accounting for purchased inputs and discounting for the cost of capital. Where a return to labour exceeds the average daily wage rate, individuals with their own land will prefer this activity to off-farm activities; it also justifies hiring non-family labour. Returns to labour valued at private prices can be viewed as a primary indicator of profitability for smallholders' production incentives.

Cost of establishment, as an indicator of cash flow constraints, is defined as NPV of all inputs used prior to positive cash flow to establish a system– including the imputed value of family labour and family owned implement, but excluding any imputed costs for family land and management (Vosti et al., 2000). This is to assess whether the investment required by the systems are barriers to adoption by smallholders.

With regard to **labour requirements**, three different indicators are used in the assessment: total person-days required for establishment (i.e. the period before positive cash flow occurs), person-days required for operations (i.e. the period after positive cash flow starts) and total person-days employed over time (Tomich et al., 1998; Vosti et al., 1998). The last two indicators are expressed on an average basis, per hectare per year, throughout the relevant time period. From farmer's perspective, unmet labour requirement indicators reflect labour constraints that farmers face. From policy makers' point of view, the figures reflect employment opportunity that may exist.

Pricing costs and returns

Profitability assessment needs a detailed farm budget calculation3. It is necessary to clarify the appropriate prices for calculating costs and returns and the macroeconomic assumptions used in this assessment. In determining the prices, we used the annual average prices of 1998 - 2009 of all tradable farm inputs and farm commodities that were cast in the respective constant 2007 prices (2007=100)[4]. The local market prices in Jambi were used for calculating farm budget valued at private prices. For comparable farm budgets at social prices, export or import parity prices at farm gate were

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[3] This assessment did not include the environmental benefits provided by jungle rubber. Further study is needed to value the environmental benefit of jungle rubber.

[4] This refers to 2007 price as an index from which overall effect of general price inflation has been removed. So that the prices of all inputs and outputs used in the assessment have been deflated to real term. Shortly, the nominal prices net of inflation.

used. Farm budget calculation was done based on the macroeconomic parameters of year 2009 (Table 2), representing the recent situation.

Real interest rates, or the nominal interest rate net of inflation, are the discount factors used to value future cash flows into present terms. A private discount rate of 10% and a social discount rate of 5% were used for calculating NPV at private and social prices respectively[5].

Sensitivity analysis of rubber system profitability to interest rate and wage rate was carried out to understand to what extent these variables can influence profitability.

Table 2 Macroeconomic parameters used in the study (2009)

Exchange rate (Rp/US $)	Rp 10,374
Average *real* wage rate in Sumatra 2004 – 2009, Constant 2007 price (Rp/person-days)	Rp 28,409
Real interest rate (net of inflation):	
At private prices At social prices	10% per annum 5% per annum

Smallholder rubber systems under study

Two common smallholder rubber systems in Jambi were selected for this assessment. The first is the extensive traditional jungle rubber agroforestry that covers around 86% of the existing total rubber system (Penot, 1995) that is characterized by a high variability in vegetation structure and composition - ranging from near-forest with hundreds of plant species to near-monocrop plantations with little non-rubber vegetation. Farmers' decision making process in the selection between a rotational system versus a *sisipan* system in jungle rubber agroforestry are discussed. Under a cyclical system, farmers usually clear old rubber gardens (35 to 44 years old) to start new rubber plantations. We use the average figure of 40 years for rubber garden age in our assessment. Under a *sisipan* system, farmers actively interplant rubber seedlings or maintain rubber saplings within productive rubber plot to ensure a continuous income from these rubber gardens. We assume that under a *sisipan* system farmers begin to interplant new rubber seedlings only at year 20 and these rubber plots will continue to be productive until year 68 – close to two cycles of rotational system.

The second system used in this evaluation is the improved monocrop plantation using GT1 clone representing a high-input and high-output system that is being promoted in rubber development projects. It is a nearly a clean system (no other natural vegetation) and requires intensive plantation management to ensure optimal yield of latex. Available data indicate that these plantations remain productive up to year 30.

Field establishment and latex production

Establishment of a new rubber garden involves land clearing, mostly through a slash and burn activity, followed by planting rubber propagules, guarding against wildlife damage and frequent weeding and maintenance until the rubber plants are established. Other crops such as maize, dry land rice and other cash crops may be cultivated in the first two or three years. The main differences

[5] Capital markets in Indonesia are fraught with imperfections, particularly in rural area. Private interest rates, particularly for the smallholder sector have been very high in real terms. The real social interest rate is less than the private rate (Tomich et al. 1998)

between the traditional jungle rubber and monoculture system are in the use of tradable purchased inputs, the corresponding crop care activities, hence labour requirements. Monoculture systems using selected clones almost always require fertilizer input but also yield higher latex production. The details inputs used and the outputs of both systems are shown in Appendix 1B. The next difference between the two systems is in the continuity of rubber gardens in producing latex. Under the cyclical system, once the old rubber plot is cleared, there is an establishment (or waiting) period, six to ten years, before rubber trees can be tapped (45 cm girth at breast height). Under a *sisipan* system, no clear felling is necessary, as rubber seedlings are planted in small gaps (hence the term "gap replanting"), and rubber plots keep producing latex, albeit at a lower rate.

Latex productivity of jungle rubber constitutes a major data challenge for this assessment as it requires latex production in sequential planting years. Moreover, little data is available regarding jungle rubber productivity. Although crude estimates of production had been used for jungle rubber (Penot, 1995; World Bank, 1984) these figures appear not to take into account the large range of stocking density, management flexibility and complexity of the system (Vincent et al., this issue). Data based on recent observations of the system (ICRAF, internal reports) have been used in the current assessment. The trend used in the production data of Indonesia Smallholder Rubber Development Project II (The World Bank, 1984) was used to develop production scenarios for the monoculture rubber system. Figure 1 indicates rubber production scenario for the three systems used in the current assessment; figures are provided in Appendix 1A.

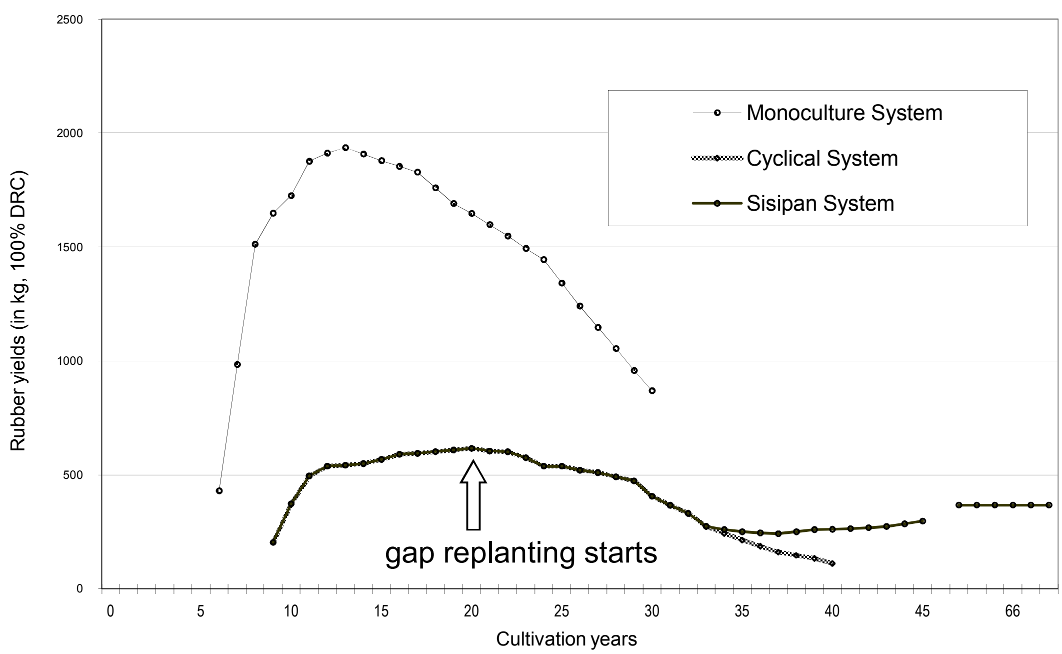


Figure 1 Rubber yield estimates over time of selected rubber systems

Non-rubber products

Although latex is the main source of income from rubber agroforestry, farmers also collect products such as annual crops (e.g., paddy rice, maize, vegetables) in the initial years of rubber establishment while fruits, medicinal plant, tubers can be collected in the latter years. However, a few products have any commercial value. Many fruit trees in rubber agroforestry, for example, are considered public property; anybody in the community may collect fruits for self consumption. Accordingly it is assumed that only half of their potential contributes to household income. Fruits of durian *(Durio zibethinus),* petai *(Parkia spesiosa) and* jengkol *(Pithecellobium jeringa)* are the most common fruits collected from rubber agroforest that have market value. Because of their infrequent occurrence in jungle rubber agroforests, it is estimated that on average only three fruit trees per species per hectare of jungle rubber contribute to household income.

Currently timber is considered only a by-product from rubber agroforestry. Rubber wood is of little importance as it requires fungicide treatment within two days of felling. Otherwise, the blue stain fungus renders the wood undesirable. In the absence of such processing facility in the vicinity, rubber wood from jungle rubber in Jambi has little value. However, woods of other high quality timber species are a high-value product. This assessment includes timber from the clearing activity both prior to establishment and at the end of the tapping stage. Clearance of secondary forest for rubber garden yields only about $4m^3$ ha^{-1} of marketable timber. At the end of the each rubber cycle (40 years) in Jambi, 25 m^3 of marketable rubber wood and 13.5 m^3 of other marketable timber species per hectare can be harvested (Phillippe, 2000). From *sisipan* system that reaches 68 years old onward, it is estimated to contain $30.7m^3$ ha^{-1} of marketable rubber wood and 23.4 m^3 ha^{-1} of non-rubber timber in the system.

RESULTS OF THE ASSESSMENT

Profitability

Estimates returns to land and returns to labour of the smallholder rubber systems under study, both evaluated at private and social prices, are summarised in Table 3 and Table 4. The profitability assessment for the three systems yielded similar results. With the current rubber price, IDR, 13,000 per kg (in real term), the three systems are profitable, indicated by positive values for returns to land and the calculated IRR higher than the discount rate. They vary in its production incentives (returns to labour at private prices). Return to labour of the S*isipan* system is not much different from the real average wage rate in the province (IDR 28,409), and the cyclical system is 25% higher slightly higher. The monoculture rubber system, well managed and without any credit to pay back, is more profitable than traditional systems. As shown in Table 3, the monoculture system is the highest NPV for both private (financial) and social (economic) prices, as well as its estimated IRR. Positive estimates of return to land and returns to labour of this system suggest that the system is attractive enough for farmers. This is true for an ideal rubber monoculture setting. It is hereby assumed that the monoculture system is optimally managed (pest control, tapping and other maintenance) following recommended practices and using easily available planting material. However, in reality and even in project areas, these ideal conditions are exceptions rather than norms.

For traditional systems, the assessment assumes a “standard” jungle rubber and the inherent flexibility of these systems are difficult to cater for in such evaluations. It is to be noted that rubber farmers do not necessarily maximise latex production from their rubber gardens, but rely on a number of alternative sources, including on-farm and off-farm jobs to maintain their household income. Furthermore, economic assessment tends not to include family labour – the most dominant labour inputs in smallholder rubber cultivation – in the component of expenditure; hence, cost of labour is actually returns to the family labour involved. Perhaps this explains why traditional rubber production systems, despite their negative economic indicators, continue to be practised.

Table 3 Profitability Matrix of Selected Smallholder Rubber Systems in Jambi Province (in IDR 000)

	Traditional Rubber agroforest						Monoclonal rubber (30 years)		
	Cyclical System (40 years)			*Sisipan* Systems (68 years)					
	private	social	effect of divergences	private	social	effect of divergences	private	social	effect of divergences
Revenues	28,943	81,986	(53,043)	29,836	96,173	(66,337)	75,965	184,747	(108,782)
Cost									
Purchased inputs									
Tradables	2,380	4,261	(1,882)	1,985	4,295	(2,310)	15,122	24,184	(9,063)
Non Tradable	1,635	1,813	(178)	372	1,977	(1,606)	166	355	(190)
Domestic factors									
Labors	19,644	39,406	(19,762)	26,119	45,262	(19,143)	42,967	77,205	(34,238)
Capital	246	253	(7)	26	301	(275)	1,330	1,006	324
Profit	5,038	36,253	(31,215)	1,334	44,338	(43,004)	16,381	81,996	(65,615)

Table 4 Profitability Matrix: Smallholder Rubber systems in Jambi (constant 2007 prices)

System	RETURN TO LAND (NPV) *IDR '000 per ha*			INTERNAL Rate of Return (IRR)		RETURN TO LABOR *IDR/ person-day*		NPCO 2)
	Private Prices r=10%	Social Prices r=5%	Divergences	Private Prices	Social Prices	Private Prices	Social Prices	
RAF Traditional								
Cyclical system (40 year cycle)	5,038	36,253	(31,215)	14.8%	16.7%	36,600	54,400	0.56
***Sisipan* System (68 year cycle)**	1,334	44,338	(43,004)	15.1%	16.82%	29,800	56,100	0.46
Monoculture (30 year cycle)	16,381	81,996	(65,615)	16.7%	19.8%	38,900	57,800	0.63

Note:

1) Profitability coefficient (PC) is ratio between NPV at private prices to the comparable NPV at social prices, showing the extent to which financial-private profit differ to the comparable economic-social profit. PC measures the incentives effect of all policies and provides a ratio to determine the relative net policy transfer (Monke and Pearson, 1995)
2) Nominal Protection Coefficient on tradable Output (NPCO) is a ratio that contrasts the observed (private) commodity prices with the comparable world price. This ratio indicates the impact of policy (and of any market failure not corrected by efficient policy) that causes a divergence between the two prices. NPCO > 1 is indicative of private prices of output being greater than social prices reflecting that producers are positively protected.

Divergence between private and social profitability

NPVs of all rubber systems under study at private prices are lower than those at social prices. This behaviour is reflected by the negative values under the column "divergences" in Table 3. The higher private discount rate of 10%, as compared to the lower 5% rate to reflect the social discount rate, was the major cause of these divergences. When the private discount rate were altered (i.e. no difference in two discount rates), the analysis revealed that the difference in discount rates contributed to the divergences as much as 98%. Hence, the cost of capital, as it reflected by the interest rate, was an important factor in enabling the rubber system to remain feasible for smallholder farmers. This is related to the long establishment periods in both traditional and monoculture systems.

There are negative output transfers in both traditional systems and the monoculture system. The Nominal Protection Coefficients on tradable output (NPCO) of all selected rubber systems vary from 0.46 (*sisipan* system) to 0.63 (monoculture system). The product market situation and the macroeconomic policy (reflected from the real interest rate) have reduced the potential returns as much as 37% to 54%. Without any difference in the discount rates, the results of NPCO computation ranged from 1.002 to 1.004, indicating that the market situation alone, especially for rubber (Figure 2) has permitted the systems to receive better returns than the external world market.

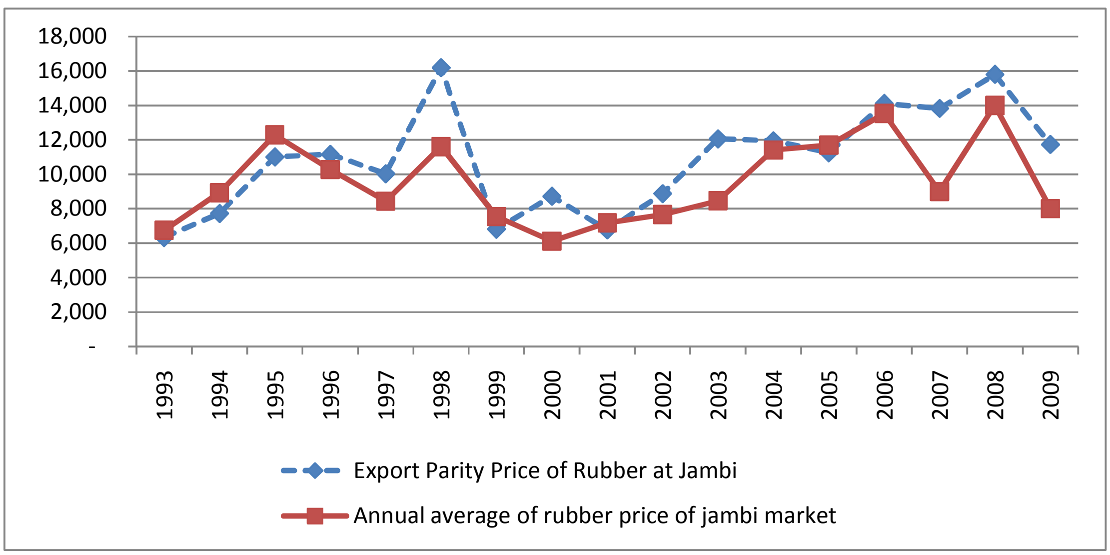


Figure 2 Rubber price fluctuation (Rupiah kg^{-1}of 100% DRC; constant 2006 price)

Labour Requirement

Table 5 presents three indicators of labour requirement for the three rubber systems under study: (1) total person-days (ps-days) required for establishment; it refers to the period before positive cash flow occurs; (2) Average ps-days required for operations (defined as the period after positive cash flow) per ha per year; and (3) Total ps-days employed over time per ha per year

Estimates of labour requirements for establishing rubber agroforests reveal some interesting results. Monoculture system with a six year establishment period requires 741 ps-days ha^{-1}; this is reasonably higher than the traditional systems (both cyclical and *sisipan*), that employ 474 ps-days ha^{-1} for 9 years of establishment period. Translated into yearly employment, monoculture system requires 123 ps-days ha^{-1} $year^{-1}$, and the traditional systems require only 53 ps-days ha^{-1} $year^{-1}$.

Table 5 Labour requirements in rubber agroforestry systems in Jambi

Systems	Years to Positive Cash flow	Labour requirements	
		Establishment phase ps-day/ha	Operation Phase ps-day/ha/year
Traditional RAF			
Cyclical system	9	464	104
Sisipan system	9	474	115
Monoculture Rubber	7	744	211

Estimates of labour requirement during latex production phase, also show significantly different figures between monoculture and traditional systems. Although monoculture system has a shorter production phase (24 years), it requires 185 ps-days ha^{-1} $year^{-1}$ for tapping and other maintenance activities. While the two traditional systems, cyclical and *sisipan*, with 31 years and 59 years of production phase respectively, require 115 and 104 ps-days ha^{-1} $year^{-1}$. Monoculture system requires the more labour for all activities. From farmers' perspective, higher labour requirements impose a more serious constraint when the average wage rate increases beyond the returns to labour. For policy makers, monoculture systems could be probably attractive as employment generation in rural areas. But this requires a careful check with the population data and whether economically active population in agriculture can actually meet the labour requirements of monoculture system. As additional information, published statistics on population and agriculture area of Jambi (BPS, 2001) and estimates of Economically Active Population in Agriculture in Indonesia (FAO) show that population density per unit agriculture land in Jambi is 218 per km^2 or roughly 2 persons per hectare. Assuming that average working days per annum for rubber cultivation is 180 days per person, it can be roughly estimated that there are 360 ps-days per hectare per year available for rubber cultivation.

Cost of establishment - a constraint?

Table 6 includes two perspectives on multi-year cash flow constraint: years to positive cash flow and establishment cost that can be defined as discounted cash outflow prior to positive cash flow. The imputed value of family labour is included in these establishment cost because these labour inputs presumably represent opportunity cost – foregone earnings – in the other activities, even when they do not require any cash outlay.

Positive cash flow in both traditional rubber systems starts in year 9 (establishment period). This does not appear to be a constraint for smallholder rubber farmers as they usually keep two or more rubber agroforests at different stages of maturity. However, there are indications that this establishment period has shortened primarily as land scarcity has increased and farmers' waiting capacity has declined. During the waiting period, farmers can also work on other parcels of land or work in off farm activities.

Table 6 Cash flow constraint matrix in 2009

Rubber System	Years to positive cash flow	Discounted establishment cost at private prices *IDR 000/ha*	Discounted establishment cost at social prices *IDR 000/ha*
RAF Traditional			
Cyclical System	9	11.907	13,408
Sisipan System	9	11,789	13,259
Monoculture Rubber	7	30,087	30,335

The amount of IDR 13.4 million required to establish the system seems not an insurmountable barrier for smallholder. The monoculture system with positive cash flow for occurs in year 7, requiring IDR 30.1 million to establish. This amount is too expensive for smallholder to invest. But the competing land use option (oil palm plantation) that requires slightly lower investment (about IDR 25 million/ha) with higher return to labour (approximately two fold of rubber monoculture system) is attractive for farmers to invest. However, there are some technological constraints for some farmer to invest in oil palm plantation at the current stage.

Influence of discount rate and wage rate on profitability

The current analysis indicated the importance of discount rate and wage rate in determining the overall profitability of these systems. To understand to what extent these parameters changed the NPVs of rubber systems in Jambi, sensitivity analysis of profitability to the discount rate and the wage rate results was carried out. The results are summarised in Figure 3. There is a differential impact of changes of interest rate to the profitability (NPV). The lower the discount rate the more sensitive are the NPVs (traditional system's profitability) to the change of interest rate. Beyond a discount rate of 30%, profitability of rubber systems in Jambi is no longer sensitive to the change of interest rate. This illustrates that rubber cultivation is not a capital-intensive type of investment, meaning that the initial capital is only a small proportion of the total expenditure over time. This capital investment is perhaps affordable to many smallholder farmers. However, below 20% discount rate, profitability of rubber system becomes more sensitive. This implies that maintaining lower capital investment will indirectly increase profitability of traditional rubber agroforestry.

Figure 3 also indicates that an increase in wage rate in agricultural labour market lowers returns to land in all rubber production systems. The trend line of monoculture system is steeper than that of the traditional systems; it proves that monoculture system, although providing better returns to labour and employment opportunities in rural area, is more susceptible to any change of wage rate than traditional systems. Traditional production systems appear to be less sensitive than monoculture system to rubber price fluctuation hence provides an important buffering to overall latex production (Box1).

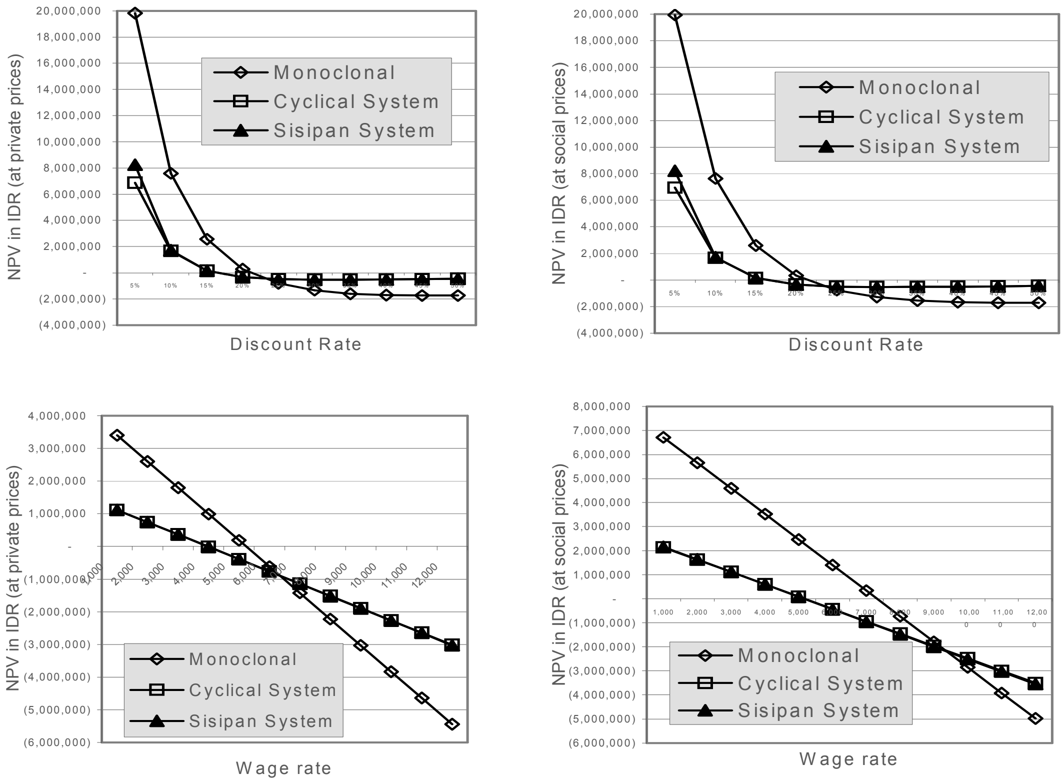
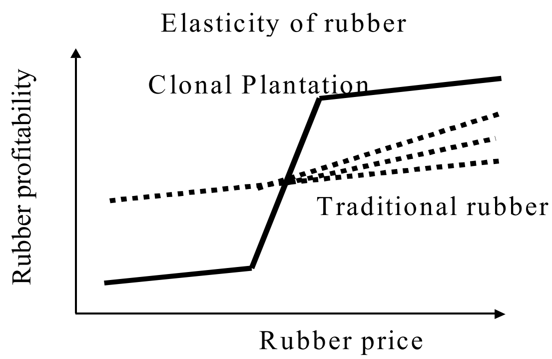


Figure 3 Sensitivity analysis of rubber profitability to the discount rates and the wage rates.

Box 1. Elasticity of traditional rubber cultivation contribute to sustenance of natural rubber production

Smallholder farmers manage over 86% of rubber production area in Indonesia and more than two thirds of this area is managed as traditional jungle rubber. This is despite over two decades of government projects and efforts to convert traditional system to monoculture plantations. This is premised on dominant views of government and development professionals that traditional system is both as a lost opportunity and that maintains rural poverty. From an economic perspective, however, one cannot ignore the important role this traditional system plays in 'buffering' the market or price of natural rubber that has gone through peaks and troughs over the last several decades. Traditional rubber cultivation, due to its very little input requirement and high flexibility in terms of its management is less affected by price of rubber (See Figure). The intensive monoculture plantations, on the other hand become profitable above threshold price of rubber, below which it become totally unfeasible. At least in Indonesia, this rigidity of monoculture systems is balance buffered by natural rubber production in traditional systems.



Theoretical sensitivity of rubber production in clonal plantations and traditional systems. Above a threshold return (price), clonal plantations become 'profitable' and hence flourish. Under low profit or uncertain return, the traditional systems maintain their output without seriously affecting overall national (and international) production.

Palm cultivation: a competing land use option

Oil palm cultivation is currently an attractive land use option for smallholder farmers in Jambi as in many other provinces in Indonesia. Oil palm cultivation began in Jambi in 1986 as oil palm estate (Barlow 1991); but it expanded rapidly to cover 44,000 ha in 1990, 185,934 ha in 1996, and 200,000 ha in 1997 (Potter and Lee, 1998).

Independent smallholder oil palm cultivation, on smaller scale of 2-10 ha appeared in Jambi (Rimbo Bujang and Kuamang Kuning) only in 1995. This followed the success of government promoted *PIR Trans* (NES) model. Oil palm remained a choice crop for independent smallholders and its cultivation continued to expand rapidly in Jambi when the assessment was carried out. The latest assessment shows 10,159 hectare of rubber agroforest in 2002 have been replaced by oil palm plantation in 2008 (Ekadinata et al., 2010)

The attractiveness and superiority of oil palm over rubber for independent smallholder has been demonstrated by Pepenfus (2000). His assessment of independent smallholder oil palm cultivation (2-10 ha) in a 25-year span estimated a return to land per hectare was five times higher than monoculture rubber system and a return to labour was four times higher than prevailing average agricultural wage rate in 2000 (real term 2000 price). Oil palm cultivation, and its profitability is very much dominated by chemical fertilizers as it takes up as much as 33% of the total production cost. The fertilizer requirement increases in less suitable land; this is the case in most parts of Sumatra.

Large-scale oil palm cultivation is less profitable than independent smallholder farming. (Tomich et al. 1998) showed that the estimate of return to land of a 10,700 ha of oil palm plantation was nearly the same with most productive rubber systems and return to labour was only 35% higher than average agricultural wage rate. It was partly because of requirement for a much higher infrastructure (road and drainage network) and management costs compared to small-scale plantations. In a 10,700 ha of oil palm plantation, for example, the discounted cost for road construction was estimated to be around 20% of its investment excluding road maintenance during the 25 year-span.

LESSON LEARNED AND FUTURE DIRECTIONS

Traditional rubber agroforestry system still remains in Jambi. However, it is clear, both from our current assessment and with observations made by others, that rubber agroforestry with low latex productivity has little competitive advantages and is not financially attractive for farmers to engage in. This is also indicated by the rapid conversion of old jungle rubber with monoculture oil palm and rubber in the recent years. On-going monitoring of land use change in Bungo Tebo area in Jambi using Geographical Information System and remote sensing analysis of 1973 – 2002 spatial data points to very high rate of disappearance of forest area and rubber agroforest area in recent years (Ekadinata et al., 2010) the same time monoculture rubber and oil palm cultivation has increased significantly. Traditional rubber agroforestry may provide better environmental benefits; but currently this does not translate to any significant incentives to farmers.

While the traditional rubber agroforests are important for biodiversity conservation and other forest functions, the economic analysis of the system concluded that profitability of the system is marginal compare to other land uses. In spite of this, the system was the most important land use in the local economy until late 1990s. Therefore, there remains the potential to conserve biodiversity and other environmental services within agroforest systems through appropriate innovative interventions including payment mechanisms.

Between rubber systems, current assessment clearly shows the economic advantages of monoculture rubber over the traditional systems. Despite its advantages, adoption of monoculture system entails easy availability of good quality planting material. This, however, has remained a significant bottleneck in most smallholder rubber development projects. Where this constraint is overcome, a significant increase in both returns to labour and returns to land can be achieved. However, in the current analysis no consideration was made of the establishment risks such as those imposed by an inferior quality of clones in the market and low survival rate of planting material in the field due to vertebrate pests during the establishment phase.

Farmer management of high yielding rubber clones also requires intensive care and input. Even in project endeavours in Jambi and South Sumatra where farmers received orientation and training on good management and tapping, farmers have been observed to tap at a much higher intensity than recommended, thereby affecting the health of rubber trees and significantly shortening their production phase to less than 10 years. Whether this is due to lack of knowledge of tapping or due to other constraints remains unclear.

The monoculture system may provide higher returns to both land and labour and overall higher latex productivity for smallholder rubber farmers. Nevertheless, from a conservation perspective, the monoculture system poses a serious threat to the mega biodiversity that is a characteristic of the

Sumatran forests. In the current analysis, the environmental services provided by the traditional jungle rubber have not been considered as currently the value of this biodiversity is yet to be determined. Studies to assess environmental valuation of biodiversity and other services provided by these systems need to be undertaken urgently. It is likely that the conservation value of traditional jungle rubber compensates for its lower latex production potential.

ACKNOWLEDGEMENTS

This is an extended assessment of the profitability of rubber agroforestry system that was previously carried out in 1997, under Alternatives to Slash and Burn programme, and been recalculated and updated in 2009. The new data on latex and timber production in a range of jungle rubber systems in Jambi used in the current calculation was provided by Gregoire Vincent of ICRAF/IRD.

Appendix 1A: Financial Calculation on the Selected Rubber Systems

1. Summarized Input – Output Tables of the selected Rubber systems understudy

Input - Output Components	Unit	Monoculture Rubber (30 yr)	Traditional RAF	
			Cyclical system (40 yr)	*Sisipan* System (68 yr)
Tradable inputs				
Fertilizers and chemicals				
Urea	kg/ha	3,489	0	0
SP 36	kg/ha	2,989	0	0
KCl	kg/ha	301	0	0
MOP (Muriate of Potash)	kg/ha	1,900	0	0
Herbicide (Round up)	litre/ha	66	0	0
Fungicide (Furadan)	kg/ha	15	0	0
Formic acid / cuka para	bottle/ha	746	278	480
Non tradable inputs	IDR/ha (discounted)	53,565	17,202	17,252
Domestic factors				
Labours				
Land clearing (forest clearing)	ps-d/ha	89	74	74
Rubber Planting activities	ps-d/ha	43	41	41
Making wild pig trap and fencing	ps-d/ha	70	50	50
Intercrops farming activities	ps-d/ha	120	55	55
Rubber garden maintenances				
Total labour employed	ps-d/ha	969	256	592
Average labour employed	ps-d/ha/yr	32	13	9
Rubber tapping preparation	ps-d/ha	10	10	10
Tapping and latex processing				
Total labour employed	ps-d/ha	3, 941	3,267	5,704
Average labour employed	ps-d/ha/yr	158	102	95
Harvesting of non rubber product	ps-d/ha	0	324	740
Capitals				
Working capital (cumulative)	Rp/ha (discounted)	264,807	45,636	45,919
Outputs				
Rubber (100% DRC)				
Total Rubber Outputs	Kg/ha	37,298	13,718	24,041
AVG. Rubber Outputs	Kg/ha/yr	1,492	439	401
Rice (local variety)	Kg/ha	2,000	1,000	1,000
Durian	Unit/ha	0	2,100	5,100
Petai	Bunches/ha	0	5,265	11,565
Jengkol	Kg/ha	0	12,900	29,961
Timber				
Rubber wood	cu-m/ha	25	25	31
Non rubber species	cu-m/ha	5	18	28

2. Summarized financial returns of the selected Rubber systems under study (in 000 IDR - discounted, constant 2007 prices)

Output Components	**Monoculture Rubber (30 yr)**		**Traditional RAF**			
			Cyclical system (40 yr)		***Sisipan* System (68 yr)**	
	At private prices	At social prices	At private prices	At social prices	At private prices	At social prices
Rubber (100% DRC)	5,467	9,491	1,058	2,088	1,061	2,109
	(76.8%)	*(84.0%)*	*(44.2%)*	*(56.1%)*	*(44.3%)*	*(56.4%)*
Rice (local variety)	*855*	*943*	*427*	*471*	*427*	*471*
	(12.0%)	*(8.4%)*	*(17.9%)*	*(12.7%)*	*(17.9%)*	*(12.6%)*
Durian	-	-	*16*	*46*	*17*	*49*
	-	-	*(0.7%)*	*(1.3%)*	*(0.7%)*	*(1.3%)*
Petai	-	-	*31*	*87*	*32*	*90*
	-	-	*(1.3%)*	*(2.3%)*	*(1.4%)*	*(2.4%)*
Jengkol	-	-	*65*	*185*	*66*	*194*
	-	-	*(2.7%)*	*(5.0%)*	*(2.8%)*	*(5.2%)*
Timber	*794*	*858*	*792*	*840*	*789*	*824*
	(11.2%)	*(7.6%)*	*(33.1%)*	*(22.6%)*	*(33.0%)*	*(22.0%)*
	7,117	*11,293*	*2,392*	*3,721*	*2,394*	*3,740*
	100%	*100%*	*100%*	*100%*	*100%*	*100%*

Appendix 1B: Estimated yields of the selected rubber systems under study

Year	Traditional Jungle Rubber				Monoculture Rubber	
	Cyclical System		Sisipan system			
	Gtt[1)]	*Total* [2)]	*Gtt*[1)]	*Total* [2)]	*Gtt*[1)]	*Total* [2)]
0						
1						
2						
3						
4						
5						
6					12	430
7					16	984
8					20	1,512
9	11.3	203.9	11.3	203.93	21	1,648
10	13.8	373.1	13.8	373.05	22	1,726
11	15.3	495.4	15.3	495.40	23	1,877
12	15.7	538.6	15.7	538.63	24	1,912
13	15.9	542.5	15.9	542.47	25	1,936
14	16.1	550.1	16.1	550.06	25	1,908
15	16.2	568.4	16.2	568.38	26	1,879
16	16.4	590.7	16.4	590.74	26	1,855
17	16.5	594.6	16.5	594.58	26	1,829
18	16.7	602.2	16.7	602.15	26	1,760
19	16.9	609.6	16.9	609.59	25	1,691
20	17.1	616.9	17.1	616.89	25	1,648
21	17.2	605.0	17.2	604.98	25	1,598
22	17.1	601.5	17.1	601.47	25	1,549
23	16.8	575.6	16.8	575.59	25	1,494
24	16.6	538.5	16.6	538.54	25	1,445
25	16.6	538.5	16.6	538.54	25	1,343
26	16.1	521.1	16.1	521.11	24	1,241
27	15.7	510.3	15.7	510.28	24	1,148
28	15.2	491.6	15.2	491.60	24	1,055
29	14.6	473.8	14.6	473.77	23	959
30	14.1	406.1	14.1	406.07	23	869
31	13.6	367.3	13.6	367.32	21	717
32	13.1	331.1	13.1	331.06	20	620
33	12.7	274.3	12.7	274.28	20	552
34	12.3	243.3	12.3	259.57		
35	11.9	214.2	11.9	250.40		
36	11.5	186.9	11.5	245.15		
37	11.2	161.3	11.2	242.21		
38	10.9	147.0	10.9	250.73		
39	10.6	133.5	10.6	260.42		
40	10.3	111.5	10.3	261.74		
41			10.1	264.52		

Appendix 1B: Continued

Year	Traditional Jungle Rubber				Monoculture Rubber	
	Cyclical System		*Sisipan* system			
	gtt	total	gtt	total	gtt	total
42			9.8	268.50		
43			9.6	273.70		
44			9.4	285.48		
45			9.2	297.92		
46			9.1	310.86		
47			8.9	324.01		
48			8.8	337.06		
49			8.6	357.88		
50			8.5	366.75		
51			8.4	375.33		
52			8.3	375.24		
53			8.2	375.15		
54			8.1	375.07		
55			8.0	375.00		
56			8.0	372.07		
57			7.9	370.61		
58			7.8	367.77		
59			7.8	367.77		
60			7.7	367.77		
61			7.7	367.77		
62			7.6	367.77		
63			7.6	367.77		
64			7.5	367.77		
65			7.5	367.77		
66			7.5	367.77		
67			7.4	367.77		
68			7.4	367.77		

Note:

1. Gtt ; gram per tree per tapping
2. Total yield is function of Gtt, number of tapping trees and number of tapping days per year