Environmental aspects of smallholder rubber agroforestry in Indonesia : reconcile production and environment.

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Paper presented at the

International Rubber Conference 1998, Paris, May 1998

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Abstract

Smallholder natural rubber area covers 3 milions ha in Indonesia, among it 2 million ha are rubber agroforests (locally called "jungle rubber") in Sumatra and Kalimantan. These rubber agroforests are the most widespread complex agroforestry system in Indonesia combining production (however productivity is low) and environmental benefits, as well as a certain biodiversity conservation, due to agroforestry practices. Beside being the key to Indonesia's future competitive advantage in natural rubber production, a workable strategy to raise productivity of these rubber smallholders also could play an important role in both poverty alleviation and environment conservation.

The "jungle rubber" system is a low-input agroforestry system in which rubber competes with the regrowth of the natural forest. The system is inexpensive and requires little labour to establish and maintain. From the viewpoint of environmental conservation, a rubber jungle with a planting scheme similar to a secondary forest has a positive value, because its habitat is good for environmental conservation. Its good hydro-orology characteristics will resist erosion and enrich plant biodiversity. It positively supports the "green movement", which has acquired a lot of interest from big industrial countries who are also the major consumers of natural rubber.

The Rubber Association of Indonesia (GAPKINDO) in collaboration with the International Center of Research in Agroforestry (ICRAF), Southeast Asia Program and CIRAD-CP-TERA (France), have been conducting o-farm trials with participatory approach and economic analysis of improved smallholder agroforest system, funded by a grant from USAID, as well as socio economic surveys in order to identify pros and cons of RAS technology adoption(improved Rubber Agroforestry Systems) . The network has been developed in West Kalimantan (Sanggau and Sintang), Jambi (Muara Bungo) and West Sumatra (Pasaman). The objective is to manage the rubber jungles more intensively by planting high yielding clones which are suitable for the rubber jungle system with different degrees of intensification in inputs and labour. Hard-wood and fruit trees, pulp trees fro shading against Imperata, annual crops and various type of covercrops are combined with rubber trees, in different trials, to identify the best and more adoptable combinations as well as maintaining a certain level of biodiversity. Biodiversity is considered as an interesting by-product with no cost . The secondary forest regrowth in between rubber lines is even considered as a labour saving pratice and the best anti Imperata strategy. RAS systems aim also to rehabilitate Imperata grasslands. Rubber Agroforestry systems do have both economically and environmental sustainability.

BACKGROUND

Smallholder rubber covers 84% of the total area of rubber (3.23 million hectares) planted in Indonesia. It contributed 76% of the total production of 1.54 million tons in 1996. Approximately 2.5 million farm households rely on rubber production. Thus, rubber provides livelihood for more than 8 million people, mainly in Sumatra and Kalimantan.

To date, only 17% of the smallholder rubber area has been impacted by government rubber development projects. The remaining 83 % of smallholder area has not been reached by these projects and are still predominantly managed as "jungle rubber". They are established with unselected rubber seedlings intercropped with food crops in the first year of a shifting cultivation system. They have a very low annual yield of less than 600 kg dry rubber per hectare as a result of unselected planting material. The main objective to improved jungle rubber is therefore to replace seedlings by adapted high yielding clones, conserving agroforestry practices as a labour saving practice with a limited number of inputs in order to make RAS (improved Rubber Agroforestry Systems) more affordable for farmers.

A workable strategy to improve productivity of rubber smallholders, while maintaining the positive environmental attributes, would serve the three pilars of economic development in Indonesia : growth, or at least the maintaining of income in these time of crisis in 1998, equity (in particular limiting social economic gaps and stability (long term economic and environment sustainability). Increases in smallholder rubber productivity is clearly a major engine of growth and poverty alleviation in major parts of Sumatra and Kalimantan, and several areas of eastern Indonesia, such as Seram Island and Irian Jaya, in particular since the economic crisis gave limited scope to foodcrop farmers. Rubber farmers have maintained their level of life due to the fact that rubber is an export product, however world rubber market is depressed and prices are relatively low. Since September 1997, the rupiah has lost 75 % of its value. Food prices doubles but rubber prices increased between 100 and 150 % during the same period. Economically speaking, rubber farming is definitly sustainable. One of the other objective of SRAP (SmallHolder Rubber Agroforestry Project) is to make rubber farming environmentally sustainable as well.

GAPKINDO, in collaboration with the International Center for Research in Agroforestry (ICRAF) and CIRAD-CP-TERA of France has developed a new approach since 1994 to assist smallholder rubber farmers increase their productivity through improved rubber agroforestry system (RAS) which maintain the economically and ecologically advantageous aspects of jungle rubber.

The research project is, or has been, funded, by GAPKINDO, USAID, ICRAF and the French Embassy in Jakarta.

SRAP has developed the following program outputs :

- Development and promotion of Rubber Agroforestry System (RAS) recommendations at the farm level;
- Development of an operating network of trial plots (80 hectares) with well trained farmers (approximately 100 farmers) in three major rubber producing provinces, namely Jambi, West Kalimantan and West Sumatra.
- Development of methodology for the RAS approach and guidelines for the transfer of technology;
- A positive impact on rubber supply and rubber quality in the mid-term with the spread of RAS among non-project farmers;
- Increase of income for a segment of the potentially 1.2 million farmers family, who

mainly depend on rubber as a source of their income, in Kalimantan and Sumatra.

Site characterization of the project areas is given in Table 1.

2. IMPLEMENTATION

The main achievements are the following

- Surveying the demonstration plot locations, data recording and real participatory approach in trial evolution.
- Establishment of 100 fields (27 trials with generally 3 or 5 replications). Various types of demonstration plots have been implemented as shown in the Table 2.
- Monitor planting, growth, performance and evolution of the demonstration plots in particular for the following features : rubber and associated trees growth, intercrops and cover crops performance, use of inputs at various degrees of intensification;
- Monitor innovation adoption process according to farmers typology through farming system surveys and constant monitoring of farmers practices;
- Establishment of rubber budwood gardens for planting material supply and providing the required planting material supply for farmers who want to have access to RAS technology;
- Conduct training for the total participating farmers in rubber and perennials nursery management, budwood gardens management (grafting techniques) and RAS technology management;
- Determine conditions of adoption of technology and innovations and their impact on farmers livelihood and prosperity; and
- Implementing some specific studies on the following topics: agronomic performance of RAS technology compared to other rubber based technology (nutrient cycling, competition, etc), economics of ecological components of RAS technology, innovation adoption process, use of improved rubber planting material by non project farmers, comparison between projects and non project farmers.

3. BRIEF HISTORY OF RUBBER AGROFORESTRY IN INDONESIA.

Rubber has been introduced in Indonesia at the turn of the century in North Sumatra and originally cropped in private estates. Farmers saw immediately an opportunity in rubber production and began to collect seeds from estates to plant their own rubber. Rubber was cultivated in a very intensive way in estates, with fertilizers and continuous weeding requiring a lot of labour. Local farmers, as well as spontaneous transmigrants, adapted their own system according to their own limited resources in cash and labour in planting rubber trees with rice after traditional slash and burn and then let the rubber trees grow with the secondary forest with much higher planting density than that of estates in order to compensate tree losses due to competition. This system has been called "jungle rubber" or karet hutan by Indonesian farmers.
Farmer profit from a no-input and very low labour rubber cropping system with a certain income diversification as jungle rubber produces also fruits, nuts, timber for housing as well as other products such rattan and timber forest products, such as medical plants, gaharu, resins and local vegetables. Such a system has been described and defined, on a botanical point of view, as a "complex agroforestry system" (H de Foresta, 1992).

In the case of jungle rubber the advantages are quite clear i.e. no cost of establishment (unselected seeds with no value and no fertilisers), low labour investment (few days for rubber planting as land has been already cleared for upland rice) and no maintenance during immature periods. One can add biodiversity conservation (biodiversity is close to that of primary forest or old secondary forest for a mature old jungle rubber, and environmental benefits in terms of soil conservation and water management due to its forest-like characteristics.

The constraints have also been well identified, primarily a delay in production. Rubber trees are being tapped after 8 to 10 years compared to those in estates, tapped after 5 or 6 years after planting and a relatively low productivity compared to plantations planted with clones. Farmers in 1998, are still relying on unselected rubber seedlings for jungle rubber as estates have all now adopted improved planting material, amongst them rubber clones have proven to be the best in terms of yields and secondary characteristics. Yields of clonal rubber are between 1400 to 1800 kg/ha in estates in Indonesia or with the best farmers in SRDP rubber scheme (Prabumulih areain South Sumatra). Other improved rubber planting materials such as clonal seedlings and polyclonal seedlings have generally been abandoned to the profit of clones, more homogeneous, adapted to high level of production and with good secondary characteristics in particular for the clones of the third generation, available since the 1970's. Clonal rubber is therefore the first most important innovation to be adopted by farmers.

Farmers' demand with clones is increasing and private nurseries are flourishing in some provinces (South and North Sumatra, Jambi). Un fortunately, a recent survey in Jambi province (Penot, 1998) show that the quality is low and clonal purity is not garanted at all .This problem of clonal purity and certification of planting material is a key constraint to further development.

In the 1970's, Indonesian government began to support the smallholders with projects using a technological model directly derived from the estate model : monoculture rubber with high level of labour and inputs requirements and no intercropping during rubber immature period (use of covercrops instead). The objectives were to maximize return to capital and return to labour as well as developing a simple rubber monocropping system that can be widespread in vast areas without major adaptation to local conditions. This model has proven efficient but costly. So far, only 17% of Indonesian farmers have been reached by such projects and only a part of them led to full productive plantations (estimated as between 50 to 60 %).

As a general rule of PRPTE/SRDP/ TCSDP/NES approach, farmers were provided with whole credit package supposed to be refunded within 15 years including the following components :

- clonal rubber plants
- fertilizer
- pesticides for diseases
- cash money to help farmers to do some terracing
- land certificate
- a wage for the first 5 years (in NES/PIR only).

Farmers have adjusted for themselves the "estate" model into a complex agroforestry system where secondary forest is allowed to grow with rubber. Planting density of rubber is increased sometimes up to 2000 plants per ha in order to compensate expected losses due to competition with no extra costs as seeds do not cost anything. They are collected from the old jungle rubber. Innovations have been included in the jungle rubber system as presented in the IRC 1997 paper, but optimization of jungle rubber has now to go through clonal planting material adoption , with at least a mimimum set of agronomic practices to ensure a correct clonal rubber growth in an agroforestry environment. The purpose of research on RAS is to identify these practices , and the mimimum level of inputs and labour that RAS requires.

Smallholders, when asked about the main factors of choosing agroforestry systems, instead of monocropping, have the following answers :

- The lack of cash to afford the complete "estate" rubber package and the lack of labour that is required in this system. RAS are aimed to a level of investment that is affordable to farmers. Farming system characterization surveys, implemented in 1997 (A Kelfoun and E Penot) show that most farmers can afford to invest in a system that requires less than 1 million rupiah for the first 2 years of plantations establishement (see table 4. in the Annex)

- The savings of time and money on weed control : Farmers used to say that they are doing only one weeding per year that proved to be sufficient in the jungle rubber system. Adopting clones in RAS means a minimum of 4 weeding per year during the first 2 years , the most critical period for RAS establishment. The use of adapted herbicide, generally glyphosate based, against *Imperata cilindrica* infestation, at least for 2 out of the 4 required annual weed control seems to be very labour saving and efficient.
- The labour returns are equal to zero during rubber immature period, therefore reducing immature period from 8-18 years (10-15 years in kalimantan) to 5-6 years is a priority. Cultural practices in RAS, basically weeding on the rubber row and boost fertilization for a good growth, are aimed to ensure tree opening at the 6th year at maximum.
- Land was, and still is in many areas, available and enables a relatively extensive rubber cropping system. But wit the sky rocketing development of oil palm plantations, land is becoming very rapidly scarce as well as in transmigration area, creating a land market that was just not existing 5 years ago. Land productivity is essential and rubber clones in RAS are expected to have a similar yield than that in monoculture.
- Smallholders speak about the efficiency of agroforestry systems as an efficient way of controlling erosion, and as a sustainable source of biodiversity through timber and fruit species planting. This aspect is major in terms of environment sustainability and should be conserved in RAS.

In other words, the jungle rubber system has reached its limits and should upgrade, except in remote and pioneer areas where it still can be considered as one of the best alternative. The future of this system is the possibility to include clonal rubber to boost rubber production meanwhile conserving agroforestry practices that provide income diversification, a better adaptation to farmers' limited resources and environmental and biodiversity advantages with RAS systems.

4 RUBBER AGROFORESTRY SYSTEMS (RAS) DEVELOPED IN PILOT PROJECTS

The objective of this new approach is to show the interest of experimenting in real farmers conditions with a participative approach, improved rubber agroforestry systems (RAS) as alternatives to traditional "jungle rubber" practices or to classical rubber based development schemes based on estate technology. The main challenge for research is to test various kinds of improved planting materials and appropriate levels of inputs and labour to see which grow and produce best in such agroforestry systems, and which are most appropriate and affordable for smallholders. In other words, the objective of the farming system research program is to improve the system's productivity through optimisation of labour and minimisation use of inputs and costs, keeping the benefits of agroforestry practices and clones of these current practices to increase the adoptability or technical innovations. Even with agroforestry systems, very close to what farmers currently do, it seems really necessary to link innovations with a constraint and opportunity analysis of existing farming systems, taking into account farmer strategies and trends, and integrate them into an operational farming system typology. To that respect, the farming system perspective, whatsoever technical innovations in quantity or quality are concerned, still seems to be relevant to integrate apparent or hidden farms' constraints into strategies leading to innovation adoptions.

All innovations tested in this program have been discussed with farmers in order to improve adoptability and suitability of RAS technologies according to farmers' resources and requirements. Experimentation is based on how to minimize inputs and labour meanwhile conserving agroforestry practices and its advantages; income diversification, income during rubber immature period through intercropping, maintenance of a certain level of biodiversity and environmentally friendly.

The pilot project has been using a participatory approach to do on-farm experimentation with three main kinds of rubber agroforestry systems (RAS).
Each is being tested for its suitability for local agro-ecological conditions, for labour and cost requirements and to determine the best level of intensification.

The first system (RAS 1) is similar to the current jungle rubber system, in which unselected rubber seedlings are replaced by clones selected for their potential promising adaptation. The selected clones are PB 260, RRIC 100, BPM 1 and RRIM 600. These clones must be able to compete with the natural secondary forest growth; various planting densities and weeding protocols are being tested. This will indentify the minimum amount of management needed for the system, a key factor for farmers whose main concern is also to maintain or increase labour productivity. The biodiversity is very similar to that of jungle rubber, quite high and relatively close to that of primary forest. The main outputs are the following :

4 weedings per year are sufficient (with 2 weedings using Round-up).

selective cutting of the regrowth in the inter-row might be done only if rubber is outcome by vegetation. 1 preventive selective cutting , 6 months after planting, is generally sufficient.

The use of good quality planting material (in size and shape), stumps in polybag with 1 whorl and early planting in the rainy season are key factors.

rubber growth is not affected by secondary forest regrowth in the inter-row in these conditions and data from the trials show that rubber is having a growth comparable to that of monoculture.

Biodiversity is high in RAS 1, comparable to that of secondary forest, including economically interesting fruit and timber trees such as Belian/Iron wood;, Meranti species, Nyatoh (pallaquim spp) , durian, rambutan, cempedak (a wild jackfruit), rattan....

This is the best way to get rid of *Imperata* at low cost (no herbicide is used in the inter-row) as it is the shade that effectively "kill" Imperata.

In RAS 1, plant biodiversity is effectively used as a real agronomic pratice to suppress competition with weeds, in particular Imperata. So far competition from this vegetation is far less than that of Imperata and does not jeopardize rubber growth.

RAS 1 preliminary results (Penot, Wibawa, 1997) clearly show that clonal rubber is adapted to agroforestry practices as well as unselected rubber seedling was with jungle rubber but , however, with more labour and input requirement. This increase in input and labour, roughly half of that required for monoculture still fits farmers'own possiibilities. In terms of biodiversity , this system is very close to that of old jungle rubber or secondary forest. Rubber agroforest have been well described in Sumatra and Kalimantan (by Colfer *et al.*, 1988, De Foresta 1990, Sundawati 1993, Lawrence 1996, Salafsky 1994, Momberg 1993, Werner 1993, Pramoth Kheowvongsri 1990). The comparison of biodiversity for birds (Thiollay, 1995) and vegetation shows that rubber agroforests are very close to secondary forest. A preliminary characterization has been done by H de Foresta in South Sumatra as well as in Jambi by S Werner. D Lawrence found rubber agroforest less rich than that of Sumatra, at least in the Gunung palung area in West Kalimantan, (Ketapang area) but it is partly due to the assessment method. If all trees with a diameter (DBH) >1cm are taken into account, then the number of species and number of trees per ha are potentially similar to the South Sumatran situation. The methodology of biodiversity assessment is very important for comparison. Evolution of biodiversity in RAS 1 has yet to be characterized in order to see if weeding on the rubber row and earlier canopy closing (5 or 6 year after planting) have any effect on biodiversity compared to that of classical jungle rubber.

The second, RAS 2 is a complex agroforestry system in which rubber (550/ha) and perenial timber and fruit trees (100 to 250/ha) are established after slashing and burning. It is very intensive, with annual crops being intercropped during the first 3 or 4 years, with emphasis on improved upland varieties of rice (RAS 2.2), with various amounts of fertilisation as well as dry season cropping such as groundnut. Several variations or crop combinations are being tested including foodcrops or cash crop such as cinnamon (RAS 2.5). Several planting densities of selected species are being tested according to the tree typology, in particular : rambutan, durian, petai and tengkawang (Illipe nuts). Biodiversity is limited to the planted species (between 5 and 10) and those which naturally will regenerate and will be selected by farmers (fruit and timber trees). The main outputs are the following :

- intercropping with rice can still be a risky crop if pesticide, insecticide and bird watching are not used . Yields are correct the first year, very average the second year and close to failure the third year (Penot, 1997. It is clear that figures generally released by Foodcrop Research Institutes in Indonesia on rice intercropping are too optimistic. A combination of crops such as vegetables , chili, pineaple and banana, or indeed, a rotation rice/groundnut, is highly preferable to rice after the first year.
- Associated fruit and timber trees are définitely not competitive with rubber during immature period (even at 250 associated trees/ha) . Competitiveness might increase after 10 or 15 years, depending of the size and shape of trees. Associated trees are carrefully selected to minimise that risk. Previous experimentation in Malaysia (RRIM) and southern Thailand (RRIT in Hat Yai area) clearly suggests that there is no such competition., at least not before 20 years after planting where most of the production potential has been already used.
- preliminary results in successful trials in Jambi and Kalimantan show that RAS 2 is very successful and that a planting density of 250 carefully selected associated trees per ha with 550 rubber /ha is feasible.
- Weeding for rubber is limited as weeding for crop is already implemented. Economic calculation of RAS (Penot , 1996) suggests that , in fact, economic return for intercrops are not so attractive and comparable to that of shifting cultivation, but indirect economic return to rubber is excellent as immature period is expected to be reduced to 5 years only.
- RAS 2 implementation in Pasaman area, in West Sumatra, on very degraded land with Imperata, is very successful due to good food intercrops yield (complete package for improved rice varieties) and the use of *Flemingia congesta* countour lines for erosion control.

In some areas, farmers do effectively plant associated trees in their former monoculture plots and re-introduce agroforestry practices., after rubber growth has been secured through monoculture for the first 5 years. In former

SRDP[1] monoculture plots, 1/3 of the smallholders in the village of Sanjan have planted, or let grow from natural vegetation, between 90 to 290 timber and fruit trees/ha (see table 3), without noticeable decrease of production of their clonal rubber, GT 1 (E Penot, W Shueller, 1997). This strategy has been observed also in North and South Sumatra (SRDP). If intercropping is commonly done by smallholders (system "tupangsari") and fully accepted by projects officialy since 1995 only, on the other hand planting trees with rubber with the notable exception of rattan (implemented by TCSDPin 1997/98) is still considered as having a negative impact on rubber by officials.

The third system, RAS 3, is also a complex agroforestry system with rubber and other trees planted with a frame similar to that of RAS 2; the difference is that it is established on degraded lands covered by Imperata, or in areas where Imperata is a major threat. Labour or cash for controlling Imperata with herbicides are the main constraint. In RAS 3, annual crops, generally rice, are grown the first year only, with no climbing cover crops grown immediately after rice harvesting (Mucuna, Flemingia, Crotalaria, Setaria and Chromolaena) or multipurpose trees (wingbean, Gliricidia) or fast growing trees such as pulpwood (*Paraserianthes falcataria*, *Acacia mangium* and *carcicarpa*, and *Gmelina arborea*) are established (several combinations are being tested). The objective here is to eliminate the weeding protocol by providing a favourable environment for rubber and the associated trees to grow, consequently suppressing Imperata growth with low labour requirements. The association of these cover crops and multipurpose trees for shading is aimed to control Imperata. Expected biodiversity should be similar to that of RAS 2. The main outputs are the following :

- among the various covercrops, *Chromolena Odorata, Mucuna and Flemingia congesta* are the best but quality of seeds *for Flemingia and Mucuna* is very low and may jeorpardize covercrops establishment.
- If covercrops failed, pulp tress used as shade trees (with an economic putput after 5 or 8 years) are very efficient for *Imperata* suppresssion. In Transmigration areas, in *Imperata* grasslands, *Acacia mangium and Gmelina Arborea* are the best trees. In traditionnal forest areas or after an old jungle rubber, *Acacia carcicarpa , Gmelina arborea and Paraserianthes falcataria* are more adapted. .Existing vegetation, although very poor, such as *Melastoma spp* and Jacaranda, are favoured and help to suppress Imperata.

We remind that Imperata is delaying rubber trees opening and can increase immature period up to the 8th or 9th year after planting (Wibawa, 1997) and should be considered as the first top weed to be suppressed. It RAS 3, we try to take advantages of local species through the establishement of shade by pulp fast-growing trees, on a more ecological basis, reducing the use of herbicide in the inter-row. Shading appear to be the most efficient and ecologic way to suppress Imperata. Pulp trees used for that purpose have also an economic output as they can be sold either for pulp production (there is an increasing market in Indonesia for trees used in paper production), or for firewood, between 4 and 8 years after planting.

5 ENVIRONMENT BENEFIT OF R.A.S.

Rubber plantations, even in monoculture, have been since a long time recognized as sustainable environmentally speaking due to the fact that rubber does not neet any fertilization during production period ans that the product exported is basically composed of hydrocarbon, but no minerals.

[1] SRDP = Smallholder Rubber Development Project, implemented by DGE and funded by the World bank.

The nutrients removed for an average production of 1500 kg/ha is the following in kg/ha/year:

N	P	K	Mg	Total
16	5	15	4	40

This total of 40 kg/ha/year is very low if we compare with nutrients removal for tea with 285 kg/ha/year (for a production of 3 000 kg/ha) or for coconut with 157 kg/ha/year (for a production of 1500 kg/ha) (source : Samarapuli, 1996, Tillekeratne & llalani, 1996). The annual liter fall of rubber trees is quite high with 6.3 tons/ha (dry weight), compared to 4.2 tons/ha for a legume covercrop and 9.4 tons/ha for a mature forest. The nutrient content in Kg/ha is quite similar to that of a forest except for N and CA (see table 5). The litering effect of an agroforest is higher than that of rubber and should probably be considered as very similar to that of a secondary forest, covering largely nutrients export from rubber production. In fact, rubber being a self sustaining ecosystem on a nutritionnal point of view, soil fertility is definitly improving with rubber agroforest. In other words, RAS systems contribute to soil replenishment , in particular for very unfertile and degraded soil under *Imperata.* Another important feature is that rubber is a surface feeder, unlike deep rooted species such as Eucalyptus (Sethuraj, 1996).

In terms of total biomass, a 35 years old rubber plantation represents 445 tons/ha, very comparable to himid tropical evergreen forest in Malaysia, Thailand or Amazonia (table 6) ranging from 210 to 665 tons/ha). An untapped rubber plantations after 35 years is even developping a larger total biomass than forest with 964 tons/ha. (The Planter, vol 68, N° 800, 1992). The nutrient bank of a 35 years old rubber plantation is larger than that of a forest in malaysia except for N (table 6). For these reasons, rubber plantations have been considered to be a relatively efficient converter of solar energy into dry production matter, contributing directly to carbon sequestration on a large basis, in particular in Southeast Asia, Malaysia, Thailand and Indonesia where 80 % of the total natural rubber is produced , and covering an area close to 7 millions hectares. A rubber plantation can be considered as effective as a virgin forest for photosynthesis inconsuming the products of fossil fuel burning and in oxygen production. A roughly 10 millions ha (total rubber area in the world) wil produce an estimated 200 millions tons of biomass per year (Sethuraj, 1996).

It is quite clear that rubber plantation and, a fortiori, RAS, are not only maintaining, but , in fact, improving the environment in terms of soil fertility, erosion control and total biomass produced during the lifespan of rubber systems , generally around 35 years (might be more eventually with RAS as they can evolve from a rubber based agroforest to a timber and fruit tress based agroforest). This physical sustainability has been already largely discussed (see A Gordon, , C Goldthorpe, M.R. Sethuraj, A Rahman & K Jones...)

Beside, the rehabilitation of degraded land, slopy land with low fertility like in Pasaman area, West Sumatra, or Imperata grasslands, like in West Kalimantan, with RAS wil also largely contribute to regreen lands that are today largely considered as "lost" or too difficult to reclaim by farmers with other cropping systems , in particular foodcrops. On the other hand, RAS will have to compete for land with oil palm, a very efficient plant that raise income as soon as the third year but does not seem as environmentally sustainable as rubber is. Farmers might consider in the very next future to have 1 or 2 hectares of oil palm for capital building and the rest of the cropped land in RAS or any other rubber system in order to maintain their traditionnal environment and a source of various products such as firewood, timber, fruits, rattan or medicinal plants. Obviously Dayak farmers in West Kalimantan are very sensitive to that argument when Melayu farmers, In Jambi province , might be less interested in the social and environmental value of rubber agroforestry if oil palm can provide a better income (which is not anyway always the case).

6 THE ECONOMIC RATIONALE OF RAS

Two of the main constraints concerning clonal rubber in monoculture are its cost of establishment and the length of the immature period, requiring credit with long delay before reimbursement (generally between the 7th and the 13th year after planting). RAS are less expensive than the monoculture package (E Penot, 1996) and are still afordable by farmers. A complete cost-benefit analysis of RAS has been published in 1996. Main conclusion is that return to labour is improved compared to that of "estate" model. Benefit is also higher due to other crops, annual or perennial (through an incremental cost/benefit analysis).

Surveys conducted in West-Kalimantan and Jambi provinces in 1997 (Ph Courbet, A Kelfoun and E Penot) on farming systems characterization show that the annual income is generally sufficient for rubber farmers to invest in , at least, a half hectare plot of RAS every 2 or 3 years for instance .

RAS establishment costs are the following :

IN 1000 rp x per hectare

RAS type	Year1	Year 2	Year 3	Total
RAS 1	500	200	200	900
RAS 2[2]	850	400	300	1500
RAS 3	850	150		1150

The figures in annex (table 4;x) shows that capital might not be the first problem for rubber farmers to invest in RAS systems, at least in Jambi province, even for farmers still relying on jungle rubber, with an annual farm income of 4 to 5 milion rupiah. Cash availability at a given time for purchasing planting material, polybag nursery establishment, planting and fertilizing for instance might be the real constraint.

Farmers with 1 or more hectare of clonal rubber have definitly the capacity to reimburse investment cost of establishment of 1 hectare of RAS with an annual farm income of 10 millions rupiah in Jambi province in transmigration area (3.5 to 4 millions rupiah in West Kalimantan province due to lower rubber yields with SRDP farmers) . Farmers still relying on old jungle rubber in West Kalimantan province might have some difficulties to raise sufficient capital with an annual farm income around 1 million rupiah (1.3 million rupiah in foodcrop oriented transmigration areas).

A former clonal rubber plot, or oil palm plot, is clearly a capital buiding strategy that allow farmers to invest further in RAS.

7. CONCLUSION

So far, these RAS systems are still under experimentation but there is a strong demand from surrounding farmers that want to join the project. The scale of the project is currently limited to 100 farmers with a rubber plot of 0.3 to 0.8 ha each, a sufficient plot size to reflect the reality. But after 4 years of project implementation, local farmers began to implement RAS on their own.

RAS are based on farmer demand and including some of the previous innovations developed by farmers themselves. So far, preliminary assessment of RAS adoption by farmers seems to be above 70%, although the experimentation process may bias this estimation. One of the main constraints is the ability of farmers to integrate into their current practices a minimal amount of inputs and labour, intermediate between the current one in jungle rubber (very low) and the existing one in the "estate" model (very high). Farmers have shown their ability to develop very interesting innovations. Jungle rubber is now covering more than 2.5 million ha in Indonesia and it is the next challenge to help these farmers to proceed to the required further innovation adoptions.

The future adoption of RAS at large scale , compared to rubber monoculture or any other monoculture such as oil palm or Acacia mangium plantations, enable a far better soil, hydrolic and environment conservation as well as maintaining a certain level of biodiversity at no cost to farmers. In RAS, the maintainance of

[2] Including costs for intercrops for RAS 2 and 3.

biodiversity in the rubber inter-row is not even considered as a source of income for fruits, timber and rattan, but also as the best anti Imperata cultural practice, requiring less input and less labour.

Economic and environmental sustainability can be obtained with RAS at a low to medium cost within the range of possibilities of local smallholders in terms of labour and capital requirement.

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