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When does technological progress in agriculture reduce deforestation?

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DOES RUBBER TRIGGER REFORESTATION AFTER DEFORESTATION ?

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Summary

Since its introduction to Sumatra and West Kalimantan in Indonesia at the turn of the century, rubber has been a major cause of deforestation. Rubber planting triggered deforestation on a large scale (more than 2.5 million hectares in Sumatra and 0.9 million hectares in Kalimantan), and this was mostly due to smallholdings (83% of the total rubber area today). However, as rubber was mainly planted in a complex agroforestry system with a level of biodiversity close to that of a secondary forest, rubber has also helped to re-green the deforested land. In terms of tree density and biomass, and as the largest current reservoir of biodiversity in regions where forest has disappeared, these rubber based complex agroforestry systems may be considered as agents of reforestation. This 'jungle rubber' system, with its agroforestry properties has helped to reverse the idea of a tree-crop being purely an agent of deforestation.

The jungle rubber system was originally based on seedlings, and did not require any chemical inputs. Since the 1980s, a number of official projects have introduced technical changes and 'modern agriculture' with clonal rubber planting material plus a package of fertilisers and some other inputs. This 'modern agriculture' took the form of monoculture systems. Although the main target was to increase the Indonesian supply of rubber, the theory that technological progress in agriculture reduced pressure on forests may have helped to promote the establishment of these monoculture systems. It is true that they increase short-term incomes and lower the requirements for land. In terms of incomes from rubber per family, 2 hectares of monoculture may replace 8 hectares of jungle rubber. However, rather than the monoculture system itself, the shortage of labour (despite immigration), and a lack of information and planting material prevented these monoculture systems from actively encroaching into remaining primary forests. Otherwise, rubber monoculture could have been and could still be a more 'efficient' deforestation agent. If the conditions of a pioneer phase are considered (i.e. abundance of available forest land, reservoirs of labour and migrants, a crop opportunity and an attractive and seemingly sustainable market), it is true that technological progress is likely to increase deforestation. Technological progress may reduce the pressure on forest only when the pioneering effect is already slowing down. The case study of rubber serves as an example of this.

As is the case with cocoa and some other tree crops, one major technological progress is the recent use of herbicides. These enable more and more farmers to control Imperata cylindrica and replant rubber on degraded lands. This applies to Indonesia, and to a lesser extent to Côte d'Ivoire where rubber is adopted as a diversification crop. In that case, technological progress clearly seems to encourage reforestation.

Finally, returning to the agroforestry techniques used by Indonesian smallholders over the last century, the paper will mention recent CIRAD/ICRAF research and on-farm trials based on the idea of combining two technical advances: clonal rubber planting material and agroforestry techniques. This combination of agroforestry and clonal material may be considered as a new form of technical progress in itself, and its impact on the deforestation/reforestation process is also explored.

Introduction

Since its introduction to Sumatra and West Kalimantan in Indonesia at the turn of the century, rubber has been a major cause of deforestation. Rubber planting triggered deforestation on a large scale (more than 2.5 million hectares in Sumatra and 0.9 million hectares in Kalimantan), and this was mostly due to smallholdings (83% of the total rubber area, see Figures 1, 2 & 3). Rubber was mainly planted as a complex agroforestry system (CAF), with a level of biodiversity close to that of a secondary forest (de Foresta, 1997). In such a system, rubber has also helped to re-green the deforested land, and moreover, can be considered as a real agent of reforestation, as the level of biodiversity in the system is far higher than that of monoculture. This system is called 'jungle rubber' ('hutan karet' in Indonesian), and its agroforestry properties have helped to reverse the idea of a tree-crop being purely an agent of deforestation. Jungle rubber is now effectively the main reservoir of biodiversity in regions where forest has almost disappeared (there are less than 1.5 million ha of lowland forest in Sumatra (excepting mangroves), in contrast to 2.5 million ha of jungle rubber). The general aim of this paper is to identify how different types of technological change in various situations with rubber based farming systems have affected agricultural expansion, and how this again has affected deforestation.

After defining the type of innovations and the major technological changes in the history of the "rubber boom" (Section 1), we will consider the particular conditions in which innovations have emerged, with reference to a typology of villages representing a range of situations (Section 2). Special attention will be paid to herbicides (Section 3), and then we explore the effect of these changes on the "forest dynamics" (Section 4). In conclusion, we see how rubber adoption and technological changes in rubber farming systems can be simultaneously considered as factors contributing to deforestation and reforestation. This will also depend on the exact definitions of deforestation and reforestation.

Our study area is composed of two of the main rubber producing provinces in Indonesia: Jambi in Sumatra and West Kalimantan in Borneo. The West Kalimantan hinterland is populated with Dayak people who were collectors of forest products a century ago, and are still very keen to preserve forest and forest products. The plains of Jambi are populated with Malayu people, partly mixed with Javanese and Minangkabau people from Java and West Sumatra respectively (two areas with a very high density of population), as immigration has always been very important and facilitated the colonisation of the province. The Malayu have also developed jungle rubber, but do not rate the importance of forests as highly as the Dayaks. They did not develop long term and sustainable fruit/timber based agroforestry systems such as "tembawang" as the Dayaks did. Finally, the last ethnic group taken into account in this study are poor Javanese in transmigration areas (either in food-crop or tree-crop based schemes).

1 Technological changes and types of innovations

1.1 "Innovations" ?

Many studies have been carried out on the impacts of technology, on the effects of certain types of technological change on land use and how this might have affected forest use. But what do the terms 'technology', or the 'adoption and diffusion of innovations' mean in this context?

"Technology adoption" is a very reductive concept, as many "innovations" are the result of a long process of "elaboration of innovation" rather than adoption/diffusion of innovations (Penot, 1997). Innovation in itself is the fact that a "technology", or a "technique of production", has been created, either by local people using indigenous knowledge (such as jungle rubber), or by organisations (projects, estates, etc.). This is then redefined through use, and improved according to farmers strategies or requirements. So whatever the technology, the result is that the technological change integrates the expertise of farmers, and their ability to transform, adapt or improve a particular technology. Such adaptation aims to provide a better solution to production constraints, or one more appropriate to local conditions.

In other words, innovations are not only simply "adopted", they are re-created, transformed, integrated, improved, and evolve into an output completely reviewed and adapted by farmers. Indigenous knowledge, expertise and external technical innovations are integrated into this process of elaboration. The various technologies might have different histories and evolution processes. Therefore, assessing if technology changes directly affect deforestation or reforestation is not easy. There are a wide range of "technologies" according to the way they have been "re-appropriated" and "elaborated upon" by local populations. Technologies and innovations occur differently in different contexts at different levels: national (agricultural policies) and regional, as well as at the farm level. We will consider two different situations: planting in pioneer zones, and replanting in former pioneer areas where land use change has now stabilised.

1.2 Jungle rubber and monoculture

Up until the 1960s and early 1970s, jungle rubber was the only way of producing rubber by smallholders without any help in terms of information and inputs from governmental agencies. Jungle rubber is an efficient agroforestry system which saves labour and does not require any capital, but which however delays the immature unproductive phase of rubber up to 10 years, and which is extensive and land consuming. It has been the main tool of the Indonesian rubber boom since the turn of the century. It clearly contributed to the original deforestation process in Sumatra and Kalimantan.

One, two, or even three generations after the adoption of jungle rubber, land is becoming less abundant and jungle rubber farmers face difficulties. They do not have enough land to keep the system profitable. The necessity of shortening the investment phase, increasing yields and labour productivity of traditional jungle rubber while reducing risks (crop failure) is becoming critical.

At this point, farmers are, or should be, ready to adopt clones (improved planting material) and replant clones in old traditional rubber areas. Rubber clones came at the right time to enable a significant increase of productivity in a changing economic environment.

In the 1970s and 1980s, the government, helped by International Agencies[1] set up a large number of clonal rubber-based projects at a high cost, however a very low percentage of rubber farmers in Indonesia actually benefited from these projects (estimated at 13% in 1999[2]). Despite this, the government effort was sustained, and it is currently estimated that development projects between 1970 and 1998 reached an area of 350 000 ha.

More importantly, the strength and the potential of 'copying effects' (emulation of the project model by farmers establishing their own independent plantations) were probably underestimated. In the late 1990s, the fantastic 'demo effect' of the rubber projects has had two main impacts. The first one is the demonstration of rubber monoculture as an expensive but efficient and highly productive rubber system, mainly through the use of clones. The second one is the use of herbicide as a labour saving method and technically efficient way of controlling *Imperata cylindrica*.

After this huge "demo effect" of projects, herbicides and other inputs such as fertilisers and pesticides became available even in remote areas. This was facilitated by networks of private traders, in particular those involving collection of rubber in weekly markets, as well as the village co-operatives (KUD).

A network of private nurseries providing improved planting material expanded rapidly at least in two provinces: South and North Sumatra, and to a lesser extent in Jambi. Unfortunately, the quality and purity of this planting material varies widely[3].

The development of this small private sector, outside official projects, has helped to improve the availability of clonal plants for farmers in some areas. Such private nurseries flourished on a small scale around Sanggau and Bodok in West Kalimantan (Schueller *et al.*, 1997), and in 3 specific areas in Jambi (Sungei Tiga in Batang Hari district, Sabir in Sarko district and NES Rimbo Bujang in Bungo Tebo district (Penot *et al.*, 1998).

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[1] In particular the World Bank (NES and SRDP/TCSDP projetcts) and the Asian Development Bank (TCSSP project).
[2] Although 13 % of the area has been replanted with clones, part of this area never developed into fully productive plantations due to poor management. We can roughly assess that around 70 % of plantations have been fully productive.
[3] In 1993, more than 500 private nurseries were identified in South-Sumatra, and more than 100 in Jambi in 1998.

1.3 Innovations and rubber farming systems

The technical innovations involved in rubber cropping systems are linked with the two main cropping systems: complex agroforestry (CAF) and monoculture based on clones. However, some farmers have spontaneously started to combine some jungle rubber techniques with clones in the mid 1980's in former SRDP plots. Some projects are now moving the same way[4].

CAF: The main features are the combinations of crops; both perennial and annual, both food and cash crops (fruits, foodcrops, timber and rubber), integration of secondary forest into rubber (in the case of jungle rubber), and low input/low labour technologies. In addition to the agroforestry practices that constitute the heart of the jungle rubber system, technical innovations have been the use of high stump seedlings for planting, planting in lines, limited weeding once a year in the rubber rows to decrease the immature period, selection of associated trees amongst the natural vegetation and the use of herbicide to control *Imperata cylindrica* in the first year of planting in order to favour secondary forest regrowth. CAFs are generally established after clearing forest or old CAFs, as they need a stock of seeds for the regrowth of woody vegetation.

Monoculture: Technical innovations are based on improved planting material (mainly clones) and the use of inputs (fertilisers during immature period, pesticides against leaf and root diseases, herbicides, cover-crops to control vegetation regrowth in the inter-row, tapping techniques and stimulation, etc.). Monoculture is very labour-intensive. Rubber monoculture can be established either after clearing forest or in *Imperata* grassland (requiring more inputs in that case).

Composite systems: Some techniques from monoculture have already been integrated by some innovative farmers into "composite systems"; CAF with clones, or clones with CAF. Some of these non-project CAF experiences have been documented in Indonesia (Schueller *et al.,* 1997) and Thailand (Buranatham *et al.*, 1997).

This endogenous experimentation with "composite systems" initiated by farmers themselves have been used as a methodological base for RAS (Rubber Agroforestry Systems) experimentation by CIRAD and ICRAF[5] since 1994 in Sumatra and Kalimantan. Such CAFs based on the use of clones in order to improve both yield and labour productivity are now 4 years old. Several RAS were designed for different levels of intensification. Some RAS are also designed for *Imperata* grassland rehabilitation, with a limited but valuable rebuilding of "economically interesting" or "productive" biodiversity (fruit and timber, rattan, etc.).

The use of a participatory approach with large contributions from local farmers in RAS design, conception and evolution, as well as field implementation of on-farm-trials led to

[4] TCSDP is providing rattan seedlings, to be planted in association with rubber. This a good idea only if rattan is established towards the end of the productive life of the rubber trees. Rattan harvest, 5 to 8 years after planting, almost entirely destroys the rubber trees.

[5] By the SRAP, Smallhoder Rubber Agroforestry project (CIRAD/ICRAF)

the identification of improved rubber CAFs adapted to farmers' requirements in terms of labour and capital. Preliminary results concerning the RAS systems establishment phase are very promising (Penot *et al.*, 1999).

The analysis presented in Section 2 is based on surveys implemented with a sample of SRAP and non-SRAP farmers in Sumatra (34 farmers in Jambi) and in West Kalimantan (91 farmers) (Courbet *et al.*, 1997) (Kelfoun *et al.*, 1997).

We will focus our analysis on three main technical innovations: clones, fertilisers and herbicides (Round Up used against *Imperata cylindrica*) and consider for various situations what the farmers' strategies and technical choices are. We will also discuss the problem of replanting, as planting in pioneer zones with the jungle rubber system has already been described in detail by Dove (1993), Barlow (1987), Gouyon (1995) and Levang & Michon (1990).

2 A typology of situations : the context

2.1 Planting and replanting: two different dynamics.

Pioneer zones are still important in terms of area and dynamics, as there are always new families of local or spontaneous migrants from Java searching for land for food production. These pioneer zones are now located at the borders of central plains, in the piedmont zones where land and primary or logged forests are still plentiful. Whatever technology farmers use to increase the value of land, the result is always deforestation with shifting agriculture and jungle rubber establishment. Planting rubber in this case, is therefore always synonymous with deforestation.

Replanting is a totally different process. After the first cycle of jungle rubber, farmers who are ready to replant may have several options, according to their resources, skills and knowledge. These include the following patterns:

jungle rubber again (the most common up until very recently),
monoculture with or without clones, according to capital and clone availability
another tree crop (generally oil palm)
semi-perennial cash crops (e.g. pepper in the Putussibau district in West Kalimantan), in areas where rainfall may become a constraint to rubber production (rainfall > 4000 mm/year).

The determinants of replanting may be shortage of land, access to labour and capital, the presence of a project in the area, land status, know-how, technological packages and access to roads and markets. For official transmigrants, land shortage is a serious constraint right from the beginning.

Technology in itself is far from being the main factor that triggers replanting. However, the existence of a particular technology (monoculture vs CAF for instance), know-how and capital can trigger the choice and type of the new plantation, and potentially trigger a process of elaboration of innovations if specific constraints are present (e.g. land shortage). If the available technology is not intensive in terms of capital and labour (such as jungle rubber), deforestation will occur in relation to population increase. If technologies are more capital-intensive, they lead to intensification (e.g. rubber and oil palm monoculture, RAS) and if they are accessible to farmers, they help each farmer to reduce his cropped areas and to adapt the new system to their available labour force.

Planting trees is also part of a land acquisition process recognised by "adat" (the local law). However it is only officially recognised by the government if the plantation is planted with clones.

Around Palembang in South-Sumatra for instance, farmers now have 2 to 4 hectares of clonal rubber and sometimes another 2 to 4 ha of jungle rubber (that are not all tapped), as a land reserve for themselves and for their children. Their total land holdings are now 5 to 8 hectares per family, compared to 15 ha 25 years ago, and 30 ha (with shifting cultivation) 50 years ago.

However, natural population increase, at 2.5 % per year will "consume" this available land in less than two generations.

The hypothesis that improved cropping systems will conserve land is true at a given time in non pioneer zones. However, due to continuous increasing demographic pressure, and without out-migration to industrial or urban employment, in the long term this is no longer true. It does enable a higher population density per unit of land.

Adoption of new rubber technologies is more the consequence of the constraints of decreasing land (and forest) availability, rather than a concious effort to conserve land and forest resources "(and old jungle rubber which can be considered as a valuable secondary forest).

However, if decisions are made in time (when land is still available), in accordance with the wishes and willingness of the local people, improved technologies could pave the way for a redefinition of land use at the village level, and the creation of protected forested or reforested areas, as is already the case with "tembawang"[6] areas in Dayak villages in West Kalimantan (Momberg, 1992).

Institutional creativeness is necessary to optimise some positive impacts of the technological progress with regard to forest protection. Such institutional arrangements should be designed to hamper or block migration, as this is clearly a major cause of deforestation.

[6] Tembawang are fuit and timber based CAF, generally managed by the communities in order to provide fruits and other products such as medicinal plants or vegetables, timber for housing, etc

2.2 Description of selected surveyed villages

Table 1 : Typology of situations : main characteristics of the villages

Province	JAMBI		WEST KALIMANTAN						
Village name	Sepung-gur	Rimbo Bujang	Kopar	Engkayu	Sanjan	Embaong	Trimulia	Sukamulia	Pariban-Baru
Villaget type/ project	Traditional	Trans-migration	Traditional	Traditional	Traditional/SRDP	Traditional/SRDP	Trans-migration	Trans-migration	Trans-migration
Ethnic group	Malayu	Javanese	Dayak	Dayak	Dayak	Dayak	Javanese	Javanese	Dayak
	Muslim	Muslim	Catholic	Catholic	Catholic	Catholic	Muslim	Muslim	Catholic
Population density inhabitants per km²	28	90	10-30	10-30	30	10-30	50	50	10-30
Access to roads	+	+	-	+	+	++	-	+	-
Access to land	+	- -	+	+	-	-	- -	- -	+
Land to sell	-	-	+	+	-	-	+	+	+
Land title	no	yes	no	no	yes partly	yes partly	yes	yes	yes
Environment	forest	deforest-ed	AF	AF	AF	AF	Imperata	Imperata	Imperata
Jungle rubber	yes	no	yes	yes	yes	yes	no	no	yes
Clonal rubber	no	yes	no	no	yes	yes	no	yes	yes
2nd Forest/fallow	yes	no	yes	yes	yes	yes	no	no	yes
Irrigated rice (sawah)	no	yes	no	no	no	no	yes	no	no
Main project	SRAP	NES	SRAP	SRAP	SRDP	SRDP	SRAP	DISBUN	PKR-GK/SRAP
No. of projects	1	2		2	7	4		2	2
New projects	no	TCSDP	Oil palm	Oil palm	no	Oil palm	no	no	no
Main cropping system	JR	mono-culture	JR	JR	JR/mono	JR/mono	mono-culture	sawah	JR/mono

Source:Courbet *et al.*, (1997), Kelfoun *et al.* (1997)

SRDP : Smallholder Rubber Development Project (World Bank/DGE)
TCSDP : Tree Crop Smallholder Development Project (WB/DGE)
NES : Nucleus Estate Scheme (WB/PTP/DGE)
SRAP : Smallholder Rubber Agroforestry project (Research)
DGE : Directorate General of Estate (Ministry of Agriculture, now of Forestry)
PTP : Governmental estate sector

2.3 A typology of situations concerning replanting

Three main situations have been observed, and can be summarised in Table 2.

Table 2 : Typology of situations: Replanting

Situations	Main cropping system	Ethnic groups	Ecological environment	Villages surveyed
1 Traditional area with jungle rubber **REPLANTING BY INITIATING A NEW CYCLE OF JUNGLE RUBBER**	Jungle rubber and upland rice in shifting cultivation	Dayaks in Kalimantan Malayu or Minang in Sumatra	Forests, agroforests. Jungle rubber and tembawang in plains.	*Kalimantan :* Kopar and Engkayu *Sumatra* : Sepunggur
2 Traditional area with clonal rubber from projects (SRDP/TCSDP) REPLANTING WITH CLONAL MATERIAL	Jungle rubber, paddy shifting cultivation and clonal rubber plots	Same	Same	*Kalimantan:* Sanjan Embaong
3 Transmigration areas -food-crop oriented **REPLANTING AFTER GRASSLAND FALLOW** **-tree-crop oriented (NES)**	NES clonal rubber plots, Irrigated rice (sawah)	Javanese or Madurese	Imperata grasslands in plains endemic or after deforestation	*Kalimantan* : Trimulia, Pariban-Baru, Sukamulia *Sumatra:* Saptamulia, Sukadamai

2.3.1 Traditional areas with farming systems based on jungle rubber

This situation can be summarised by the following three main points:

- *No replanting, or only slow replanting of jungle rubber.*
- *Relatively low pressure on land because of few migrants.*
- *Possibility of radical change with the arrival of oil palm projects.*

Situation 1 is that of old rubber villages that are stable in terms of land and population, with a potential problem of replanting of old jungle rubber. Land can be classified into four main types:
1) Communal land for annual food-crop shifting cultivation (still existing in Kopar/Engkayu in Kalimantan, but not any more in Sepunggur in Jambi), or for fruit/timber CAF (such as "tembawang" in Kalimantan)
2) Land planted with tree crops, such as jungle rubber or clonal rubber plots that can be considered as private land, although this land is still technically communal land with long term use rights, for the duration of tree life-span
3) Protected areas with no private use (generally primary of old secondary forests) 4) "Regrouping land" for project areas, that can be formerly communal land and intended

to be privatised (for rubber or oil palm projects for instance). This traditional land tenure, according to "adat" (custom law), is officially recognised by the government by default as long as the government does not claim the land[7].

In 'traditional' villages, the fourth type of land might not exist. The two main cropping systems are jungle rubber and upland rice. The more jungle rubber area or transition to clonal rubber, the less shifting cultivation. In this situation, some villages may previously have been approached by rubber projects, but had declined to participate. In our example, the 3 villages eventually agreed to participate in the SRAP with RAS systems in 1994. Very recently, in 1997/98, the 2 villages in West Kalimantan agreed to join an oil palm project. The main reason for this latest decision was to avoid missing out on this opportunity for development, in light of the fact that they had rejected several similar opportunities in the past. However strong disagreements have occurred between community members and farmers groups ("Kelompok petani"), regarding the type of alternatives that should be developed.

In West Kalimantan, jungle rubber plots are declining in yield, as they are getting old[8] (see rubber yields in Figure 4). This is purely a problem of replanting; the main constraint being limited capital (see Figure 5). In Jambi, jungle rubber produces higher yields per unit area, off farm employment is relatively limited, and farmers' strategies are based on exploitation of the maximum area of jungle rubber available. Net farm income is even better than farmers with clonal rubber in West Kalimantan (but this is partly due to low clonal rubber yields resulting from leaf disease in that province).

2.3.2 Traditional areas with access to clonal rubber through development projects (SRDP/TCSDP) in West Kalimantan.

Partial replanting of old jungle rubber with clones

Situation 2 is that of villages that had access to a project, either with a "full approach project" including a complete technological package, credit and extension (SRDP/TCSDP) or with a "partial approach project" where inputs are provided only for the first year (PKG-GK, APBN, PKT, P2WR). In our case, the 2 villages participated in the SRDP programme (Smallholder Rubber Development Project), a World Bank tree crop programme oriented towards local farmers. Farmers decided to re-organise their land tenure in order to provide a block of 25 hectares to be planted with clonal rubber through projects (SRDP and TCSDP). For partial approach projects, farmers are free to use their existing plots of land[9].

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[7] 74 % of the Indonesian territory is officially covered by "forest" and therefore can be claimed for any purposes by the government for projects.

[8] Soils and climate are not also as favourable as in Sumatra.

[9] In all cases, there is no land title provided to farmers but clonal rubber plots are officially recognized as "private land".

These villages are innovative firstly because they accepted the official projects, and secondly, due to farmers' ability to adapt the monoculture concept to fulfil their own needs. For example, monoculture was turned into CAF in the village of Sanjan, and in Embaong, farmers developed their own new clonal rubber plantations, completely independently of the original project.

Incomes are far better than for farmers still relying on ageing jungle rubber (Figure 5). Total income from rubber is lower in West Kalimantan than in Jambi, due to the unsuitability of the selected clone (GT1), which is susceptible to *Colletotrichum* leaf disease, which seriously decreases yield. This may limit the effectiveness of external technological progress in the long run.

Clonal rubber yield in West Kalimantan is around 1000 kg/ha/year compared to 1300 in Jambi (NES project with poor tapping skills). The new clones introduced in the 1990's in TCSDP projects, in particular PB 260, have a better potential yield around 1600-1800 kg/ha/year (as observed in TCSDP plots in South Sumatra). In the long term, new plots with such clones will provide farmers with higher capital availability for investment in replanting. Farmers are already investing in clonal rubber replanting with PB 260 in Embaong and Sanjan villages through the purchase of plants (Embaong) or the development of their own budwood garden (in Sanjan) and self-production of clonal planting material by communities.

2.3.3 The transmigration areas

Replanting after grassland fallow: a form of reforestation

Situation 3 is peculiar to transmigration villages. Two cases can be observed: food-crop oriented transmigration villages where it was forbidden to plant tree crops until 1992, and tree-crop transmigration villages where rubber or oil palm plantations were provided through the NES programme. NES 'Nucleus Estate Scheme" is a World Bank funded tree-crop development programme specifically designed for transmigrants.

In both cases, migrants received 2.5 hectares and a small house. Our selection of villages is representative of both cases: former food-crop oriented transmigration villages where upland food-crop systems have generally been a complete failure and a real disaster. In some places in West Kalimantan (in the Sintang area with Pariban Baru village with local Dayaks, and in the Sanggau area with Trimulia and Sukamulia villages), up to 80 % of the Javanese migrants left the project. Those who stayed had access to low-lying land that enabled them to grow some irrigated rice. Since 1992, they have tried to increase the value of their small plot of land, (which was often invaded by Imperata), by planting tree crops, in particular rubber. They used unselected seedlings or grafted clones if available, or if they had sufficient capital). In this case, clonal rubber is generally not yet productive. Farm income levels are comparable with those of traditional areas based on jungle rubber (Figure 5). However the sources of income are different (Figure 8), mainly derived from rice production in sawah (irrigated rice) and off-farm activities (generally employment in surrounding oil palm or *Acacia mangium* plantations as workers). De facto, these transmigrants constitute a captive labour force for these estates. Farmers have very recently invested in clonal rubber plantations, in order to develop capital for further investment, as is the case in Trimulia and Pariban Baru village. In Pariban Baru, local Dayak farmers have joined the transmigration project to be closer to the road[10]. Part of their income (40 %), is provided by their old jungle rubber (Figure 8).

In Sukamulia, some farmers have developed private nurseries and specialised their farming activity for production of clonal planting material for sale.

In Jambi, two villages were selected in the rubber-oriented NES of Rimbo Bujang (Saptamulia and Sukadamai villages with Javanese migrants). In this case, although the clonal rubber is not always well maintained and correctly tapped, the project can be considered a success in terms of population establishment and income generation (see Figure 6).

2.4 *Inputs, farm income and capital*

All data are presented in Table 3 in the Annex and are discussed in following paragraphs.

2.4.1 *Farm incomes and investment problems*

Figure 5 displays gross and net farm incomes after food and education expenses. The latest "real net farm income" is the capital available after all expenses for basic needs including education costs for children that can be an important part of the expenses (see Figure 9). It is clear that the capital available for investment in tree-crop replantation with improved varieties, is clearly insufficient for traditional farmers in West Kalimantan who still rely only on ageing jungle rubber. In the past, jungle rubber has enabled a subsistence income that covered basic needs, housing and education costs for children. However it is clearly insufficient to allow investment in improved cropping patterns. Jungle rubber maintains a basic income but does not allow any investment, at least in West Kalimantan. These farmers also try to cover their rice requirement by cropping rice in sawah and ladang (upland rice). This reduces rice purchases, which can be 30 to 50 % of all expenses in transmigration villages, or in traditional villages with clonal plantations. The trend is to buy rice rather than to produce it, as soon as farmers have productive clonal plantations. Effectively the labour productivity of clonal rubber is far higher than that of rice production even in sawah (irrigated rice fields).

The situation is not the same in Jambi, where traditional local farmers crop more productive jungle rubber areas, and also profit from share cropping. Income from these jungle rubber plantations *does* enable farmers to invest in new plantations, and they generally do so on a step by step basis.

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[10] In almost all transmigration projects, initially aimed at poor Javanese farmers, a small part of the land and plantations, if any, is allocated to local farmers through a "trans-lokal programe ".

In short, what must be learnt from this rapid revenue analysis is the potential indirect effect of clonal rubber adoption on 'deforestation' or more probably on 'reforestation'. By increasing revenues, clones encourage farmers to reduce or even stop shifting cultivation for rice production. It might be not good news for the national campaign for self-sufficiency in rice, but it may help fallows to regenerate in secondary forests.

2.4.2 Input cost distribution

Figure 10 displays the distribution of input costs for each village. Use of inputs is higher in transmigration areas with clonal rubber, mostly due to investment in new plantations, in particular Round-up and fertilisers during the immature period. Inputs are still important in traditional areas with clonal plantations. Costs of the planting material are not presented in these figures. Input costs are annual average costs for cropping systems (rubber in Figure 10 and rice in Figure 11).

An initial hypothesis was that "local farmers rely more jungle rubber and are less keen than Javanese transmigrants to use inputs in order to improve cropping systems productivity". This is no longer true as local farmers, as well as the Javanese, use inputs for tree-crops as soon as they can afford them or have access to them. Intensification for tree-crops is not directly linked with ethnicity.

Javanese transmigrants do not have any choice other than intensification due to their degraded land (generally covered with *Imperata cylindrica*) and the very limited land area (around 2.5 ha), particularly if they have no access to sawah. This explains why input costs are important in Trimulia for instance (Figure 12) as they do not have any other opportunities such as clonal planting material production (Sukamulia) or old jungle rubber (Pariban Baru). On the other hand, intensification with annual crops, including the use of draught power, is more common with Javanese transmigrants. Input costs for rice are more important in Trimulia and Sukamulia than in other areas (Figure 11)

In short, it is not technological progress which influences deforestation rates, but more in line with Boserup's theory, (E. Boserup, 1970)land scarcity and deforestation which trigger innovations.

3. Herbicide replaces Gotong Royong

A key labour saving technology

The largest proportion of input costs is the labour cost (Figures 11 & 12) explaining clearly why farmers replace manual labour for weeding by chemical methods. In particular, Round-Up used against *Imperata cylindrica*, is far more effective in the short term (4 months), than manual weeding. Labour costs are relatively high and enhanced by the nature of "Gotong Royong" (mutual help[11]) for annual crops. The use of herbicide can cut labour costs by a factor of 2 or 3. It can also guarantee a certain level of

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[11] We use here the Javanese word for mutual help, "gotong royong" but similar patterns with local names do exist for local people.

maintenance for tree-crops, and ensure successful establishment of new clonal plantations if labour is scarce.

Gotong Royong is traditionally used for annual crops, in particular for upland rice, but its cost is becoming too prohibitive. The move from annual crops to tree crops also decreases interest in, and the use of Gotong Royong. Farmers develop a more individual strategy where herbicide replaces mutual help. Besides these economic reasons, there is also a strategic reason, as there is greater flexibility and freedom in the decision making process when using herbicide rather than complex forms of labour such as Gotong Royong. "Upah" or local use of wage labour on a daily basis seems to be more developed than some years ago. Beside these different labour use possibilities, share-cropping ('bagi-dua' with 50 % of net income to each) is still very important, particularly in Jambi. With limited family labour and the presence of spontaneous Javanese migrants searching for land and employment opportunities, part of the farm's jungle rubber area is commonly exploited on a share-cropping basis, providing an extra source of income from rubber. In the long run, it also enables the integration of the Javanese population with the local Malayu, as long as land is not a constraint.

The very large scale development of oil palm and *Acacia mangium* plantations in Jambi has largely contributed to the trend of land becoming scarce, and a major constraint. Due to this, and in light of the demand from Javanese migrants in NES programmes, the land market is emerging, and land prices increasing (Figure 13). Prices in Jambi are twice those in West Kalimantan where land is still relatively plentiful.

In transmigration areas, income from off-farm activities is invested in new clonal plantations which are still in their immature period, in particular for fertilisers and herbicide for clonal rubber (Figure 12).

In conclusion, the use of herbicide decreases replanting costs by reducing labour costs as a whole (for both trees and intercrops) and by increasing efficiency[12] (4 months for Round-up, compared with one month for manual weeding). Herbicide is probably the most powerful labour saving tool, in particular for rubber and rice crops.

4 Forest dynamics

4.1 Biodiversity integration and productivity

Jungle rubber has been a very important opportunity for both income generation (it is economically more interesting than shifting cultivation as labour productivity is four times higher, Penot, 1997), and also as a refugium for biodiversity (Werner 1997). It is probably one of the most relevant examples of integration of this biodiversity into a productive tree-crop system. However jungle rubber has lived its best years. It is now

[2] This efficiency can be furthermore improved if combined with a selection of adapted cover-crops but armers are reluctant to establish a crop that does not provide an immediate output.

not able to compete with more productive systems, most of them based on monoculture (oil palm/rubber), or simple agroforestry systems (coffee or cocoa).

Some hopes for integration of clones in Rubber Agroforestry Systems (RAS) in the future

Rubber is a very "flexible" plant in terms of light competition, and can be integrated into complex agroforestry systems (such as jungle rubber with unselected seedlings). Besides the optimisation of jungle rubber with clones, one of the objectives of the RAS experiments is to see if clones can maintain the same production potential in an agroforestry environment as in monoculture. If this is the case (and the preliminary results are very promising in that respect), then the replacement of jungle rubber by RAS in the long run will maintain this level of biodiversity integration in cropping systems, at least for the 3 million ha of jungle rubber that need replanting. If not, then there are few alternatives in these humid tropical areas, other than reducing farm land requirement by very highly productive systems such as oil palm. It is hoped that this trend will enable farmers to spatially re-organise their territories, and redefine land use to include some forest or "forest-like" areas.

The solution probably lies between these alternatives, with the development at the farm level of both tree-crops, RAS and oil palm, to counter the decrease in productivity of jungle rubber and provide farmers with more than the basic subsistence needs they have had until now.

4.2 Technical change and forest dynamics

To answer the main question of the seminar:
"Does technological change in agriculture limit the expansion into forests (because the same amount of food can be produced within a smaller land area), or does it stimulate agricultural encroachment by making agriculture at the forest frontier more profitable?"

Technological progress may reduce the pressure on forest only when the pioneering effect is already slowing down. The rubber case study helps to demonstrate this.

The answer therefore depends on the degree of deforestation already achieved:
- "Yes" for replanting, rehabilitation or renewal of plantations in areas which are already populated and deforested, where land has been 'appropriated' (which may also mean that land conflicts have been resolved). Yes...... at least for a certain period of time.
- "No" when technological advances trigger the process of planting in pioneer zones, under the influence of other factors (prices, patrimony, etc)

After a second, or a third generation (20 to 40 years), with the natural population increase, the reduction of land requirements per farm will be compensated for by the demand for land from the newcomers, and the same problem will occur again. If natural population increase is a key factor, then immigration, (whether spontaneous or organised), can also be considered as a "multiplicationfactor".

Finally, the only way for already established communities to maintain a certain level of forested area is firstly to secure part of their territory in the form of protected forest areas and to have a say in controlling these areas. The best time to adopt such a strategy at the community level is when the majority of farmers adopt or develop improved technologies at the same time, creating an opportunity for a new land use system in the village.

In short, technological change may have some impact on deforestation only if consolidated by creative and sensitive institutional arrangements.

Secondly, one option for technological change may be to integrate or re-integrate biodiversity into improved cropping systems such as RAS or improved jungle rubber and recreate 'agroforests'.

In the long run, it seems that the most effective way to conserve forest is to set aside areas of forest land, and maintain them as such, with no agricultural use first within a particular village based land-use policy. This designation of land-use type must be implemented not only at the village level, but also at the regional level. Another alternative would be to integrate forest species into cropping systems where this is technically feasible, such as in complex rubber agroforestry systems. However, it is vital that both the community and the government recognise the importance and value of these new land-use designations and strategies, and can define suitable and comprehensive policies to ensure their success. Technological progress could have a significant impact on reforestation, or in slowing deforestation, if it is linked directly with land-use policy at both community and regional levels. Introduction of new technologies such as block planting of rubber or oil palm in large projects often force a reappraisal of land use in a community, and this could be an important opportunity for setting aside land to conserve forest resources.

Conclusion

Technological progress will increase the expansion of agricultural land in pioneer zones, and even if already deforested land is used, it will still probably act to "boost" deforestation in the mid-term, as has been seen in the Sulawesi cocoa booms (Ruf & Siswoputranto, 1995).

In the case of replanting, technological progress may decrease deforestation for a limited period. However a 2.5 % annual population increase will alter this situation. Therefore the "Borlaug hypothesis" "Technological progress in sedentary or intensive agriculture will reduce the pressure at the frontier " may not necessarily apply to jungle rubber because it remains to be proven that jungle rubber is sedentary and/or intensive. But if we admit that it is, the hypothesis does not work in the long run.

Considering these points, *"Labour-intensive technological change is **not** more likely to reduce deforestation than capital-intensive technological change*", at least in the long run. Even if capital and labour are reduced, it will not change the main trend in the long term, as long as the demographic increase is not absorbed by industry or tertiary activity in urban areas.

Again, it is not certain whether the hypothesis *"Technological progress in isolated and poor subsistence-oriented agrarian societies is more likely to reduce deforestation than in market integrated and richer areas"* can be tested in the case of rubber. Even the most traditional villages of Kalimantan are integrated into the international market. If we decide to test the hypothesis on rubber, again it does not work in the long run, as clonal rubber development in South or North Sumatra shows.

Considering any technological change without considering its global economic and demographic environment over a longer time scale might lead to contradictory answers in the short and long term.

Finally, as for cocoa, technological change has had little impact in preventing deforestation, but may have much more influence on 'reforestation'. The use of tree crops, either in monoculture or agroforestry systems (hopefully the latter, but not necessarily), will achieve the supposed 'main goal': generation of family incomes, while in addition will recolonize degraded fallow and thus help in 're-greening', and will re-establish tree cover (and thus aid carbon sequestration).

Therefore, efforts should be maintained in current development-oriented research such as RAS experimentation, in order to release optimised cropping patterns acceptable to farmers.

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