

Agroforestry Systems Improvement in Southeast Asia

Annual Report for 1994

Project 4.6

Agroforestry Systems Improvement research in Southeast Asia focuses on the development of alternatives to unsustainable slash-and-burn agriculture, and the rehabilitation of degraded uplands. This work is targeted to three of the region's key ecosystems: The forest margins, the *imperata* grasslands, and the sloping permanent farmlands.

This was the second year of ICRAF's program in Southeast Asia. We formulated a central hypothesis to focus the work in each of our three key ecosystems. We began implementing research in Indonesia and the Philippines to address the three issues.

1. The Forest Margins: Improving the technical efficiency of the rubber agroforestry system

On the forest margins, we are testing the proposition that complex agroforestry systems or 'agroforests' provide a superior alternative for small-scale farmers to either food crop systems or monoculture plantations of perennials. Complex agroforests may increase production sustainability, increase biodiversity, reduce production risks, and increase returns to labor as alternatives to unsustainable slash-and-burn. They are one of the most viable alternatives to

slash-and-burn agriculture in the humid tropics. They encompass a wide range of farmer-developed systems. In Southeast Asia these include industrial crop-based systems (eg rubber agroforestry), fruit tree-based (eg durian agroforests), and timber tree-based systems (eg damar [*Shorea javanica*] agroforests).

Rubber agroforestry is probably the most widespread type of complex agroforestry in Indonesia. Although the smallholder rubber agroforests occupy 84% of the rubber area (some 2.5 m ha), and provide 75% of the rubber production, there has been little effort to improve their technical efficiency. Within the context of the global initiative on Alternatives to Slash-and-Burn we launched a collaborative initiative to understand and improve the productivity of rubber agroforestry systems without losing the benefits that farmers perceive in practicing this biodiverse farming system.

Rubber agroforests are low input systems practiced for generations by Indonesian shifting cultivators. Rubber seedlings are established as intercrops with annual food crops, and other perennials. After the swidden is fallowed, the trees are not provided further maintenance. The rubber trees compete with the regrowth of the natural secondary forest. Gradually, these mixed rubber gardens replace the natural secondary fallows (Figure 1).

Rubber agroforests or 'jungle rubber' maintain a forest-like environment that retains biodiversity. A variety of products tend to be harvested in addition to latex, including many types of fruits and timber. But the yield of latex is low (300 to 600 kg/ha/year). The conventionally recommended way to improve productivity is to shift to a rubber

monoculture, with improved planting material, fertilizers, and intensive weed control. This path entails substantial investment costs, beyond the reach of most smallholders. Although there has been much emphasis on providing smallholders full technical packages through development projects, these have reached only about 13% of the farmers (Table 1). An additional 10-20% of the smallholders in the vicinity of these projects have had indirect benefit through technical information and improved planting material. But as the typology of rubber smallholders in Table 1 shows, some 75% of the farmers have not had access to improved systems, and continue practicing 'jungle rubber' culture.

We hypothesize that there is an alternative pathway to smallholder rubber improvement more feasible to farmers and more efficient in terms of public investment: The management of improved planting material within the low-cost rubber agroforestry system. A range of improved rubber clones and poly-clonal materials is available, but it has not been evaluated under the prevalent smallholder rubber agroforestry systems. There is reason to believe that rubber yields could be substantially increased by planting these materials with minor increase in labor and inputs. If so, the case can be made that public investment may be more efficient in reaching much larger numbers of smallholders with new genetic materials rather than intensive high-cost projects that provide a full package but can only reach a small proportion of the target farmers.

In the context of the Alternatives to Slash-and-Burn Program, ICRAF has initiated a research project to test this hypothesis, in collaboration with CIRAD (France), the Rubber Research Institute of Indonesia, ORSTOM, and GAPKINDO, the Indonesian rubber processors

association. The recommendation domain of the Rubber Agroforestry Systems (RAS) project is the class III farmers (Table 1): the non-project farmers that want to improve the productivity of their current rubber cropping pattern without being able to afford extensive change in their management intensity or investment.

The work will be carried out in two major smallholder rubber regions, western Jambi province, Sumatra, and in West Kalimantan, with strong local government involvement. In the current phase, a more detailed characterization of the smallholder rubber agroforestry systems is being conducted in the study areas, and budwood gardens are being established locally to provide clonal materials for the on-farm trials. Current yields of latex and other products are being assessed from the smallholder enterprise and analyzed as a basis for the work. Research on the biodiversity of rubber agroforests, which has been in progress for several years by ORSTOM, will be integrated with this project.

The trials will be targeted according to three production systems. The first system (RAS 1) will address the performance of selected improved planting material within the current jungle rubber management system, interacting with modest or no cash investment in inputs. Farm-scale plots will be emphasized for realistic farmer participation. The second system (RAS 2) will investigate the direct establishment of complex agroforests through combinations of rubber and other perennials (fruit, nut, and timber species), in which the compatibility of the species combinations will be an issue.

In terms of land types, RAS 1 trials are targeted to forest margin conditions where there is an adequate supply of natural species propagules to regenerate a secondary forest-like environment. RAS 2 research is targeted toward the imperata grasslands, where natural forest regeneration will not occur, and the species mix must compete with the highly competitive grass.

2. The Grasslands: Agroforestation through smallholder timber production on the frontier

The alang-alang grasslands (*Imperata cylindrica*) of Southeast Asia are receiving intense scrutiny as an underutilized land resource for providing land for settlement and for providing future timber needs to replace the rapidly depleting natural forest stocks. In rehabilitation the grasslands, our systems hypothesis is that small-scale agroforestry systems will be a superior alternative to plantation reforestation, in terms of production, equitability, and participation objectives.

It is commonly perceived that small-scale farmers on the agricultural frontier must assume a very short term perspective in their farming practices due to poverty, family food needs, and lack of access to investment capital. In Southeast Asia these pioneer farmers are typically found on the margins of protected forests, and in the grasslands dominated by *Imperata cylindrica* (*alang-alang*, *cogon*). The conventional paradigm is that they practice annual cropping for food security by converting protected forests to shifting agriculture, and consequently degrade the sustainability of the fragile uplands. Policymakers are very

concerned about the prospects for successfully protecting or rehabilitating natural ecosystems, and maintaining the agricultural potential of the hillslope lands of the region.

Large-scale government reforestation projects have a history of over 50 years in many countries, but most have failed due to fire and lack of local support. Currently, there is much experimentation with contractual arrangements that subsidize private or NGO tree plantations. These efforts are based on the principle that a public subsidy is useful and necessary to induce the private sector to engage in the reforestation effort.

We have been researching a situation where small farmers have independently begun farming timber trees on infertile grassland soils in the uplands, and doing so as a dominant enterprise using their own capital resources. This development among pioneer farmers in Mindanao, Philippines, challenges prevailing assumptions, and opens up new possibilities for the public sector may support this development. It may suggest a powerful prospective model for reforesting the uplands.

The study was conducted in two parts. The first examined the timber marketing system in northern Mindanao. Interviews were conducted with the saw mill companies in Cagayan de Oro, the major entrepot in north-central Mindanao. Timber and sawn lumber prices were gathered from major timber companies and from the regional office of the Department of Environment and Natural Resources. The second part was a set of open-ended interviews conducted with timber-tree farmers in several villages in the sloping uplands of Claveria, Misamis Oriental, a town located 25 km from Cagayan de Oro. The interviews and field

visits documented the tree farm production systems and marketing practices and understand the farmer decision-making processes. The sample of farmers was targeted to full-time farmers with relatively small land holdings.

The key factor responsible for the development of smallholder timber plantations was the recent emergence of attractive market-driven demand for fast-growing timber species. Timber prices have risen rapidly in the last decade. Prices for medium-sized logs of *falcata*, i.e. *Peraserianthes falcateria* (*Abizzia falcateria*) increased from \$24.00 per m³ to \$64.00 per m³, an average of 20-30% per year. Small diameter logs of *Gmelina arborea* were prices similar to *falcata*.

Forty-two smallholder timber farmers were interviewed. Farm size ranged from 1.7 to 4.0 hectares. The primary enterprises prior to tree farming were annual food crops of maize, upland rice, and cassava. The area that they had planted to timber trees ranged from 0.5 to 3.0 hectares (17% to 100% of the farm). Ninety percent of the farmers had planted *Gmelina arborea*. Ten percent planted mahogany (*Swetenia spp.*) and *Acacia mangium*. The tree plantations were established as intercrops with annual crops of maize, rice or cassava.

Most plantations were planted in a 2 m by 2 m block spacing. Many farmers practice field boundary planting. The remainder were planted on contour lines on sloping land with a 1 m spacing between trees, and with food crops in the alleys of 6 to 8 m width. Annual intercropping usually continued for two years until canopy closure (Figure 1). In field with wide hedgerows it continued longer. Most of the tree planting of the farmers sampled has

occurred within the past three years. Accelerated timber tree production on small farms was observed throughout this and adjacent provinces.

Seeds or seedlings were obtained from traders, neighbors, local mother trees, and DENR. All respondents indicated that the primary motive of engaging in tree production was the expectation of increased income, but 40% emphasized that they were seeking a replacement to annual crops because of declining yields. A similar number related the objective to have wood for building homes in the future, a market substitution response to high prices.

Harvesting and marketing follow one of two pathways: Contracting directly with the sawmill or a timber trader through a bulk contract wherein the contractor cuts and hauls the logs or rough-sawn timber to the mill, or direct delivery by the farmer of logs or the sawn lumber to the mill. The second path is usually relied upon only for small quantities.

Conventional wisdom surrounding forest plantations in the tropics has focussed on the argument of returns to scale; that is, large production units are necessary to minimize costs and justify the investment of management expertise. But returns to scale are often elusive, and may be outweighed by other considerations. Large-scale enterprises have not been competitive with small-holders in the production of some commodities. Major examples are rice and maize production.

In the production of fast-growing timber trees the returns to scale issue needs to be re-assessed. We have identified three major competitive advantages of smallholder timber plantations vis-a-vis larger scale timber estates:

- 1) land preparation and weeding costs in the initial years are charged to the annual crops, minimizing tree establishment and maintenance expenses;
- 2) the cropped alleyways provide fire breaks that can drastically reduce wildfire damage; and
- 3) the more intensive management of the small farmer may better insure that the trees reach harvestable age.

The second issue, fire control, may be the most crucial advantage. Fire is a source of high (often extreme) production risk throughout the tropics, and particularly in areas dominated by imperata grasslands. Fire control on a plantation scale is expensive, and management intensive, but does not eliminate the threat. The greater intensity of land use that is characteristic of small-holders, lends itself much better to cheap fire control. This is enhanced by clean cultivation and more intensive site management in general.

In the recent past the timber resources of Southeast Asia were abundant and wood prices were comparatively modest compared to other commodities. That situation has changed dramatically in a relatively short time. The destruction of the natural forest has had one positive spinoff. It has become profitable to grow trees as crop commodities. Evidence now

exists that small full time farmers on the upland agricultural frontiers are moving into the production of timber trees as a major self-financed enterprise.

Research can materially assist this process. Improved germplasm and dissemination methods for the important species are needed to improve productivity. Another major issue for ICRAF and collaborating institutions is how to diversify these systems into mixed species agroforestry systems to reduce risk and better stabilize income. Currently, we are continuing these studies through the development of a simple model to investigate the effects on overall productivity of combining full-canopy trees and annual crops in the four major permutations: Field boundary planting, contour hedgerows, wide contour strips, and separate block planting (Figure 1).

3. Sloping Farmlands: Understanding and ameliorating the scouring effect as terraces develop behind vegetative barriers

The early literature on contour hedgerow systems indicated the advantages of vegetative barriers in reducing soil erosion on sloping fields. The natural development of terraces was observed with a buildup of soil behind the barrier. The new soil layer is deepest at the hedge, and overlays the old surface to a progressively thinner extent upslope. This was emphasized as evidence that soil loss was being effectively controlled.

On moderate to steep slopes the soil may be redistributed across the alley quite rapidly after hedgerow installation. At ICRAF's research location for sloping land agroforestry in Claveria,

Mindanao, Philippines, a 60-cm drop in soil level between the alleyways occurred after 2.5 years on a field with 25 % slope in a hedgerow experiment involving *Senna (Cassia) spectabilis*. Numerous farmer adopters' fields showed similar rates of terrace development.

There have been few longterm observations of crop yields in contour hedgerow systems on slopes. At our research site in Claveria we have now monitored some trials for as many as 8 years, and find a distinct pattern of low yields on the upper alleys and higher yields on the lower alleys. After 5 years of upland rice cropping between *Gliricidia sepium* hedgerows on a Typic Hapludox with 20% slope upper alley yields were 50% lower than those in the lower alleys. Without added P fertilizer the differential between the upper and lower alleys was even more pronounced. A similar response was recorded with *Cassia spectabilis* and *Pennisetum purpureum* (Napier) hedgerows. At a nearby experimental location, a yield depression in the upper alleys was observed with both rice and corn associated with *Gliricidia sepium* hedgerows after 4 years.

The pattern of response that is typically found suggests that the phenomenon cannot be explained by competition between the hedgerows and crops. In experiments with *Gliricidia*, *Cassia*, and *Pennisetum* we excluded both above-ground and below-ground hedgerow competition by intensive pruning and installation of 50-cm deep plastic barriers. The spatial pattern of yields was not changed by the barriers compared to treatments without barriers. These results indicated that processes other than hedgerow-crop competition is operating in these situations.

Soil Spatial Fertility Gradients. Suspecting that soil fertility was a factor in producing the skewed grain yields, we began to more carefully monitor the pattern of soil properties across the alleyways. We sampled the soil in the alleyways of a *Cassia spectabilis* hedgerow experiment showing across-alley grain yields skewed toward the lower alley. We found that soil organic carbon was varied from 1.7% near the hedgerow in the upper alley to 2.8% near the lower hedgerow. Available P was twice as high in the lower zone compared to the upper. Soil pH was unchanged but exchangeable aluminum increased. These patterns were observed in the subsoil (15-30 cm) as well as in the topsoil.

In a *Gliricidia* hedgerow trial we intensively sampled 5 points across the alleyways in four strips in each of four replications. A linear soil fertility gradient was observed (Fig 3). Exchangeable calcium, organic C, pH, and Bray-2 extractable P increased from the upper to the lower alleyway, exchangeable Al decreased, while K and Mg were unchanged. In a row-wise study of soil properties elucidated on an Oxic Palehumult in Laguna Province, Philippines, we observed a linear increase in organic carbon (from 2% to 3 %) and nitrogen (0.20% to 0.27%).

Why does this fertility accumulation occur towards the buffer strips, and why does it happen so rapidly? Terracing tends to reduce the slope length and slope angle, reducing the energy of water to move soil particles downslope. The effectiveness of the vegetative barrier insures that very little enrichment of soil can occur from above. It is the upper alley where maximum soil loss occurs. The large amounts of profile scouring observed in many hedgerow systems leads to the presumption that tillage transport must account for the overwhelming amount

of soil movement. We are currently attempting to measure directly the amount of soil movement due to tillage in order to estimate the relative contribution of these two processes to soil redistribution within the alleys. Upper alley scouring, and rapid soil displacement to the lower alley, seem particularly prominent where draft animals are used in land preparation. The plow efficiently turns soil downhill, and makes frequent tillage practicable.

Modeling Crop Performance Across the Alleys. The row-wise performance of crops in alleyways subjected to scouring suggests a response surface that is determined by two phenomena: The classical hedge-crop inter-species competition for growth resources, and the soil scouring during terrace formation. The conventional response function of crop yield or dry matter (but not plant height) may be represented as the integrated effect of the two independent sets of processes. Fig 4 diagrams the generalized response surfaces that tend to be observed in situations where both processes are operating, compared to the response surfaces observed where the independent processes are desegregated. In future, as more work focuses on the disaggregation of the integrated effect we should be able to model the interaction between these gross effects as part of a more general understanding of the entire tree-crop system.

The diagram illustrates the utility of dividing the alleyway into homogeneous zones in which the species competition effect and the scouring effect are differentially active. A minimum of five zones seem necessary to capture the response surface and analyze contributing processes to this skewed distribution. The scouring deposition effect creates a radically more favorable crop environment above, as opposed to below, the hedgerow, but species competitive

interactions in the area of direct interface (the upper and lower zones) tend to deflate the differences among their integrated effects on performance.

Is Farming on Natural Terraces Sustainable? The effects of scouring raise serious issues concerning the short-term and long-term agricultural sustainability of natural terraces. It is generally assumed that the scouring effects will dissipate with time as the terrace surface stabilizes and more organic matter can be retained in the surface soil in the upper zones. But it is not known how long this process may take on different sites and under different management regimes. It is not surprising to expect that the short-term losses due to scouring may appear to make the investment in contour hedgerow installation and maintenance unattractive to farmers.

We urgently need to know: (1) Whether scouring effects are a short- or long-term phenomenon, and (2) How they can be effectively avoided or alleviated. It is possible that scouring is only a temporary phenomenon.

In some experiments we have observed that grain yields were still higher with tree legume hedgerows, although a scouring effect was evident. In other cases, particularly with grasses or natural vegetative strips, yields were similar or lower. The absence of short-term benefits crop yield is a deterrent to adoption. We are currently monitoring longterm hedgerow trials to observe when and under what species combinations and management practices the upper alley yield depression may disappear.

Alleviating the 'Scouring' Effect. There are three basic ways to try to cope with scouring: To avoid it, alleviate it, or change the cropping system to live with it. The research agenda for each is briefly addressed.

Reducing the intensity of tillage. To avoid scouring a farmer must avoid frequent primary tillage. In zero tillage systems there is little tendency for hedgerow risers to develop or for soil scouring to occur. Unfortunately, they have not proven practical for annual crops in the tropics. But there are many variations of reduced tillage that smallholders can adopt. We are currently experimenting with ridge tillage. In ridge tilled fields unplowed (but superficially scraped) strips are maintained indefinitely, and the annual crops are planted consistently in these strips. Adapting the ridge till concept to small-scale farmers has received almost no attention to date.

Adjust biomass and nutrient inputs. To alleviate scouring it is logical to consider changing the spatial pattern of nutrient inputs. The application of crop residues, hedgerow prunings, animal manure, and fertilizers may be biased to the upper alley zones. Since scouring tends to redistribute topsoil nutrients downward naturally, application to the upper alley may ensure a more even distribution in the long run. But it may also be argued that application to the lower zones with more favorable soil may make more efficient use of limited nutrient inputs. This depends on the comparative nutrient utilization efficiencies of crops growing in the different zones. We have initiated experiments in Claveria to elucidate these fertility management issues, and gain a predictive knowledge about them.

Change the Cropping (or Hedgerow) System. The final strategy is to accept the scouring effect and to alter the cropping system to adjust to the changes (particularly if they are drastic). Substitution of perennials (eg bananas, timber trees, or MPTs) for annual crops, or more tolerant annuals (eg cassava), are practices that have farmers have experimented with. Researchers and farmers must learn how to better exploit the degraded zone that a conservation technology may create.

Cognizant that the highest soil fertility is found inside the hedgerow strip, it has even been suggested that this fertility be exploited by periodically moving the hedgerows downslope and cultivating the former hedgerow area. (Of course this idea is more practical with a grass strip than with trees.)

A concerted research effort is needed to elucidate these processes more fully, model the interactions, and gain a predictive understanding of when, where, and how contour hedgerow systems embody a superior technology for hillslope agriculture.

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1. Typology of smallholder rubber farmers in Indonesia.

TABLE 1. TYPOLOGY OF SMALLHOLDER RUBBER FARMERS IN INDONESIA

Class	Situation	%	System
1.	Gov't projects	13	Estate-like monoculture
2.	Non-project but good access to markets, credit	12	More intensive rubber agroforestry; tendency toward monoculture
3.	Moderately isolated	50	Jungle rubber some improved management
4.	Isolated, no access to credit, extension	25	Jungle rubber