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From Slash and Burn to Replanting

Green Revolutions in the Indonesian Uplands

EDITED BY

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Preface

What are the alternatives to slash-and-burn in the Indonesian uplands? This provocative question was put to our CIRAD team by a World Bank official in 1996.

One answer is that, if these alternatives do exist, they have been mostly invented and implemented from "below" by farmers and middlemen rather than by projects and governmental agencies. Farmers are the true entrepreneurs and innovators in the uplands.

This conclusion was stressed in early 1997 in our report using fieldwork mostly done in late 1996. After a review of the literature, the challenge for a team of three to five people was to spend about three days in some 40 small regions throughout Indonesia and take stock of each experience. The output was a preliminary report, "Indonesia Upland Technology Study," edited by F. Lançon and F. Ruf in April 1997. After discussions with the Agriculture Agency for Research and Development in Indonesia and with Gershon Feder's team at the World Bank, it was decided to include more in-depth case studies and prepare a book.

In the meantime, high-quality studies on Indonesian uplands in environmental history and sociology were published in the late 1990s. These included "Paper Landscapes," edited by Peter Boomgaard and others (1997) and "Transforming the Indonesian Uplands" by Tania Murray Li (1999). The international and interdisciplinary ASB research program (or "Alternatives to Slash-and-Burn") was launched and produced a number of studies and reports, including in Indonesia. In 2001, a reference book entitled *Agricultural Technologies and Tropical Deforestation*, edited by Arild Angelsen and David

Kaimowitz, discussed recent changes in tree crop farming, including in Indonesia.

During the same period, Indonesia was shaken by a financial, and then a social and political, earthquake. Economic and ecological changes in Indonesia were critical during 1997 and 1998. The currency and economic crisis struck city dwellers, while El Nino and forest clearing had devastating effects in some areas. However, Indonesian smallholders showed some ability to adapt to changes, both to the unexpected windfalls from lucky export crops in 1998 and the no-less-unexpected plunge in prices in 1999 and 2000. Recent publications on these changes—including *Agriculture in Crisis: People, Commodities and Natural Resources in Indonesia, 1996-2000* by Gerard and Ruf (2001); *Economic Crisis, Small Farmer Wellbeing*; and *Forest Cover Change in Indonesia* by Sunderlin and others (2001)—provided further reasons to publish the present book.

The results of the original 1996 fieldwork in some 40 small regions of Indonesia (work done by researchers from various disciplines, backgrounds, and training) give this book its originality. Additional reports were added from people with extensive knowledge and years of experience in Indonesia between 1989 and 2001. Some chapters take into account changes that occurred after the financial and political crisis of 1997–1998. In any case, the conclusions derived from the 1996 fieldwork on innovative upland agriculture remain generally valid. Finally, after the 1998–2001 period of intense difficulties, this is the time to help demonstrate the strength of the innovations made by Indonesian upland farmers.

Summary

The most traditional and widely used farming systems in the humid upland tropics are based on fallowing and various forms of slash-and-burn agriculture. Their sustainability depends on the duration of the fallow; as long as the fallow stage is longer than seven or eight years, slash-and-burn systems usually remain efficient. They produce a moderate yield using a low-input technology that is especially efficient in terms of returns to labor. With a few exceptions, yield per hectare and labor returns decline when fallow duration drops below the threshold of seven or eight years. This decline can be interpreted as the loss of the "forest rent," one of the main concepts used in this study. Forest rent also applies to most perennials, which despite their name are often managed under a kind of shifting cultivation.

Tree Crop Shifting Cultivation

As coffee, cocoa, and even rubber farms are sometimes abandoned to "fallow" and replanted later on, a tree crop system may well be considered as an extended form of shifting cultivation, hence the concept of tree crop shifting cultivation used in this study. If the coffee or cocoa farms are not abandoned for several years to enable a regrowth of a secondary forest, replanting is more difficult or more costly than initial planting. Yields and revenues can be expected to be lower. This decline of revenues and increase of costs matches the concept of the loss of forest rent.

Forest Rent

The concept of *differential rent* was introduced by Ricardo in 1815. He observed that farmers usually grew wheat on the most suitable soils. As population and demand increased, farmers grew wheat on less and less suitable soils. This led to a cost difference between varying ecological settings. As long as the price of wheat covered production costs in the least suitable areas, farmers cultivating the best land enjoyed extra profits, which Ricardo referred to as *rents.*

The same principle of differential rent can be applied to most commodities grown in the tropical forest with only one major change. Farmers who benefit from differential rent typically move on to set up new plantations once the initial forest rent has been exhausted. The differential forest rent applied to a commodity is defined as the difference in production and investment costs between a ton produced on a farm established just after a forest is cleared and a ton of the same commodity produced by replanting on fallow land or after felling of the first plantation.

The cost difference is directly related to ecological changes and reduction in the benefits provided by the forest. This is not a simple problem of fertility or erosion in the uplands. The benefits include low frequency of weeds; good top soil fertility; moisture retention due to high levels of organic matter in the soil; fewer problems with pests and diseases; protection against drying winds; and the provision of food, timber, and other forest products.

When forest has been massively cleared, cultivation becomes more difficult. Farmers lose all or most of the advantages named above, which increases production costs as well as the cost of living. In short, forest rent has vanished. Weeds, pests, losses in fertility, lower yields, and shortened economic life for trees mean more labor and inputs and a higher average production cost. The replanting problem partially explains regional shifts of a commodity such as cocoa as producers seek lower production costs and lower investment risks and costs.

Upland Development Policies

In the last decade, the development of upland agriculture has become an important policy objective of Indonesian agriculture. Numerous projects and programs have been implemented to achieve this goal, based on the dissemination of new agricultural technology. These technologies aim to improve the yield of upland crops by maintaining, if not enhancing, their sustainability.

Land conservation techniques have been widely disseminated in the most ecologically fragile upland areas. However, farmers adopt these techniques only when they are able to combine them with cropping systems that significantly increase their income.

Staple food crops do not play a major role in generating income, except for improved varieties of maize that are increasingly being adopted. To enhance their standard of living, upland farmers are diversifying production toward more profitable crops such as vegetables, fruits, and perennials. In most cases, this adoption of new crops comes from farmers' self-help action, but official projects may play a role.

Capital versus Loss of Forest Rent

In most cases, the shift to new crops is part of a larger technical change and starts to be an alternative to slash-and-burn based on paddy and maize. This change usually means a strategy to overcome the loss of the forest rent and more generally that of "natural resources" rent. This change and strategy also imply an introduction of capital into the farming system, part of which is in the form of biological capital.

Tree crops are a most effective use of biological capital to simultaneously enhance the sustainability of upland farming systems and farmer welfare. Tree crops, however, should not be idealized. In the history of uplands, massive migrations motivated by tree crop revenue used to be among the most powerful tools of deforestation. Once the forest is gone, however, tree crops may be turned into reforestation tools.

This study showcases several situations where degraded fallow has been converted into successful, commercially oriented tree crop farms, either as monocrops or various forms of agroforestry. As in the case of coffee-vanilla systems, agroforestry can help make tropical agriculture sustainable by enabling its rapid change and adaptation to ecological and market changes. Whether agroforestry or monocrop, tree crops will remain a key to the future of the uplands.

Introducing animals to a farming system is another innovation that can be an alternative to slash-and-burn, a source of biological capital that can make up for the loss of natural resources rent. Terraces and small on-farm reservoirs are other forms of efficient capital that help build alternatives to slash-and-burn. Closing the gap between producers and consumers through road construction and technical progress on all types of transportation (including speed boats) is yet another introduction of capital to upland agriculture. This technological progress, however, is not neutral because it usually accelerates migration and thereby deforestation. Nonetheless, once the forest is gone, roads and direct access to markets generate a location rent that can help overcome the loss of forest rent.

One other innovation, a reasonable use of fertilizers, pesticides, and herbicides, helps to maintain sustainable systems and renew degraded fallows. Once again, monetary capital has been introduced to overcome the loss of forest and other natural resource rents.

Markets

Competition and free markets from which farmers can maximize income are major factors in the adoption of innovations. Upland farmers are very sensitive to price changes and the flexibility of many upland farming systems allows them to shift easily from one crop to another, even with tree crops. Most tree crop commodities are exported, but the growing domestic markets for vegetables and tree fruits, especially oranges, have captured farmers' attention.

Migration and Population Pressure

The relationship between population level and available land is complex and must be considered from the perspectives of both history and dynamic changes. Population pressure does not necessarily preclude wise management of natural resources. Several upland areas in Java lack the appropriate labor resources to implement labor-intensive technology that would be less harmful to the environment. In the outer islands, the spread of tree crops is often associated with massive migration.

Savings and Credit

Capital constraints are more or less acute depending on the type of innovation and the channels through which it is transferred. Credit schemes are important for official projects, but in most cases if a new technology or crop is sufficiently profitable, private traders are able to provide advances in cash or in-kind to farmers.

A "Hidden" Green Revolution

This introduction of capital and technical changes partially fits the concept of a Green Revolution. This book argues that spontaneous Green Revolutions have occurred in the uplands but have been largely ignored, mostly because they originated with the farmers and traders themselves and were not a direct result of government policy.

At a macroeconomic level, the fate of upland farming systems is closely related to the future of lowland irrigated agriculture. It is important to consider that in terms of competition, the comparative advantages to upland farmers of growing trees and vegetables may exist only as long as rice remains the most profitable and least risky crop in irrigated systems. The supply of low-cost staple foods from lowland areas is an important factor that facilitates the adoption of tree crops in upland farming systems. Several examples of periodic labor migration from lowland to upland areas have been recorded.

For tree crops, innovation and sustainability raise the issue of replanting. If there is no replanting at all, as mentioned above, a tree crop system may well be considered as an extended form of shifting cultivation.

Replanting or Lack of Replanting

Replanting after an old plantation or after grassland is very different than initial planting after forest clearing; however, both types of replanting are extremely important. One of the main challenges for the future of the uplands is how to plant and replant tree crops on degraded land covered by the grass *Imperata cylindrica.* A combination of commercial tree crops, with the provisional support of leguminous trees and a reasonable use of chemical inputs that are compatible with agroforestry practices seems to be the answer.

Last, whatever the type of replanting strategy, what matters first is the sustainability of the family. If a coffee or cocoa farming system can help farmers to build decent houses and afford better transportation (motorcycles or even cars)—which happened in the Indonesian uplands in 1994 and 1998—even though farm prices plunge later on, tree crops remain a major factor in alleviating poverty.

Acronyms and Abbreviations

AARD	Agency for Agricultural Research and Development
ARP	Assisted Replanting Project
agung harvest	Peak harvest year for coffee, usually the fifth or sixth year after planting
alang alang	*Imperata cylindrica*
ASB	Alternatives to Slash-and-Burn
bagi hasil	Sharecropping system
bagi tanah	Land-sharing contract
BLIG	Bah Lias Isolated Garden, London Sumatra, North Sumatra
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CGPRT	Centre for Research and Development of Coarse Grain, Pulses, Roots and Tuber Crops (United Nations Economic and Social Commission for Asia and the Pacific)
DGE	Directorate General for Estates
DI/TII	Darul Islam/Tentara Islam Indonesia
DISBIN	Dinas Perkebunan (extension service for perennial crops)
EJRAP	East Java Rainfed Agriculture Project
gamal	*Gliricidia sepium*
GCC	Group Coagulating Center

hutan karet	jungle rubber
IATE	Institute for Agriculture Technology Evaluation
ICRAF	International Centre for Research in Agroforestry
IGPM	improved genetic planting material
IPM	integrated pest management
IRRI	Indonesian Rubber Research Institute
IRRI	International Rice Research Institute
jakau	fallow (local dialect of East Kalimantan)
kabo kabo	five-year fallow following paddy rice
kebun mamar	kitchen garden
KUD	Koperasi Unit Desa (village cooperative)
ladang	shifting cultivation
lamtoro	*Leucaena leucocephala*
NES	Nucleus Estate Project (PIR in Indonesian)
NSSDP	North Sumatra Smallholder Development Project
NTFP	non-timber forest products
PMU	Project Management Unit
PRPTE	Proyek Rehabilitasi Perkebunan Tanaman Eksport (Project of rehabilitation of export-oriented tree crops)
RRP	Rembang Reforestation Project
sawah	irrigated rice using an irrigation network (rainfed sawah relies on rainfall, with dikes able to partially control water)
SRDP	Smallholder Rubber Development Project
TCSDP	Tree Crop Smallholder Development Project
tebasan	contract trader is responsible for harvesting a farmer's crop
UACP	Upland Agriculture and Conservation Project
UFDP project	Upland Farmers Development Project
WSSDP	West Sumatra Smallholder Development Project
YUADP	Yogyakarta Upland Area Development Project

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Innovations in the Indonesian Uplands

François Ruf and Frederic Lançon

Are there real alternatives to slash-and-burn in the tropical uplands? If alternative technologies exist, where are they applied, for how long, and by whom? Are they local, or do they have a wide implementation? How do farmers and governments respond to concerns about upland environment degradation and its negative impact on yields, production, and agricultural revenues? What can be learned from a large and diversified country such as Indonesia? These questions represent the starting point of this book. Over the years they have also provoked various responses from experts and researchers. Among these responses emerge three different perspectives on slash-and-burn and its alternatives.

First, many agricultural experts and international agencies share the idea that the Green Revolution succeeded in the irrigated lowlands, while technical progress had little success in the uplands. Many experts look at the numerous failures in official projects devoted to environmental protection of "degraded uplands" and conclude that there are still relatively few convincing alternatives to slash-and-burn and its supposedly increasing damages. These experts perceive most upland farming systems to be unsustainable, prone to ecological degradation and revenue losses when human activity increases beyond a certain threshold. Upland farmers are perceived to be poorer than those in the irrigated lowlands. These perceptions certainly helped to trigger programs such as Alternatives to Slash-and-Burn (ASB), funded primarily by international agencies.

Second, the global issues of deforestation and carbon sequestration were raised. These concerns helped lead to the establishment of the ASB, a worldwide research program of the late 1990s with a strong component in Indonesia. Setting out its rationale for its Indonesia project, ASB stated:

> Conversion of tropical forests reduces biodiversity and releases stored carbon. Although a part of tropical deforestation resulting from

> slash-and-burn is linked to poverty of people living at the forest margins, the conditions necessary for increased productivity of agroforestry and other land use systems to reduce poverty and reduce deforestation are not well understood. The key hypothesis of the ASB research project in Indonesia can be summarized as follows: Intensifying land use as an alternative to slash-and-burn simultaneously can reduce deforestation and reduce poverty (ASB 1998, p.1).

Multidisciplinary research helped to identify smallholders' innovations such as the complex agroforestry systems currently acknowledged as alternatives to slash-and-burn.[1]

Environmental historians offer a third and different perspective on slash-and-burn. Based on local and extensive historical studies, they argue that "land degradation" related to slash-and-burn and, more importantly, innovations helping to rebuild sustainable systems are nothing new and are certainly not limited to the 20th century. According to one source:

> While a substantial part of Indonesia's degraded land came into this condition only in the last two or three centuries, there has also been significant repair of degradation in the same period. This repair has come both through the adoption of improved land management and through natural recovery of forest on land on which human interference has become lighter (Brookfield 1997, p. 49).[2]

The last two perspectives come from different disciplines and aim toward different objectives, but they have at least one common point. Whether in the form of agroforestry systems or through annual crops associated with livestock or tree crops, they suggest that alternatives to slash-and-burn do exist and that they look very much like smallholder strategies. In many cases smallholders started elaborating these alternatives decades or even centuries ago.

From our own surveys on various farming systems based on tree crops and annual crops in Indonesia, we share this view about smallholders' innovations (Ruf and Lançon 1997, Gerard and Ruf 2001). Innovative alternatives to slash-and-burn in the uplands are varied and numerous. Some are ancient, such as agroforestry strategies; some are much more recent, such as the adoption of fertilizers. In many cases these innovations have been ignored or at least underestimated by governments and international agencies. Did, in fact, unknown or ill-evaluated Green Revolutions occur in the uplands?

Objectives

The first objective of this book is to record case studies that illustrate and demonstrate these various forms of innovations (or "agricultural revolutions") in the uplands, especially in Indonesia, and to understand how these were built. Then comes the real challenge: using this understanding to suggest adjustments to existing policies that are favorable to or support upland smallholders.

The field studies reported here investigated upland locations representative of various farming systems both to assess promising upland technologies and to document adoption of innovations. The studies covered different components of upland farming systems, including food crops, tree crops, and livestock production, and focused on socioeconomic issues that underlie the dissemination or rejection of technologies. The team categorized innovations as techniques, inputs, or agricultural practices and then focused on the following:

- Comparative advantages of innovations in terms of current farmer practices, especially with respect to financial and natural resource management.
- Rate of innovation adoption at various intensities and potential persistence of the innovation within the observed farming systems.
- Effects of socioeconomic and institutional environments on adoption of technology.
- Socioeconomic aspects that influence the adoption process, for example, wealth distribution and equity or gender issues.

Why are these questions being studied especially in Indonesia? During the 1980s and 1990s the development of upland agriculture became an important objective of Indonesian agricultural policy. To achieve this goal, numerous projects supported by international funding agencies worked to improve the socioeconomic conditions of upland farmers by developing and disseminating new, environmentally sound, and economically viable technologies. In light of the increasing importance of environmental issues, and the challenges posed to Indonesian agriculture from trade liberalization and the widening gap in living standards between upland farmers and other population groups, the World Bank felt it important to examine existing innovations and their efficiency in modernizing upland farming. The contributions from upland as well as from lowland agriculture are vital in a country of 200 million inhabitants, and productivity improvements would clearly be in the interests of smallholders in most tropical countries, not only Indonesia.

Hypothesis on Improving Productivity

The traditional strategy of slash-and-burn agriculture works well and has no real economic alternative as long as the forest regenerates and farmers are able to maintain a sustainable farming environment. As long as the population density is low and forest areas are abundant and available, slash-and-burn is a sound strategy. But once the population density increases—either from natural growth or rapid immigration—slash-and-burn is no longer feasible. Fallow periods decrease, weeds grow more rapidly, upland paddy yields and food-crop revenues start to decline, and the forest and overall environment begin an irreversible degradation. Ecological, economic, and institutional changes occur because slash-and-burn techniques no longer work efficiently, and introduction of technology becomes necessary to adapt to these changes.

The Green Revolution succeeded in disseminating appropriate technologies that vastly improved rice yields in irrigated lowland farming systems, but now Indonesian agriculture faces a new challenge. Demand for agricultural products is steadily increasing, either for direct consumption or for use as raw materials in a booming agro-industrial sector. At the same time, at least before the 1998 monetary crisis, consumers' diets were diversifying toward more expensive products such as meat, fruit, and vegetables. There is little potential to extend irrigated areas; thus new agricultural policies are required to match these quantitative and qualitative changes in agricultural products.

Substantial funds have been devoted to developing the productivity of upland farming systems since the mid-1980s, when Indonesia achieved rice self-sufficiency and shifted its agricultural policy agenda. These upland development projects not only focused on production aspects; they also considered the ecological fragility of these systems. Hence, projects sought to disseminate technologies that could significantly raise the level of production without further threatening the sustainability of natural resources that were already jeopardized in many areas.

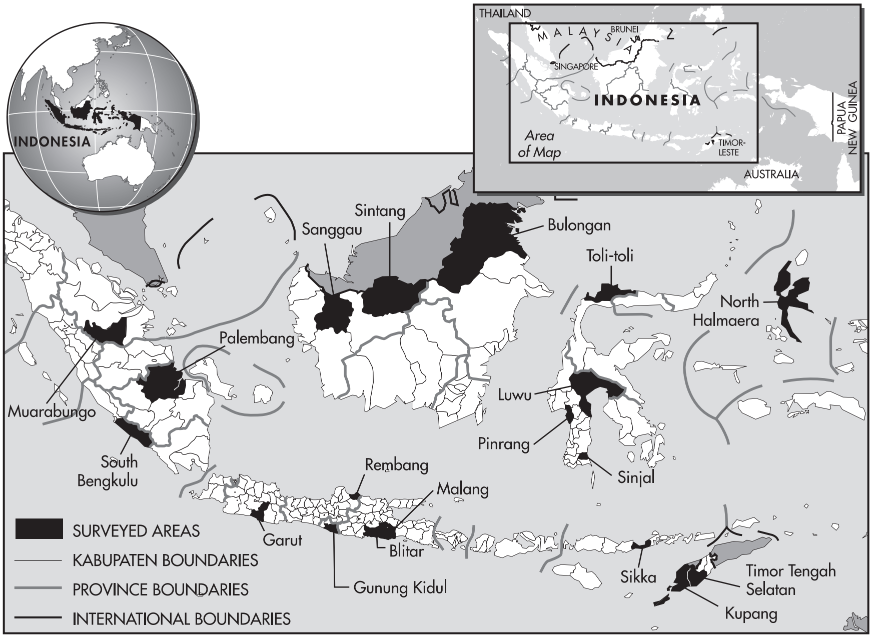
The question, however, is whether these projects and their exogenous innovations considered the more endogenous innovations triggered by farmers themselves. Again, our first hypothesis is that the upland Indonesian smallholder's ability to innovate has been underestimated. Our first objective, therefore, is to demonstrate the strength and dynamism of smallholders when they are in a positive environment.

We investigated the extent to which free markets and competition among traders of commodities and inputs remain the most important factors for optimizing farmers' ability to innovate. Beyond competition, the impact of markets on upland innovation is affected by access to information, infrastructure, and other nonprice factors. A number of Indonesian examples prove the efficiency of strong competition among traders, be they local middlemen or exporters.

Using preliminary surveys in Indonesia and other countries, we also raise the hypothesis that perennial tree crops are of much greater relevance in upland areas than are annual crops. The highest dynamism—that is, the highest combination of innovations (adoption or invention) and crop production development—is observed in tree crops, and most upland projects may have missed this trend. For tree crops, however, planting (or replanting) is an important consideration. Planting after an old plantation of grassland is quite different from initial planting after a forest area is cleared. It is logical, then, for farmers to start innovating and building new cropping systems, especially various forms of replanting, when they no longer have immediate access to forests.

We also show that as long as integrated pest management (IPM) techniques and various ecological approaches remain exploratory, the best way

Map 1.1. Location of the Main Case Studies



to achieve spectacular and sustained returns remains a combination of trees (including shade trees) and a reasonable amount of herbicides, fertilizers, and pesticides. The relatively recent change brought by fertilizers and other modern inputs must be emphasized. For example, the use of fertilizers in cocoa farming may be triggering a potential agricultural revolution in West Africa at the dawn of the 21st century (Ruf and Zadi 1998). Fertilizer adoption started in the Indonesian cocoa sector in the early 1990s and helped Sulawesi farmers, including those in the uplands, to increase their revenues dramatically. The adoption of fertilizers for use on cocoa came mostly from farmers themselves.

The examples of spontaneous and rapid innovation gathered in this survey should reinforce the hypothesis and concept of a "spontaneous Green Revolution" in the uplands. Did we ignore Green Revolutions that occurred in the uplands?

We empirically tested these hypotheses at more than 40 locations throughout Indonesia in some 16 case studies. Table 1.1 shows the importance of commercial tree crops as one of the main alternatives to strict slash-and-burn and shifting cultivation techniques that basically deal with annual food crops. That said, planting of commercial tree crops such as cocoa, coffee, oil palm, and rubber, often by migrants, has greatly increased deforestation recently. Once a region has been widely deforested, however, tree crops may suppress or at least considerably delay the fallow stage. Farming systems based on tree crops are important for the future of upland agriculture.

Table 1.1. Overview: Introducing New Forms of Capital to Farming Systems

Chapter	*Crops in the farming system*	*Introduction of biological and monetary capital (a partial substitute for forest biological capital)*
2	Animal husbandry	Animals are capital and have many links with food crops (investment, manure, forage), *Gliricidia* trees as a new source of fodder, draft animals, and hand tractors
3	Staple food crops, ladang, vegetables	On-farm reservoirs and irrigation
4	Upland paddy, maize soybean, cassava	Small dikes, hand tractors and draft animals, tree capital (various fruit and multipurpose trees in alley cropping)
5	Vegetables, chili, shallot (+ paddy), potatoes	Fertilizers and new varieties, roads that offer access to a new markets, irrigation
6	Ginger, chili, vegetables in a coffee-based system	Seeds + fertilizers through credit by middlemen, roads, combinations with tree crop replanting strategies
7	Initially upland rice (*ladang*)	Introduction of a commercial tree crop: cocoa, (dikes and partial irrigation in lowlands)
8	Initially staple food crops, (paddy and maize, ladang)	Introduction of a commercial tree-crop: cashew nut
9	Initially staple food crop (*ladang*)	Introduction of successive commercial tree crops: clove, coffee (+ cocoa), and conversion of *ladang* into commercial agroforestry plots, slight indirect terraces
10	Coffee-based system	Introduction of vanilla or *Gliricidia* + vanilla = provisional and flexible conversion of monoculture into a light agroforestry system
11	Cattle grazing and/or food crop ladang	Development of a commercial tree crop: orange trees, nursery and seedlings distributed by middlemen, pesticides and herbicides
12	Initially jungle rubber (complex agroforestry)	Clonal rubber and nursery information, combination of clonal material with simplified agroforestry systems, herbicides for replanting after grassland

(table continues on following page)

Table 1.1 *continued*

Chapter	*Crops in the farming system*	*Introduction of biological and monetary capital (a partial substitute for forest biological capital)*
13	Established cocoa farming systems	Reasonable amount of pesticides to prevent farmers from engaging in tree crop shifting cultivation
14	Initially food crop ladang	Introduction of a commercial tree crop: cocoa, introduction of fertilizers and herbicides
15	Established cocoa farming system	Replanting cocoa on grassland areas covered with *Imperata cylindrica*, with a combination of *Gliricidia* as shade trees and weed control tools, reasonable amount of herbicides
16	Coffee-based farming systems	Replanting coffee with new varieties, commercial food crops, reasonable combination of manual weed control and herbicides, various shade trees such as *Erithryna*, *Gliricidia*, mostly used as protection against heavy winds and rains
17	Established cocoa farming systems	Introduction of modern inputs such as fertilizers

More generally, one of the important hypotheses of this study is that most alternatives to slash-and-burn are innovations that substitute some capital for the agronomic function of the forest. These capital investments may be tree crops, fertilizer, animal traction, or on-farm reservoirs and irrigation, but no matter what the form, the investments help farmers to overcome loss of the forest (see table 1.1). This is a variant of Boserup's theory adapted to upland agriculture and especially to tree-crop cycles, in which deforestation leads to innovation (Ruf 2001a, annex 1.1). These investments are reviewed in chapters 2–17.

Case Study Methodology

Sites were selected to ensure a good representation of farming systems and diverse innovations as well as an efficient use of existing knowledge (Map and tables 1.2–1.5). Considering the available time and remote locations of many upland areas, the team also took site accessibility into account.

A first array of sites was identified on the basis of a desk study prepared by the Agricultural Operations Division of the World Bank, which summarized the objectives and achievements of newly completed or on-going projects on upland resource management and production development. Upland

Table 1.2. Study Sites in the Nusa Tenggara Islands

Village	*Sub-district*	*District*	*Province*	*Innovations*	*Selection criteria*
Kloongpopot Kajowahir Wolompa Rubbit	Kewapante	Sikka	Nusa Tenggara Timur	Terraces and livehedges, cashew tree	Intervention area of Nusa Tenggara Agricultural Support Project
Walomotong Umauta	Bola	Sikka	Nusa Tenggara Timur	Cocoa and agroforestry system	Improve reference base
	Lela	Sikka	Nusa Tenggara Timur	Cashew tree	Improve reference base
	Kajowahir	Sikka	Nusa Tenggara Timur	Cashew tree	Improve reference base
	Krigna	Sikka	Nusa Tenggara Timur	Cashew tree	Improve reference base
Soba	Amarasi	Kupang	Nusa Tenggara Timur	Leucaena leucocephala forest and livestock	Improve reference base
Kotabes	Amarasi	Kupang	Nusa Tenggara Timur	Reforestation programs, terraces and fruit trees	Improve reference base
Tunau	Molo Utara	Timur Tengah Selatan	Nusa Tenggara Timur	Oranges and garlic	Improve reference base
Bosen	Molo Utara	Timur Tengah Selatan	Nusa Tenggara Timur	Livestock production area reconversion to orange production	Improve reference base
Camplong II	Fatuelo	Kupang	Nusa Tenggara Timur	Control of Imperata cylindrica with animal draft and alley cropping	Intervention area of Nusa Tenggara Agricultural Support Project

Table 1.3. Study Sites in Sulawesi and Moluccas Islands

Village	*Sub-district*	*District*	*Province*	*Innovations*	*Criteria*
Arabica Tessiliu	Sinjai Barat	Sinjai	Sulawesi Selatan	Coffee and agroforestry systems development on ladang	Research site (AARD and CIRAD)
	Noling, Tampumea	Luwu	Sulawesi Selatan	Adoption of cocoa, shade trees, herbicides and fertilizers	Research site (AARD and CIRAD)
	Wotu	Luwu	Sulawesi Selatan	Pest outbreaks and pesticide adoption	Research site (AARD and CIRAD)
	Patampanua	Pinrang	Sulawesi Selatan	Pest outbreaks and pesticide adoption	Research site (AARD and CIRAD)
	Dampal utara, Dampal selatan	Toli Toli	Sulawesi Tenggah	Pest outbreaks and pesticide adoption	Research site (AARD and CIRAD)
	Tobelo,Makian, Malifut, Gane Barat	Northen Halmaera	Moluccas	Pest outbreaks and pesticide adoption	Research site (AARD and CIRAD)
Das Petah	Kapahiang	Rejang Lebong	Sulawesi Tenggah	Adoption of leguminous trees and herbicides	Research site (AARD and CIRAD)

Table 1.4. Study Sites in Java

Village	*Sub-district*	*District*	*Province*	*Innovations*	*Criteria*
Tunlunggerjo	Batu	Malang	Java Timur	Highland vegetable and apple production	Improve reference base
	Panggunrejo	Blitar	Java Timur	Terraces, food crop intensification and fruit trees	East Java Rainfed Agriculture Project
Budiayo	Panggunrejo	Blitar	Java Timur	Terraces, food crop intensificationand fruit trees	East Java Rainfed Agriculture Project
	Binangun	Blitar	Java Timur	Orange "boom"	Upland Agriculture and Conservation Project intervention area (Brentas Watershed)
Karuenjo	Ngantang	Malang	Java Timur	Reconversion of coffee plantations, dairy products	Improve reference base
Gubuglakah	Tumpang	Malang	Java Timur	Expand apple production area	Improve reference base
Ngadas	Tumpang	Malang	Java Timur	Highland potato production	Improve reference base
Umbulrejo		Gunung Kidul	Yogyakarta	On-farm reservoir development	Yogyakarta Upland Area Development Project
Selopamioro		Gunung Kidul	Java Tenggah	On-farm reservoir development	Yogyakarta Upland Area Development Project
	Sulang	Rembang	Java Tenggah	On-farm reservoir development	Local government program in collaboration with IRRI
	Bulu	Rembang	Java Tenggah	On-farm reservoir development	Local government program in collaboration with IRRI
	Malangbong	Garut	Java Barat	Diverification of intensive cassava production	Upland Farmer Development Project

sites where CIRAD researchers had been working for years were also included. Sites where major upland projects had been implemented during the 1980s and were documented in the literature, particularly in Java, were included to gain a longer-term perspective on those interventions.

When no one on the team had experience at the selected site or was able to have direct access to the site by participating in an on-going field activity, a preliminary meeting was held with Agricultural Agency for Research and Development (AARD) staff at the local headquarters or subunit of the Institute for Agricultural Technology Evaluation. These meetings provided an opportunity for team members to update themselves on the latest developments in the regions and solicit opinions on how the extension services were hampered in fulfilling their objectives.

At sites where no field surveys had previously been undertaken by a member of the team, four or five randomly selected farmers were interviewed. The team tried to have discussions with a wide variety of farmers—those who had adopted or rejected innovations, farmers who controlled different amounts of land, and so forth. Considering the short time available to undertake investigations at each site, this primary information was supplemented by discussions with key local actors such as village heads, agricultural product traders, and extension officers at the subdistrict level.

This method of rapid investigation was based on a trial-and-error process, and questions were continuously adjusted and reformulated during the discussion. We could not rely on a formal questionnaire to obtain a homogenous base of information at each location visited, so an interview guide was developed during the first site visit. This interview guide included five topics for each team member to cover, as much as possible, during farmer interviews:

- *Innovations.* How does the farmer define these innovations? When and how were they introduced? How much does the innovation differ from the farmer's current practices?
- *Main features of the farming system.* Topics included farm size and land type, review of different crop production and cropping systems, fallow duration, livestock production, off-farm activities, and main sources of income. How representative is the surveyed farm compared with other farms in the village?
- *Innovation performance.* What costs are incurred by adopting the innovations and how profitable are they compared with other opportunities? What labor and capital are required? What are the risks in implementing the new technology (that is, agroclimatic risks and market risks)? How well do the innovations integrate with the various components of the farming systems (labor and land management, fodder production, and so forth)?
- *Rate of adoption.* How many farms have tested the innovations, and what area or share of production is affected by the innovations? In addition, Feder, Just, and Zilberman (1982) have shown that the continuous rate of adoption is extremely important and often missed in

Table 1.5. Indonesian Agroecological Zones as a Percentage of Total Agricultural Area

Zone	*Agroclimate*	*Java*	*Indonesia*
Irrigated lowland	Irrigation water available > 5 months per year Water availability independent of rainfall Elevation < 700 meters asl	19	2
Rainfed lowland	Irrigation water available < 5 months per year Water availability dependent of rainfall Elevation < 700 meters asl	7	1
Dryland wet climate	Annual rainfall > 2,000 mm 6 consecutive months with at least 100 mm rainfall Elevation < 700 meters asl	30	52
Dryland dry climate	Annual rainfall < 2,000 mm < 6 consecutive months with at least 100 mm rainfall Elevation < 700 meters asl	17	10
Upland	Elevation > 700 meters asl.	27	15
Tidal/swampland		1	20

Source: Las and others 1991, from Roche and others 1992, quoted by Partohardjono (1994, p. 17).

Mm = millimeter; asl = above sea level

innovation surveys, so farmers were asked if the innovation had been fully adopted or if they had changed any component of the new technology? What type of farm adopted the innovation early, and what type adopted it late? What are the causes of rejection? If the innovation was introduced a long time ago, how long was the period of dissemination?

- *Farming system environment.* What are the main development stages in the surveyed area? When was new land no longer available to extend production? What are the mechanisms of population change (natural increase, migrations)? What types of government intervention have been implemented in recent years (development projects, reforestation projects, seeds or seedling supply programs)? What are the conditions of access to farm inputs and information on agricultural technology? What is the status of product market access (trading systems, roads)? What are the other income opportunities?

Defining Uplands and Innovations

Before moving on to the following chapters and the site- and crop-specific studies, it is necessary to propose operational definitions of the two key words used in this study—*uplands* and *innovations*. While this entire study deals with upland innovations, defining these terms is far from easy.

Uplands

In a comprehensive review of upland issues, Allen (1993, p. 226) points out the difficulties faced in defining farming systems that can be classified as uplands.

> In Southeast Asia the term is often used rather loosely to refer to unirrigated land but, if water is available, it is possible to irrigate almost any land, even steeply sloping land, if someone is willing to pays the costs. Nor is altitude a useful criterion; if "uplands" imply steeplands, or hill and mountain country, they may begin at sea level. Irrigable land of low relief may be found at over 2,000 metres above sea level. Similarly, slope is not a helpful classifier; some very steep land is found at low altitude, and some almost level land is found in the highest altitude occupied by people, now or in the past."

It seems easier to identify farming systems that are not upland than those that are. Irrigated networks and swampland are certainly not included in the upland group (tables 1.6 and 1.7). Using this "definition by exclusion," as Allen called it, means that the upland definition involves listing the different farming systems that belong to this group. Another difficulty is the heterogeneity that prevails within several types of farming systems where crops are simultaneously planted on irrigated and unirrigated land.

Simple Technology of Upland Farming Systems

Upland farming systems cannot be characterized based on a single criterion, but for the sake of simplicity, we propose to define the different farming systems on the basis of physical variables, such as available resources in terms of soil fertility and type and volume of vegetation, rainfall, and elevation and topography. These physical variables must be considered in conjunction with economic variables, including the primary type of agricultural production and cultural practices, population density, and the distance from the main active economic zones (urban industrial and irrigated areas).

On the basis of these variables, a number of upland farming systems and subsystems can be defined:

SLASH-AND-BURN CULTIVATION BY CLEARING FOREST. This system requires a low population density and is found in remote areas under various types

Table 1.6. Land Use in Indonesia, 1984–1990 average ('000 ha)

Land use	*Java*	*Sumatra*	*Sulawesi*	*Rest of Indonesia*	*Indonesia*	*Percentage of ag land*
Wetland	3.4	2.2	0.8	1.5	7.9	22.4
Total agricultural land	6.1	10.1	3.2	15.8	35.2	100.0

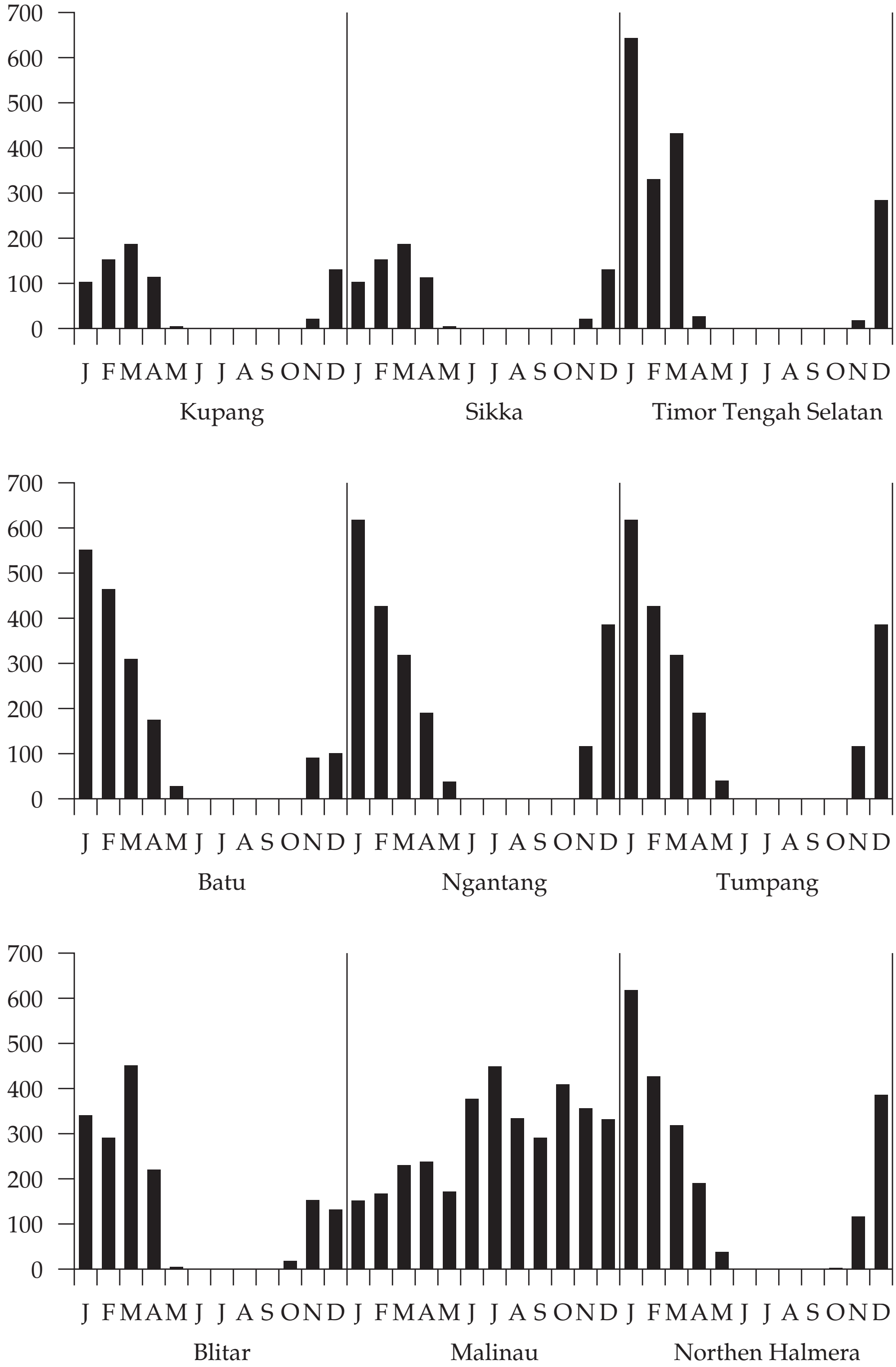
Source: BPS and RePPProT, 1990 (quoted in World Bank, 1992).

Table 1.7. Number of References Reviewed, by broad subject areas

Themes	*No. of references*
Resource management and conservation	28
Technology adoption: evaluation and constraints	69
Technical aspects	33
Economic aspects and methodological issues	36
Critical analysis, general aspects and prospects	39
Research organization, programming and impact	8
Total	283

Source: Computed from Saint-Macary and Deboin 1996.

Figure 1.1. Variation in Upland Rainfall Patterns (mm)



Box 1.1. Upland Technology Issues Discussed in the Literature

A review of the literature, mostly on the technical aspects of upland agriculture, identified and classified 283 references (Saint Macary and Deboin 1996), broken down as follows:

- Theme (70)
- Resource management and conservation (28)
- Technology adoption: evaluation and constraints (69)
- Technical aspects (33)
- Economic aspects and methodological issues (36)
- Critical analysis, general aspects, and prospects (39)
- Research organization, programming, and impact (8)

The review shows that upland farming has been characterized mainly by the fragility of its natural resources, evidenced by soil acidity and rapid erosion combined with a limited and irregular water supply. The literature shows an impressive number of cropping technologies that have been tested during the last decade, most of which were conceived and introduced as part of a farming system strategy to address environmental and production issues simultaneously.

The review concludes that food crop-based farming systems face many problems and risks. Integrated farming systems with perennial crops as a major commodity, along with livestock food and forage crops, provide better means for achieving sustainable soil productivity, while increasing farmer income. This conclusion leads to the concept of "forest rent" and to the need for biological or monetary capital, or both, to compensate for the loss of the forest rent.

of vegetation depending on rainfall level (from tropical rain forest to dryer ecological settings). In the Indonesian archipelago, this situation prevails mainly in the outer islands, including some parts of Kalimantan, Sulawesi, and Sumatra, and is dominant in Irian Jaya.

AGROFORESTRY SYSTEMS. Various forms of agroforestry are characterized by tree species cropped for commercial or subsistence purposes. They are mainly located in the outer islands. However, some types of agroforestry systems established on abandoned colonial estates can also be found in mountainous or hilly suburban areas in Java.

There are two main agroforestry subsystems. A *simple agroforestry* subsystem, such as shaded cocoa or coffee farms, consists of one tree species that is more or less cropped exclusively and that is shaded by another tree. In *complex agroforestry* subsystems, farmers combine various tree species on the same unit of land, even though one tree species may temporarily or permanently dominate. An example is the jungle rubber systems in south Sumatra. One can also classify agroforestry systems as "rotational" and "permanent," as ASB teams do.

Shifting Cultivation on Fallow (*Ladang* Systems). This major type of upland system is found in drier and less fertile or more ecologically fragile zones. This system is characterized by a fairly low population density and is located in remote areas. Within this group, subsystems can be developed according to water availability and the capacity of the initial ecological setting to regenerate rapidly.

Dryland Farming Systems without Fallow. These systems are found in several parts of eastern and central Java where soil fertility is low. They are characterized by a high population density relative to upland area norms. They are also located near the most active industrial and agricultural centers with which they have many contacts.

Within this broad type of dryland farming system, subsystems can be defined according to topography and soil variations. Examples include the farming systems prevailing in the hilly limestone area in the southeastern quarter of Java, or those located in flat unirrigated areas in the northern part of Java or in Lampung province where farmers face severe and marked dry seasons. Annual crops, especially rainfed rice, are the main source of income in these subsystems, which are very similar to irrigated rice-based farming systems.

Farming systems without fallow are considered "genuine" upland farming systems when they are located in mountainous areas. They generally benefit from good soil fertility and rainfall, particularly on upper slopes of volcanoes. These favorable conditions make it possible to grow a wide variety of crops and maintain a high cropping index. Population density can be fairly high in these areas, even in places like Mount Mutis on Timor Island, far from any main economic center. This high density is, of course, related to the good agronomic potential of these systems and is also the outcome of historical developments such as the highland farms based on the top of Mount Bromo in East Java (Hefner 1990). It should be noted that upland agriculture is a characteristic of the outer islands of the archipelago (islands other than Java), but these types of farming systems also cover a significant share of Javanese agriculture.

Innovations

In his pioneering work Schumpeter called innovations "new combinations of production factors (labor and capital)" (Shumpeter 1935). Moving from a theoretical viewpoint to a more applied approach, however, the definition and identification of innovations is even more challenging than defining the term *upland*.

An in-depth review of different interpretations of the term *innovation* is, of course, beyond the scope of this study, however. Yung and Chauveau (1995) pointed out that this subject has been at the core of analyses of agricultural changes in the North and South for the past decade.

Innovation processes can be distinguished on the basis of different parameters. They may take many forms, from simple technical innovations to more complex organizational innovations that interact with each other. Innovation processes can be conceived only in dynamic terms, which means that the adoption process should be analyzed within different time frames. Each technique is gradually becoming a traditional technology.

TECHNICAL INNOVATIONS. In the framework of this study, three forms of technical innovations are covered. *Changes in material inputs* used by the farmers is perhaps the type of innovation one thinks of first. Introduction of new varieties is, of course, the classical type of innovation in this category. Also included is the introduction of new fertilizers or pesticides. *Changes in cultural practices* are very often associated with the previous category, but not always. Farmers can adopt new planting techniques (for example, increasing planting density) or field preparation practices (animal traction) without changing planting materials.

Cropping pattern modifications may also be considered an innovation. The introduction of a new crop in the farming system is often the most tangible and obvious sign of farming developments and changes. This type of innovation may have different forms. One form is the introduction of new crops that have never been produced in the selected area. The new crop may be a substitute or may be added to existing crops, thus promoting a more diversified cropping pattern. Cropping systems can also be modified through the extension of a crop already previously produced, but within a limited area or time span. In this case, the innovation in the cropping systems may lead to a higher degree of specialization, as observed in lowland irrigated fields with rice.These various technical innovations can be combined simultaneously in a package or successively introduced.

A fourth category of technical innovation is *improving or adjusting natural resources* managed by farmers. These types of innovations, such as terracing or irrigating by using pumps, differ from the first group because they are not crop-specific but may benefit the different components of the farming system. Infrastructure development such as road construction may also be included in this type of innovation.

ENDOGENOUS AND EXOGENOUS INNOVATIONS. Innovations may also be defined according to the origin of the innovation and the channel through which it is conveyed to the farmer.

Although there is a natural tendency to equate innovations with a transfer of knowledge to the farmer from research institutions, it is important to realize that farmers themselves are responsible for many innovations. Even in the case of exogenous innovations, farmers play an active role in the development and application of new techniques by adjusting and adapting them to their own constraints. Endogenous innovations are somewhat difficult to grasp and identify once they are fully integrated into farmers' practices.

Exogenous innovations can otherwise be classified according to the type of agent that is monitoring the technology transfer. Once again, given the success story of the Green Revolution for rice production, there is a tendency to limit the analysis to official channels such as extension services. However, technical innovations can reach farmers through other channels, for example, traders who provide incentives such as credit to support the adoption of new varieties.

The distinction between endogenous and exogenous may not always be clear; however, the diverse farming systems identified in upland areas justify use of the two terms.

Upland Management Issues: Historical Perspective

In Java settlements in the uplands began to expand rapidly at the beginning of the 19th century, prompting some regulation by Dutch colonials who were worried about the impact of upland deforestation on lowland (mostly colonial) plantations that grew cane for the sugar industry. In the outer islands, most upland areas had traditionally been cultivated under swidden systems that ensured the most efficient combination of labor and land when the population was low and land abundant. In Java, although several authors collected evidence of early upland farming intensification before 1800, the first major turning point came during colonial times (Clarke 1977; Allen and Crittenden 1987, quoted by Allen, 1993; Palte 1999; Nibbering 1991; Brookfield 1997; Boomgaard 1999, 1997).

Allen (1993) wrote that the most important expansion into the uplands in Java took place between 1860 and 1925. This invasion of the uplands was induced by the colonial exploitation of agricultural resources in two ways—local populations tried to escape heavy taxation on irrigated lowland production, while at the same time large forest areas were cleared to establish tree-crop estate plantations. Plantation development required extension of communication networks to remote areas and the settlement of laborers in upland areas (Hefner 1990).

The acceleration and transformation of upland agriculture was clearly related to population increases supported by migration and natural growth. Allen (1993) maintains that population increases are relevant in all cases—sometimes as a cause, sometimes as an effect—of agricultural expansion and intensification. This is particularly true for tree crops and their worldwide markets—demand for cocoa, coffee, rubber and the like, combined with large population migrations, can trigger massive deforestation. This mechanism may cause more damage to the natural environment than food crops (Durand 1994; Ruf 1995). In addition, this momentum is not linear and highlights some temporary setbacks and spatial variations. For example, the outbreak of coffee rust before World Word II resulted in the conversion of coffee plantations to food crops, reducing the pressure on uncleared forest (Allen 1993). The same transformation process occurred later in the outer islands of the archipelago with increasing use of natural resources and forest logging that required better access to remote areas.

First Public Intervention on Uplands

According to Booth (1988), by 1920 all cultivable and accessible lands in Java were occupied, fallow periods had been shortened, and a large share of the forest area had been converted into scrub and grassland. At this level of population pressure and competition to exploit upland areas, colonial authorities started to develop a specific policy to control upland agricultural expansion.

The colonial government tried to solve the upland problem by acting on the population variable of the equation. Transmigration—moving people out of overpopulated areas—has been pursued and intensified by all Indonesian governments since the independence movement started in 1905 (Levang 1995), but results of these programs, which faced both socioeconomic and technical constraints, did not meet expectations. It soon became obvious that wise management of upland issues would require action on the other side of the equation by developing more sustainable and productive upland farming systems.

The central government consequently launched various programs designed to "regreen" upland areas, particularly in Java. But the central government was not the only public intervenor. In 1932, for example, a very successful regreening program was supported by traditional authorities in the Amarasi subdistrict on Timor Island (Metzner 1983). Regreening programs focused more on recovering forest, or absolute biomass levels, than on interactions with farmer objectives, but they were not able to keep pace with the speed of deforestation.

The strategy favoring natural resource recovery was still dominant during the 1970s. The Ministry of Forestry maintained this trend by defining objectives and implementing programs in upland areas that were rapidly occupied by farmers when former colonial estates were abandoned. State control of the forest land was in line with the Basic Forestry Law promulgated in 1967, but social forestry programs in Indonesia during the 1970s started to give control of forest land use to farmers and marked the beginning of an evolution in government management of uplands. Obviously the efficiency of any regreening program had to take into account the presence of upland farmers.

Transition from Managing Natural Resources to Rural Development

Upland development was not a sensitive issue for policymakers until the 1980s, which were marked by the multiplication of specific projects or programs, monitored by the Ministry of Agriculture, that were designed to support upland agriculture development. Several factors prompted this new trend.

On the agricultural side, the battle for rice self-sufficiency had been won, at least for a while. Indonesia stopped importing rice in 1984, but the imports began again in 1994. In the interim, research and development resources were gradually reoriented toward the new goal of agricultural diversification. Emphasis shifted from lowland irrigated rice to upland crops such as maize and soybean.

On the resource management side, rehabilitation and development of irrigation networks during the 1970s highlighted the importance of controlling erosion to maximize profits from investments in the Green Revolution (Huszar, Pasaribi, and Ginting 1994). This interdependence between irrigated lowlands and the uplands favored development of less erosive upland farming practices (Adiningshi and others 1991).

On a macroeconomic level, the development of upland areas was in line with the objective of reducing the widening wealth gap between urban and rural areas. Developing upland agriculture was also related to changing food demands in terms of both quantity and quality. Irrigated rice farming had approached its limits for both yield and planted area. Moreover, as personal income increased, consumers sought more fruits, vegetables, and animal protein, particularly in urban areas. Increasing upland food production thus became a necessity.

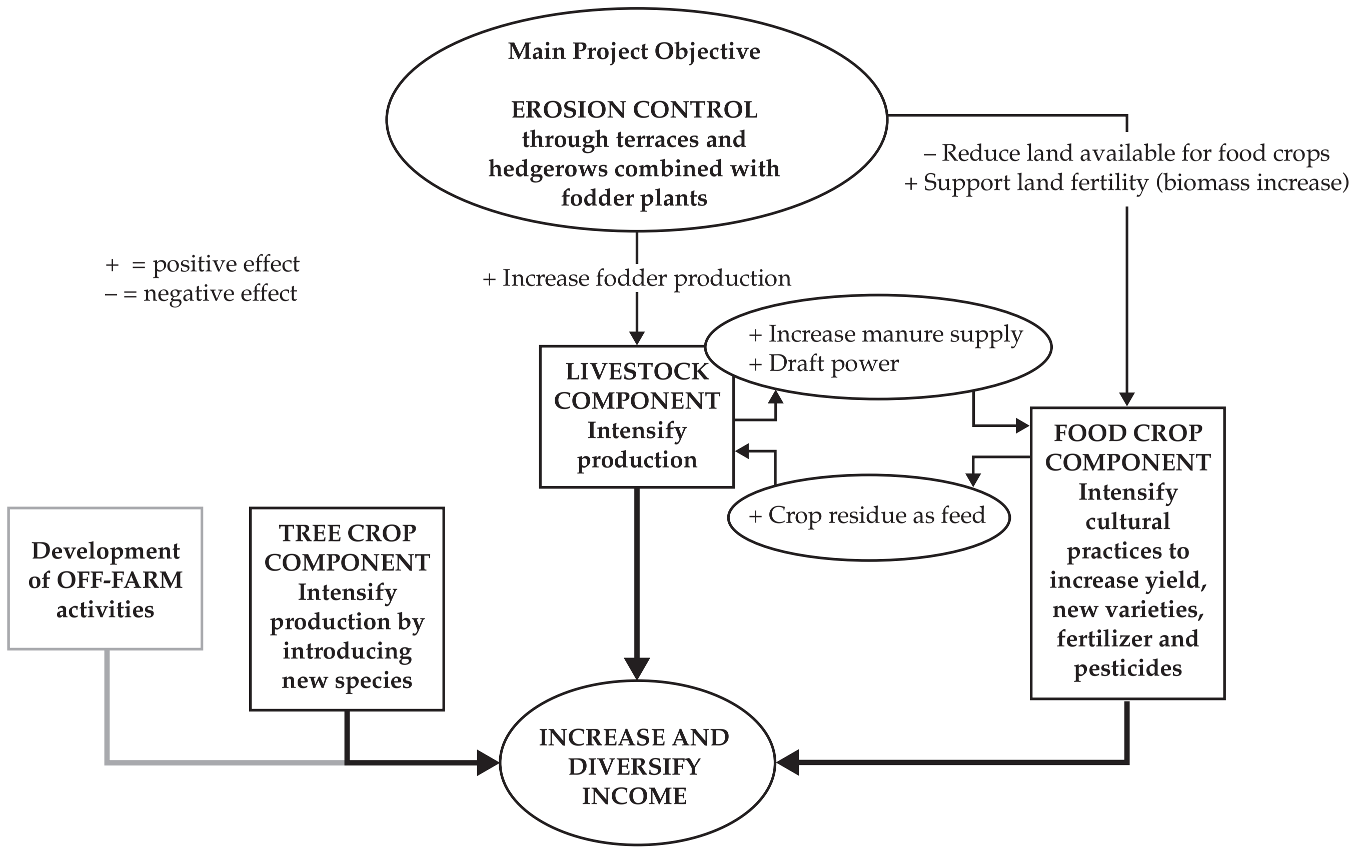
Standard Framework of Intervention

Beginning in 1980, several projects were implemented. Most of them, such as the Upland Agriculture and Conservation Projects, the East Java Rainfed Agriculture Project , the Wonogiri Project, and the Yogyakarta Upland Agriculture Project, are based in Java. The major one has a target area of well above 500,000 hectares, covering watershed areas that must be maintained to sustain large irrigation networks. The projects are derived from a common conception of upland farming that involves a combination of food crops, livestock, and tree production, and consequently the projects have similar actions and targets.

The primary objective of these projects is to disseminate more sustainable and well-known farming practices by establishing and using terraces (or live hedges, depending on the soil structure and slope) in combination with trees to reduce erosion (Adininggshi and Syarifuddin Karama 1992, p. 38). Developing and maintaining these erosion control measures requires a significant amount of labor and may reduce crop production because these structures occupy what would otherwise be productive crop land. Thus adoption of these environmentally sound practices depends upon additional income.

Farmer income is based on several related project components (figure 1.2). Intensified cultural practices are assumed to compensate for any reduction in arable land. This intensification relies on the introduction of new varieties, on adoption of fertilizer (both manure and chemicals), and in some cases on improved pest management. The objective is to improve the household nutritional status on the smallest and poorest farms and to expand the marketable surplus for the most productive ones.

Figure 1.2. Model of Sustainable Development in the Uplands



Development of fodder production by planting fodder trees and grass on terrace hedges and risers is designed to allow farmers to increase their livestock production and value by reducing livestock weight losses during dry seasons. Intensifying livestock production not only should generate additional income, but also should increase the supply of manure, thereby improving soil fertility and intensifying food-crop production. Associated tree crops are also intended to yield additional income and provide additional cash throughout the year. Some projects have tried to reduce the risk of drought by developing reservoirs, thus diminishing risks incurred by intensifying both food and tree production.

This direct action on farming system components is strengthened by interventions to enhance farmers' economic environment. Each project provides credit, in the form of agricultural inputs, and incentives in cash or in-kind (food for work) for developing terraces. The projects improve market accessibility by building or improving roads. The most recent projects have also tried to promote income diversification, especially for women, by providing training and financial support for off-farm activities such as food processing.

Even though there are some variations in projects, most emphasize developing food crops, in line with the overall objective for upland agriculture of supplementing irrigated rice-based farming systems without further depleting natural resources. This approach focuses on interactions among components of farming systems rather than on the relationship between these farming systems and their socioeconomic environments. In remote and disadvantaged areas in particular, food-crop systems dominate in subsistence farming. Apart from planting fodder trees that directly interact with soil conservation and livestock development strategies, relatively little attention is given to the tree component in these systems.

Because these large upland agriculture projects focused their interventions on upland Java, less work has been done in upland areas of the outer islands. Most of the interventions in these islands are related to transmigration and are still considerably influenced by the "Javanese experience." Given the absolute number of upland farmers living on Java and the major role of Javanese agriculture in the food supply, this geographical bias is understandable.

Concept of Forest Rent

Shifting cultivation, *swidden agriculture*, and *slash-and-burn* are common terms that describe the principle of leaving land fallow for a period of time so that biomass has time to regenerate and then cultivating the land again. The regenerated biomass is cleared and burned—fire accelerates the decomposition of plant materials and makes mineral elements available to crops subsequently planted by farmers.

Comparative Advantages of Slash-and-Burn

Slash-and-burn is the most efficient agricultural technology in tropical forest regions. As long as slash-and-burn enables forest regeneration, it guarantees the highest labor productivity, and no new technology can match it on this criterion. Labor is the limiting factor when forest land is abundant, and slash-and-burn is definitely the most efficient system when population density is low and there are no external deforestation factors. However, even though the rationality and relevance of shifting cultivation were clarified in the 1960s and possibly earlier (Geertz 1963; Ruthenberg 1978), many experts and scientists and some policymakers still use these three terms as pejoratives.

In the context of long-term fallow (more than 15 years), swidden cultivation, far from consuming forests, actually requires and maintains forests. We consider the debate on long-term fallow closed, but shifting cultivation with short-term fallow is still a topic of scientific debate in the face of increasing population density and substantial deforestation. Shifting cultivation may or may not cause this deforestation, but logging and plantations are definite agents of deforestation.

As long as there are fewer than 10 inhabitants per square kilometer, shifting agriculture is extremely efficient in terms of labor productivity and regeneration of natural resources. All exogenous attempts to "improve" native agriculture by introducing new techniques have proved irrelevant and inefficient in areas where the population remains below 50 inhabitants per square kilometer. From Africa to Asia, from colonial to more recent projects, this has always been the case.

Even in colonial times in Indonesia, attempts at improvement failed, according to Henley and Colombijn (1995, p. 5).

> Most of the numerous Dutch attempts to "improve"' native agriculture by introducing new crops, varieties and techniques were completely unsuccessful. Existing methods, commercial as well as subsistence-orientated, almost always proved better suited after all. The classic example is irrigation, tirelessly promoted by the colonial authorities but stubbornly rejected for its inefficient use of labor wherever population densities were not high enough to make its efficient use of land a significant consideration.

However, when population density increases through natural fertility or migrations, slash-and-burn may initially lead to deforestation, environmental degradation, and sometimes local economic recession. Why? Although many institutional and political factors may intervene, a biological or ecological loss turns into an economic one—the loss of forest rent.

What Is Forest Rent?

Forest rent may be defined by an example—the difference in production costs between a ton of cocoa grown on a plantation created after a forest area has been cleared and a ton of cocoa grown on replanted fallow land or on land where an earlier plantation has been cleared (Ruf 1987; 1995a). The notion of forest rent is intuitive. The forest possesses biological capital that offers “natural environment” rents through its ecological setting, which from an agronomic point of view greatly facilitates planting and growing most tropical crops.

Cost differences are directly related to ecological changes or reduced agronomic benefits provided by the forest and by a long fallow. When a farmer no longer benefits from forest rent, he faces additional labor, possible declining yields, and for trees, slower growth. Five factors indicating the loss of forest rents were identified simultaneously in Sarawak, Malaysia, for rice (Chin 1987) and in Côte d’Ivoire and other countries for cocoa (Ruf 1987, 1995b), and earlier in many other countries (Nye and Greenland 1960; Joachim and Kandiam 1948, quoted by Chabrolin 1965).

- *Plant communities.* The balance between plants and weeds and weed control may change. Under rapid deforestation, biodiversity may be reduced in the extreme, with one weed taking over others, thereby altering the capacity of woody species to grow. Two famous examples are *Chromolaena odorata* and *Imperata cylindrica*, which have generated almost as much contradictory literature as swidden cultivation.
- *Pests.* These populations may change and increase. Forest rent can be associated with the concept of “new crop” rent. A newly introduced crop may benefit from the relative absence of natural enemies, but after a pest has established itself, the new crop may suffer from an absence of any natural enemies to its new pest (chapters 6, 10, and 13).
- *Erosion.* Topsoil may erode and lose humus and nutrients.
- *Soil moisture.* Soil may retain less water.
- *Soil life.* Soil flora and fauna may change.

In addition, with cocoa booms, other consequences of rapid deforestation have been observed:

- *Wind.* The negative effects of drying winds may increase.
- *Fire.* Plantation fires do not occur at random. Plantation and forest fires are a symptom of the radical ecological changes that have taken place through deforestation, most of which has taken place at the hands of logging companies and large estates and, to a lesser extent, migrant farmers. Indigenous people, and their tradition of slash-and-burn where the forest is no longer able to regenerate, have caused far less deforestation (box 1.2).
- *Fewer forest resources.* Shortages of food and miscellaneous forest resources may occur, which can lead to lower labor efficiency.

Forest rent must not be idealized. In some cases, the proximity of tropical forest can be harmful to crops, at least in the short term. For example, forest monkeys are usually quite fond of fresh cocoa beans and young rubber seedlings. Wild pigs often deter farmers from planting coconut and oil palm.

Agroecology of Forest Rent

The relative weight of each component of forest rent varies among agroecological settings. For example, in mountainous regions, erosion of topsoil is often more important than soil fertility. Differential forest rent should not be considered a means to confer all virtues to the forest. With shorter fallow periods and declining yields, it is still often believed that the main fallow function is to restore some of the soil fertility lost with the forest burning. Theoretically a complete slash-and-burn cycle would need 40 to 50 years of forest regeneration to completely restore soil fertility. In India and Madagascar, however, experiments have demonstrated that soil fertility is hardly lowered by a much shorter fallow time. The increase of the weed biomass and the time needed for weed control are the major changes induced by deforestation and a too short fallow time. This triggers an increase of weeding time and cost, and an almost unavoidable loss of yield related to weed competition. There is a relative consensus to set the threshold around seven years of fallow to let some wood species to develop and help to make grass seeds to die and thus prevent grass species from developing at the clearing stage (Driessen and others 1976; Dove 1985; Ruf 1987; Chin 1987; de Rouw 1991; Levang 1993; MacKinnon and others, 1996).

Field studies confirm that the most clearly demonstrated impact of rapid deforestation is neither erosion nor fertility loss, but rather the increasing work required to control weeds and produce a given output, hence higher production costs (Driessen and others 1976; Dove 1985; Ruf 1987; Chin 1987; de Rouw 1993; Levang 1995; MacKinnon 1996).

Forest Rent and Farmer Practices

Because the concept of forest rent is dynamic, it is useful to define briefly the initial stages in which the approach is applied before discussing the significance of farmer behavior.

Primary forest is forest theoretically untouched by human beings, where all species are spontaneous. The high canopy is so dense that undergrowth is sparse.

Secondary forest is a forest that spontaneously regenerates after clearing. This is a first source of ambiguity. If the secondary forest is left undisturbed for 40 years, it may be quite close to a primary forest, at least in terms of forest rent components that can be used by agriculture and thus by swidden cultivation.

Fallow usually refers to land left idle for a few years and on which forest has visibly not fully regenerated as secondary forest, but a wide range of vegetation may be represented. Two main types of fallow must be distinguished: *bush fallow* with woody species; and *grass fallow* with mostly grass species such as the omnipresent *Imperata cylindrica*, called *alang alang* in Indonesia. To a lesser extent, *Chromolaena odorata* may also be considered as a grass fallow.

Box 1.2. Plantation and Forest Fires in Indonesia, 1997

In the recent past, especially when millions of hectares burned during 1983 and 1987, slash-and-burn and "primitive" smallholders were often accused by politicians of responsibility for these massive fires. To the great satisfaction of a number of nongovernmental organizations (NGOs) and researchers, in 1997 the environment minister for the first time clearly put the finger on logging companies and large plantation owners as the main culprits. Satellite images clearly showed that 90 percent of the major fires came from the concessions owned by these large companies (Soutif 1998). In the meantime, several researchers stressed that slash-and-burn was not responsible for these fires (Levang and others 1997; Sellato 1998). This is not contradictory to the forest rent approach.

Logging companies and large plantations are the main culprits and the main killers of forest rent. Fires were often started by logging companies to convert their concessions into large oil palm plantations.

Migrants who sometimes, but not always, follow the tracks opened by large companies to enter the forest also participate in the deforestation process and thus increase the risk of fire when a drought occurs. In most cases, however, they master fire techniques and usually control the fires. Accidents are rare.

Lastly, indigenous people such as the Dayaks in Kalimantan, who usually are real masters of slash-and-burn techniques, certainly have the lowest role in accidental fires. To a certain extent, they are the main victims of these accidental fires (Sellato 1998), but also play a role in the fires. They help to spread grassland, especially *Imperata cylindrica,* which can burn rapidly.

Indigenous people who keep using slash-and-burn techniques to grow paddy but suffer rapidly declining yields and returns to labor and land did not adapt themselves to ecological, economic, and political changes. One of the easiest adaptations is to plant tree crops such as rubber or cocoa, which increase returns to land and labor.

If tree crops are planted after forest clearing, which is frequently done by migrants, they are agents of deforestation. However, if tree crops are planted after clearing grassland, the planting process can be considered as a sort of regreening, reforestation, and tool of carbon sequestration, as well as an element of sustainability (see in particular Chapters 12, 15, and 17).

Primary Forest Related to Technical and Institutional Change

Farmers once preferred clear secondary forest rather than primary forest (Padoch 1982, quoted by King 1995, p. 172; Chin 1985, quoted by King 1993; Dvorak 1993). The difficulty of cutting down huge trees and the lack of market and policy incentives may explain the preference for clearing secondary forest. During the 20th century, these two factors rapidly changed—thanks in part to the invention of the chain saw and more inventive ways to use fire for clearing—and so did the choices of forest types by shifting cultivators.

From an institutional point of view, managed clearing of secondary forest followed by relatively low yields but sustained planting is often the choice and strategy of indigenous people, at least when they are not under pressure from migrants. On the other hand, rapid clearing of primary forest followed by more productive farms in the short term is often related to massive migrations.

Fallow Duration

A forest rent effect is involved at each stage of forest "degradation." Provided that smallholders know how to cut the forest and maximize its rent, primary forest brings the best opportunities for agricultural operations and yields (almost no need for weed control during the first years, easy planting, and high growth rate). Even secondary forest and a five-year bush fallow can still provide some advantages that are lost to *alang alang*.

Weeds are a major factor when planting a fallow. The shorter the fallow, the more weed seeds remain alive, and the more time must be devoted to controlling them. The time to eradicate a significant percentage of weed seeds is difficult to estimate, and the literature offers a wide variation (annex 1.1). However, weeds are the subject of many preconceived ideas. Not least are the regions where *alang alang* is not considered a weed, but rather a species valued for its use in making local roofs.[3]

Forest Rent and Crop Yield

If weeds matter more than soil fertility, perhaps that explains why yields do not fall as often as claimed in the scientific literature. Yields may be lower in cases of erosion or inadequate weed control; however, if smallholders increase the time devoted to weed control, they may effectively maintain yields. That may be possible if population density also increases, which makes sense since a higher density leads to a shorter fallow period. This situation is perfectly in line with Boserup's theory, accurately summarized by Couty (1996). When the population increases, less land is available, which leads through an automatic adjustment to more intense labor consumption relative to the amount of arable land. However, intensification of the labor factor would likely abide by the law of diminishing returns. This indicates that innovations are essential, as they bring new techniques that may or may not be linked with capital (annex 1.1).

This is the case in weed control. The introduction of herbicides during the Green Revolution in the 1980s, although not flawless, was a major innovation in the lowlands. These products, rather cheap in Indonesia compared with other tropical countries, may have some negative effects in the long term, but they offer new opportunities to upland smallholders with some capital. For these farmers, it seems economically and technically possible to grow high-value crops, usually trees, on grassland fallow without requiring additional labor (chapters 12 and 15).

Shifting Cultivation and Tree Crops

From West Africa to Brazil, a common strategy of smallholders and planters is to abandon older trees for several years and clear forest in a neighboring place. They may return to the initial plot and "replant" several years later once the forest has taken over the cocoa trees. This practice is an extended form of shifting cultivation in that farmers grow cocoa for 20 some years before moving, instead of the typical pattern of 1 to 3 years with paddy or another annual crop. As with annual crops, shifting cultivation for trees is a means to manage forest rent—fewer weeds, higher fertility, more efficient use of rainfall, and in most cases, fewer insect pests and diseases.

Any factors that may reduce the economic life of the plantation will reinforce the slash-and-burn practice; low fertility, climatic changes, and pests may significantly diminish advantages related to forest rent and accelerate the slash-and-burn cycle. During the 1970s in the Moluccas archipelago, for example, chemical spraying to control coconut pests probably reinforced pod borer attacks on cocoa because pod borers were protected inside the pod. Consequently, farmers trying to escape pod borer attacks were pushed to open new plantations further inside the forest.

As with shifting cultivation for annual crops, as long as farmers have enough forest land, the practice remains perfectly relevant and efficient. When land becomes in short supply, however, problems arise, and innovations and alternatives are needed.

Offsetting Rents

In the uplands of Sulawesi, the effect of forest rent on investment, yield, and life cycle of tree crops seems relatively clear. Cocoa producers follow the same strategy as smallholders in Côte d'Ivoire—they prefer to establish plantations on cleared forest rather than on fallow. On alluvial plains where lowlands give way to uplands, soils are fertile and producers can afford to buy fertilizers and herbicides. The effect of forest rent is relatively negligible, at least in relation to soil fertility and weed control. With high soil fertility and easy access to the plains (and taking forest policies into account), farmers prefer to plant on grassland in the plains rather than forest land in the hills.

There "plains rent" and "location rent" strongly substitute for "forest rent" and "new crop rent." There are also effects from technical changes, especially adoption of fertilizers, pesticides, and herbicides, which are certainly among the preliminary alternatives to slash-and-burn. Technical progress will probably lead to a drop in the use of chemicals and adoption of a new generation of integrated pest management tools.

Alternatives to Slash-and-Burn

It is rather difficult to introduce alternatives to slash-and-burn and shifting tree-crop cultivation until a certain level of deforestation has occurred. When forest is still available, however, alternatives to these systems cannot be excluded a priori.

Within the theoretical framework presented above, alternatives and complementary cultural practices to slash-and-burn can be analyzed through the notion of "forest capital" (or asset) and "tree capital." When forest is no longer available, alternatives often involve recovering the depleted forest capital through practices such as tree planting and improving land and water management. When forest is still available, the challenge is to optimize use of the remaining capital while considering market opportunities; thus location rent may substitute for forest rent and also trigger innovations.

When Some Forest Is Available

When population densities are still very low and the forest area is still large enough to allow slash-and-burn, farmers can make use of the forest capital in many different ways:

- *Reduce the length of fallow* within a slash-and-burn system.
- *Intensify gathering of forest products* (such as rattan or medicinal plants). This option requires the progressive establishment of agroforestry systems within primary or secondary forests and is generally selected by indigenous people who know the potential resources of their environment and the best ways to protect and maintain this capital.
- *Develop perennial crops* under monoculture. Perennial crop plantations are one of the most efficient ways to maximize use of the comparative advantage of forest rent. This option also fits well with the strategies of migrants who prefer to maximize income in the short term.
- *Develop an agroforestry system* where different tree species are combined on primary or secondary cleared forest. This alternative to slash-and-burn can be implemented under different conditions: *simple agroforestry systems* where only two species are intercropped, for example, the famous cocoa under coconut systems developed in Southeast Asia; or *complex agroforestry systems* with a high degree of biodiversity such as the *damar,* colonial pines in West Sumatra that were exploited for their resin.

These alternatives also face sustainability issues. A plantation is biological capital substituting for forest capital and is also subject to depreciation, but as a plantation ages, the timing, method, and scale of replanting must be considered. Factors involved in replanting include the type of plantation (monoculture, light, or complex agroforestry system), available technology (varieties), and resources (land tenure systems, access to credit).

For example, coffee producers in Bengkulu province replant rapidly with shifting cultivation for tree crops. In complex agroforestry systems, biological capital can be renewed more smoothly through a gradual shift in the orchard composition, which is, of course, less risky than in a monoculture plantation. It is important to stress that capital recovery becomes more difficult in both agronomic and economic terms when biological capital is based on one species than when it includes numerous species of trees. In the long run, complex agroforestry systems are a better substitute for forest capital than perennial monoculture. In this respect, the jungle rubber system found in Indonesia is an obvious illustration of the superiority of complexity over simplicity (chapter 12).

Capital as a Substitute for Forest Rent

When population density is high and forest resources are almost depleted, farmers have two alternatives: modifying the farming system through innovations, or migrating. These two options are sometimes combined within a single household. Although the migration option is covered briefly in the next and last section of this chapter, agricultural innovations are nonetheless very important. These options, which are a form of capital, include herbicides and fertilizers, pesticides, new planting materials, erosion control, intercropping trees with annual crops, agroforestry, replanting, introduction of livestock, and irrigation (see table 1.1).

Outmigration

When forest resources are almost depleted, outmigration is an important option that has several variations.

- *Permanent outmigration.* Migrants may move to areas where shifting cultivation is still possible, or they could abandon all agricultural production and move to urban or industrial centers.
- *Partial outmigration.* An intermediate solution is for the farmer to maintain production in one zone while starting new activity in another zone within a few days' walk. This partial outmigration can also occur in farmlands near urban areas, when a few members of the household unit seek unskilled work in an urban environment and thus lighten the load on the farm. Family members can also move to neighboring countries and in some cases find skilled jobs but still have a major impact on agriculture when they return periodically. The move to nonagricultural activities almost always means outmigration to urban areas.
- *Temporary outmigration.* Access to additional income and new information can facilitate the introduction of innovations in the initial production system, but regular temporary absence of the head of the farm also dictates the types of innovations that can be introduced. For example, the dissemination of crop management techniques at Garut, including continuous pest control on annual crops, is not very viable because of the regular absence of the heads of the farms who work in Bandung or Jakarta.

Multiple Farming Activities

Income sources can also be diversified without leaving the farm through small-scale production of goods and services that varies according to available capital and size of the local market. This can include marketing commodities, smuggling various agricultural products, manufacturing household goods (weaving, pottery, and the like) and other objects for daily use such as jars, and small-scale food processing.

A Special Word about Agroforestry

Agroforestry systems born from forest clearing are also a source of deforestation and unavoidably trigger a certain degradation of biodiversity and land. Nonetheless we try to show that when carefully associated with fertilizers and herbicides, agroforestry also remains one of the tools to repair land degradation. Grasslands can be rehabilitated by trees and especially by agroforestry. This is not new; for example, parts of the grassland in Kalimantan were shaded out under rubber as earlier as the 1910s or even earlier (Brookfield, Potter, and Byron 1995).[4]

More recently, in the early 1970s, agroforests such as the cocoa forests in the Sikha district of Flores were created not after forest clearing, but rather from pure reconversions of *ladang* (Ruf, unpublished results). In other words, slash-and-burn systems devoted to food self-sufficiency were converted into commercially oriented agroforestry.

Whether simple or complex, agroforestry systems may also help in a larger definition of sustainability that includes the household. In peninsular Malaysia in the 1980s, the introduction of cocoa trees planted beneath the coconut trees helped to limit outmigration. Additional cocoa revenues helped aging farmers keep their sons on the farms, a crucial factor for retaining a young labor force able to climb coconut trees and harvest fresh nuts. On the east coast of Madagascar, the introduction of bananas on old coffee farms also helped to prevent young people from moving to cities (Blanc-Pamard and Ruf 1992).

Conclusion

Although it may seem surprising to analyze major innovations in upland agriculture through the concept of forest rent and the principle that the loss of the forest rent needs to be compensated by a new kind of capital, this concept does contribute to understanding technical change in the uplands. That, at least, is one of our aims in the 18 chapters that follow.

Notes

1. This can be mostly credited to pioneer multidisciplinary field studies with a strong botany component attracting other disciplines (Torquebiau 1984; Mary and Michon 1985; Mary 1986; Michon and Mary 1987; Gouyon 1993; Gouyon, De Foresta, and Levang 1993; De Foresta and Michon 1994; Penot 1995a).

2. Details of this approach are reported in annex 1.1.

3. This is still very much true in poor regions such as Flores. During our 1996 survey, Flores farmers even complained about *Chromolaena odorata* taking over *Imperata,* which is seen as much more valuable and is still frequently sold by rolls along the roads. Potter and Lee (1997) observed similar preferences and mentioned sales of *Imperata* to hotels in Bali.

4. For more details about farmers' ability to rehabilitate grasslands that are not necessarily a "green desert," see annex 1.1.

2

Technical Innovations and Livestock Production

Frederic Lançon and Ibrahim Hasanudin

Livestock grazing and feeding are generally viewed as distinctive characteristics of upland farming systems. Upland areas are supposed to benefit from lower population pressure, thus allowing extensive livestock production. Simultaneously, considering the less favorable environments that uplands provide for food crops, livestock production is considered to be an opportunity for farmers to improve their income in this agroeconomic setting.

This chapter reviews different livestock production methods within the upland farming systems visited by the mission, as well as the literature on the subject. Considering the numerous links between livestock production and other components of upland farming, however, it is difficult to consider this activity separately, and many issues related to livestock production are also addressed in other chapters of this report.

Cattle Functions in Upland Farming

This review is limited to large livestock such as cows, oxen, and buffalo. Small ruminants, poultry, and pigs are also an important source of income for upland farmers, especially those who cannot afford to buy cattle, but they are not necessarily a characteristic of upland farming systems. In addition, the conditions under which chickens and pigs are produced have changed dramatically in the last decade. Farms specializing in large-scale poultry and pig production in connection with agro-industries (both input supply and output marketing) are developing rapidly. These types of poultry and pig farms may be located in upland areas, but they are also present in lowland areas near major cities.

In their review of potential technology for crop and livestock systems, Blair, Hoffmann, and Ismail (1991) list various interactions between livestock and other components of upland farming systems:

- *Food.* Almost all livestock keepers consume cereals, and many farmers consume some meat and milk products.
- *Investment.* Income from crops is used to buy livestock, and animals are sold to finance cropping inputs.
- *Manure.* Animal manure is used to fertilize cultivated fields and home gardens.
- *Forage.* Crop residues and fallow fields are used for fodder and pasture.
- *Draft.* Animal traction is used for cultivation and transportation.
- *Employment.* Pastoralists sometimes keep animals for farmers, or members of farm families may be employed by pastoralists for herding or cultivation.

Blair, Hoffmann, and Ismail might also have mentioned the saving and cash reserve function associated with cattle, a role that was often stressed by farmers we interviewed. Animals are often sold when farmers face an unexpected need for cash, such as illness or travel, that cannot be financed through the usual sources of cash (such as fruits, poultry sales, or daily wages) and that occur outside the main crop harvesting period or when food crops fail.

The interviews revealed an interaction that Blair and his colleagues did not describe: occasionally cattle were marketed to mobilize cash before starting a new activity. For instance, in Blitar district, East Java (Java Timur), a farmer was able to buy a piece of land to plant orange trees after selling some of his cattle. The farmers who were interviewed did not consider cattle as a regular source of cash, but rather as a means of saving that allowed them to adjust their production structure to new market opportunities.

As shown in table 2.1, the share of livestock sales in farmer income varies significantly from one location to another. For example, in East Java livestock sales were the primary source of income for only 4 percent of the farmers' income; this marginal role for livestock in irrigated systems held even in those areas where animal traction is still used to prepare rice fields. At the same time, information collected in the same survey for Wonogiri district, an upland area of Central Java province, revealed that livestock sales provide 25 percent of farmers' cash income.

But there are also variations between upland farming systems that have almost the same characteristics. Data collected during the Nusa Tenggara Agricultural Support Project show that in the western part of Timor the share of livestock in farmer income varies from 14 to 50 percent (Momuat and Bamualim 1994).

Furthermore, data on the rank of each source of income for farmers participating in the Upland Agriculture and Conservation project in Central Java province (Java Tengah) indicate that great inequalities exist between farms producing in the same type of environment (Sauer and Williams 1991).

Table 2.1. Livestock Sales in Farmer Income for Different Farming Systems

Location	*Types of farm or ecosystem*	*Farms for which livestock is the first source of income (%)*	*Source*
Central and East Java	Average of the whole sample	22	Nusa Tenggara Agricultural Support Project (Momuat and Bamualim,1994)
Timor	Alluvial soils	26	Nusa Tenggara Agricultural Support Project (Momuat and Bamualim,1994)
Timor	Mediterranean red soil	14	Nusa Tenggara Agricultural Support Project (Momuat and Bamualim,1994)
Timor	Bobonaro clay	50	Nusa Tenggara Agricultural Support Project (Momuat and Bamualim,1994)
Central Java	Upland/rainfed (Wonogiri district)	25	Soybean Yield Gap Analysis Project (CGPRT, 1992)
East Java	Irrigated simple technology	4	Soybean Yield Gap Analysis Project (CGPRT, 1992)
West Java		2	Soybean Yield Gap Analysis Project (CGPRT, 1992)
Central Java	Very Poor (0.014 ha of irrigated land and 0.025 ha of dryland per family worker)	14	Upland Agriculture and Conservation Project (Saurer and Williams, 1991)
Central Java	Poor (0.033 ha of irrigated land and 0.044 ha of dryland per family worker)	22	Upland Agriculture and Conservation Project (Saurer and Williams, 1991)
Central Java	Medium (0.0127 ha of irrigated land and 0.144 ha of dryland per family worker)	33	Upland Agriculture and Conservation Project (Saurer and Williams, 1991)
Central Java	Rich (0252 ha of irrigated land and 0.343 ha of dryland per family worker)	12	Upland Agriculture and Conservation Project (Saurer and Williams, 1991)

The poorest farms are not able to invest in livestock production on a sustainable basis, while the richest have less risky or more remunerative investment opportunities such as rice production in irrigated fields or mango production.[1]

Cattle Feeding Issues

One of the main issues addressed in projects is development of feeding capacity through various means such as forage trees, grass, and recycled food-crop residues. Not all of these techniques are new, and most of them were already used by farmers in traditional livestock areas.

Extensive and Specialized Systems

One of the most spectacular examples of forage production is the development of *Leucaena leucocephala* forests in the subdistrict of Amarasi on the western part of Timor Island. Facing a rapid decrease in forage reserves in 1920, traditional authorities forced farmers to plant the small tree *Leucaena* on plots before leaving them fallow. The traditional authorities also enclosed grazing areas, while farmers in the main part of the subdistrict were obliged to keep animals on nearby farms. These decisions ensured the stable, sustainable development of livestock production. Unfortunately, a pest outbreak in the middle of 1985 substantially reduced *Leucaena*. Farmers started to plant new sources of fodder such as *Gliricidia sepium*, but the sustainable growth of these livestock-oriented farming systems is at stake. Moreover, this crisis was exacerbated by a reforestation project that reduced the areas available for forage production.

Diversified systems

In more diversified systems, where cattle are raised not only for meat but also for other purposes such as traction and soil fertilization, feeding relies on all-purpose trees such as *Leucaena* and *Sesbania grandiflora*, as well as grasses, crop residues (such as maize leaves and stalks, rice bran and straw, and banana leaves), and other feed sources. Development of soil conservation measures such as live hedges has certainly been appreciated by farmers, especially those in densely populated and dry upland areas such as the limestone soil zone of southern Java.

The objective of intensifying fodder production is to reduce weight lost by animals during dry seasons when traditional forage sources (grass and food crop residues) are no longer available. However, farmers interviewed during the mission said that fodder availability is not the only constraint to feeding animals; labor shortages were also a problem. Sauer and Williams (1991) came to a similar conclusion during their investigation in the upland areas of Semarang district when they reviewed constraints that discourage farmers from keeping more cattle. After underlining the lack of cash to invest in cattle, they observe:

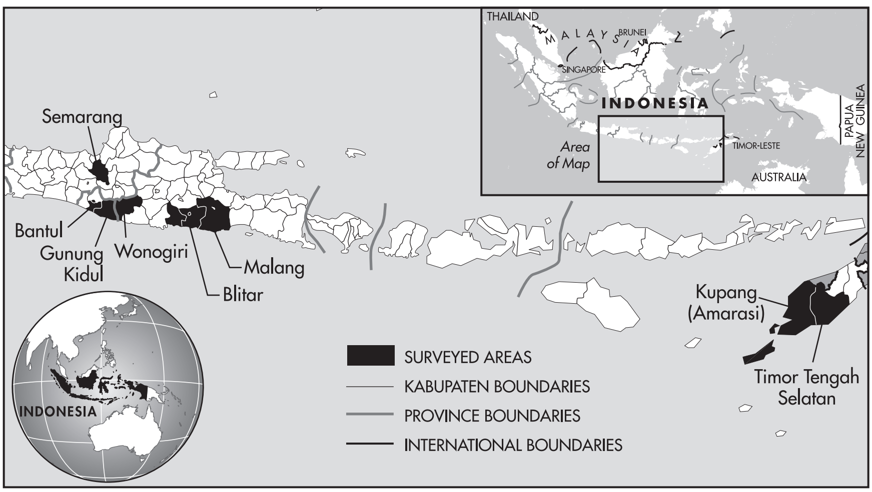
> Other answers given imply that though an absolute shortage of fodder is not a problem, the labour required to collect it is: only 5% of farmers mentioned fodder shortage as the reasons for not keeping more cattle, but 24% mentioned labour shortage. Fodder collection is the most time-consuming task involved in keeping cattle (Sauer and Williams 1991, p. 15).

Similarly, the mission team met one farmer in Blitar district who explained that he did not follow the small ruminant scheme proposed by the East Java Rainfed Agriculture Project because these animals required fodder more frequently than cattle. He preferred to keep his two cows.[2] Here again, labor is the main constraint to intensified livestock production. In Wonogiri, a site with comparable agroeconomic characteristics, farmers devote almost the same share of available labor to livestock (35 percent of total labor) as they do to food crops (40 percent of total labor).

Forage Markets

On several occasions during their mission, the team noticed forage markets in various forms. For instance, in the village of Tunau (Timur Tengah Selatan district) in a mountainous area of Timor Island, one farmer explained that he sells grass (*Pennisetum purpureum*) to livestock traders who need forage to limit animal weight losses during marketing operations. In this former livestock area now converted to fruit trees and food crops, even farmers who do not raise cattle continue to produce fodder, but as a cash crop. In Blitar district, upland farmers who own cattle rely partially on imported rice straw from nearby irrigated areas to complete their own resources. Maize leaves were also marketed as cattle fodder. One farmer estimated that animal feed cost about 2,000 rupiah (Rp) a day. Development of these forage markets

Map 2.1



must be considered not only a result of a shortage of fodder production at the farm level, but also a result of the labor shortage to collect foliage and grass. As long as the price of fodder delivery at the farm is below the opportunity cost of labor, farmers are better off buying grass, even if the farm fodder production matches requirements. This relation between paid fodder delivery services and labor is also related to a certain extent to diversified off-farm activities of household members, for example, when children go to school and can no longer do this type of work.

Interaction of Cattle with Food Crop Systems

Apart from the use of food crop residue as fodder, the connection of cattle to the food crop component of upland farming systems includes improving soil fertility through animal manure applications and using animal traction for land preparation, especially for rice.

Animal Manure

Wherever cattle are raised, farmers apply the manure to crops of all kinds. In the densely populated Timor highlands, cattle are even fed directly in the garden to avoid having to transport the manure. Cattle manure has advantages as long as food crop production is not intensified; for example, improved maize production in East Java leads farmers to rely increasingly on chemical fertilizers. Where poultry production has intensified, this manure sometimes replaces cattle manure. This substitution process is still limited because farmers believe that cattle manure better enhances the organic content of the soil. Accordingly, they reserve cattle manure for the most profitable crop, irrigated rice, while poultry manure is used for secondary crops such as maize, soybean, and groundnut.

Animal Traction

Animal traction is another argument in favor of raising cattle. In upland areas of Java, land preparation is commonly carried out with animal traction.[3] However, the extension of these techniques in upland areas where they have not yet been used is not straightforward, as shown by the attempt in the Nusa Tenggara Agricultural Support Project in Camplong II village in Kupang district (Timor Island). Animal traction was a component of a package to rehabilitate fertile areas that had been overrun by *Imperata cylindrica*. The aim was to develop new cultural practices for food production, an option that seemed to fit particularly well with existing farming systems where cattle are the main component. The technology transfer process ingeniously included participation by Javanese farmers to improve communication with farmers participating in the project. After three years, only a few of the 100 farmers participating in the project had adopted animal traction. This very limited impact is probably attributable to an economic environment that is not sufficiently rewarding to justify the investment. It is also a consequence of the limited area to which this technology can be applied—fertile soil forms only 25 percent of the total available land, thus making the investment too costly.

The development of mechanical traction may also call into question the use of animal traction in upland farming systems. This trend started in the early 1990s in lowland irrigated rice-based systems and may now gain ground in upland farming systems. For example, in Wonogiri district (Central Java) a farmers' group took advantage of a revolving fund established during a former Soybean Yield Gap Analysis project to buy two hand tractors.[4] The shift to mechanical power not only improves the efficiency of soil preparation, but it also facilitates the conversion of dryland plots to rainfed plots where improved rice production technology can be applied. Development of mechanical traction in lowland areas has brought in more dealers and increased the availability of tractor service, which could also benefit upland farmers.[5]

Innovations and Prospects for Cattle in Upland Zones

Cattle are at the crossroads of dynamics affecting the evolution of upland farming systems. An examination of the interaction between food crops and animal husbandry shows signs that this strong link may suffer in the future from development of new soil fertility management and land preparation practices. The mission was not able to collect enough relevant information on cattle marketing and processing to consider the prospects of growth for the local meat and imported meat markets. We had already noted, however, that farming systems specializing in cattle production in the eastern part of the archipelago were facing constraints that jeopardized the sustainability of forage resources. These farmers would undoubtedly be strongly affected by any intensified competition in this market.

However, the livestock component varies from one farming system to another, and the mission found innovations that demonstrate the dynamism of this upland farming activity—artificial insemination and milk production.

Artificial Insemination

At almost all the sites visited, from Timor Island to Central Java, farmers were clearly aware of the advantages of artificial insemination. This technique is used for meat production and in farming systems where cattle are involved in multiple functions.

Prices for artificial insemination vary according to location and animal breed. In Amarasi subdistrict (Timor Island), a farmer said the price was Rp 25,000. A discount system was established in East Java. The first attempt cost Rp 5,000, and in event of failure, the second cost Rp 2,500. If the second attempt failed, the third was free. Insemination services are provided by official veterinary services in Timor, while in East Java a network of private veterinarians is developing rapidly in the cattle-producing area.[6] This innovation is spreading very rapidly according to observations by Sauer and Williams (1991) following their study in Central Java.

According to Sauer and Williams, the breeding system for cattle in Central Java was poor because very few bulls were kept in the study area and artificial insemination was not available. Although this remark concerns a site that we did not visit, it agrees with farmers' statements collected during the mission. They confirmed that artificial insemination has been available only since the beginning of the 1990s. The involvement of private veterinarians suggests that artificial insemination is becoming deeply rooted in farmers' current practices, at least to the point that insemination services are becoming a profitable market.

Artificial insemination provides an efficient means for farmers to control and increase the calving rate and therefore the rotation of capital allocated to this activity. It also simplifies the management of this upland farming component, since farmers are no longer obliged to find a bull nearby and to share the income from the sale of any calves. The introduction of this new technique is also a valuable asset to link research and development and may also benefit the diffusion of new cattle breeds in the future.

Milk Production

Another remarkable change affecting the status of livestock in upland farming systems is the rapid development of milk production. The consumption of milk and other dairy products has sharply increased during the 1990s. According to a consumption and expenditure survey, the average annual consumption of fresh milk per capita increased from 0.2 liters in 1984 to 0.3 liters in 1990. These averages include considerable disparities between high- and low-income households and between urban and rural consumers. Hence, in 1990, the poorest rural people hardly drank any fresh milk, whereas the richest urban consumers drank more than 6 liters a year (Central Bureau of Statistics 1990). Even though the milk market was just beginning to emerge, the total value of milk and dairy products consumed in urban areas in 1990 was already equivalent to the value of soybean foods, a feature of the Indonesian diet in the urban market (Lançon 1994b).

Milk production is increasing rapidly in the highland areas of the Batu, Ngantang, and Pujon subdistricts in Malang district. The mission met a farmer who reduced his coffee plantation to develop new farming activities, in particular, milk production. The marketing of this upland farmer's production is ensured by a cooperative that collects the fresh milk and transports it to a dairy for further processing. This is one of the rare cases where the mission found a nonprivate organization playing an effective, if not efficient, role in the marketing of a product from an upland farming system.

The development of milk production within the Yogyakarta Upland Area Development Project shows that this type of activity is no longer the privilege of highland farming systems. The number of cattle increased remarkably during the project, from 25 animals in March 1995 to 63 animals one year later. Although, the researcher monitoring the project noted that milk productivity was low, about 5 to 6 liters per animal per day, he stressed that this new activity was providing a meaningful gross income of Rp 20,400,000 (Abdullah, Soelaeman, and Syarifuddin Karama 1996). Here again marketing of the fresh milk is handled by a public cooperative supplying a dairy in Yogyakarta.

Conclusion

Although livestock production has many advantages for upland farmers as a source of cash and as a tool to intensify food crop production and sustain soil fertility, various constraints still limit development of an efficient cattle production system. In general, upland development projects have systematically addressed the forage issue, but a shortage of labor necessary to collect animal feed substantially hinders the capacity of farmers to expand their herds.

In addition, diseases remain a major risk and constraint for the cattle owner. Disease outbreaks have often been the catalyst for the conversion of farming systems to new activities such as fruit production. The rate of vaccination is still very low, and farmers are not yet convinced of its effectiveness. In this domain, as in other components of upland farming systems reviewed in this study, the adoption of new practices and technologies depends strongly not only on additional profits but also on the risks associated with implementation.

Notes

1. The first source of income for the richest farms in the monitored sample was rice (43 percent), followed by mango (23 percent) (Sauer and Williams, 1991, p. 20).

2. He estimated that the labor to feed one cow was equivalent to the labor to feed seven goats.

3. Farmers are pushed to maintain terraces because flat land is necessary for the optimal use of animal traction.

4. Information gathered during a farmer interview in May 1995.

5. Considering the difficulties of land preparation in upland areas where soil moisture content is low at this stage of the cropping season, it would be interesting to check thoroughly whether mechanization is even more beneficial in this type of farming system than in lowland systems.

6. In almost all villages of the southern part of Blitar district, one can see *kawin suntik* advertising panels (literally “wedding injection” in Indonesian) at the side of the road.

3

On-Farm Reservoirs for Supplemental Irrigation

Pascal Perez

The shift to continuous cropping after deforestation can modify soil water capacity; thus supplemental irrigation may be part of a farmer's strategy to secure or diversify production. Supplemental irrigation promotes adoption of soil conservation techniques, reduces operating costs, and has the potential to increase income. Our investigation focused on on-farm reservoirs because such programs are widespread in Southeast Asia and because some of the first attempts at supplemental irrigation were made in Central Java.

Definition and History

On-farm reservoirs have been developed in Asia primarily for supplemental irrigation of upland rice, which is grown on some 30 million hectares. Although annual rainfall is substantial, temporal distribution of precipitation is extremely variable. In addition, beginning and ending dates of the rainy season are difficult to forecast.

The Philippines has been operating a large reservoir construction program for about 20 years. Reservoirs have a surface area of 800–5,000 square meters and are 1–3 meters deep. They are excavated using a bulldozer, and the embankments are made from compacted earth. Reservoirs are generally managed by the farmers on whose land they are. The impounded water is used for supplemental irrigation of the first rice crop during the rainy season and then for watering the second crop during the dry season. Most of the reservoirs are filled by direct rainfall (36 percent) and runoff (64 percent). Total losses by direct evaporation (25 percent), percolation, and seepage (45 percent) are much greater than the amounts used for agriculture (30 percent). By one measure (Guerra, Watson, and Bhuiyan 1994), 1,300 cubic meters of water impounded at the beginning of the dry season can water 0.43 hectares of rice.

A similar program was developed in Indonesia in the Pati and Rembang districts (Central Java province) in 1990 after a water shortage that began in April affected some 60,000 hectares. The cropping system was a first rice crop sown dry (October to January), then transplanted rice from February to May, and finally a secondary crop from June to September. From 1990 to 1994 the government subsidized the construction of more than 1,000 on-farm reservoirs, for a total of nearly $100,000 (all dollar amounts are U.S. dollars).

The surface area of these reservoirs varied from 50 square meters to more than 500 square meters, and the reservoirs were 2–3 meters deep. Some were hand-dug by individuals; others were collective works and had cement linings. Gradual construction was stressed to take advantage of available labor and capital on the farms. Collective reservoirs were built on village land or on land belonging to a private owner who was subsequently paid (Syamsiah, Fagi, and Bhuiyan 1994).

The program, which had only a distant connection to the development of the uplands, served as an example in the Yogyakarta Upland Area Development Project in Central Java. From 1990 to 1994 a component of this project developed a farm reservoir construction program. The main sites were chosen in the upland areas in Bantul, Kulon Progo, and Gunung Kidul districts. The objectives were to:

- ensure that water was available for annual crops at the end of the rainy season
- provide a source of irrigation for out-of-season crops planted near the reservoir
- make profitable use of farmer investments in cropping terraces, in particular, using water for recently planted forage or fruit trees, among which losses were high
- reduce runoff and regulate water courses by forming storage during the rainy season.

These upland reservoirs differ substantially from lowland reservoirs in that they also always use an underground source to supplement direct rainfall and interception of runoff. This is necessitated by the geomorphology of the upland region. First, reservoir capacity is strongly limited by the topography, rarely exceeding 500 cubic meters. In addition, the subsoil is porous, made up of volcanic breccia, conglomerate, tuff, and karst debris (Suryanto 1995). Two types of cross drainage are sought:

- an existing spring, where the sides are generally masonry and water is used for both domestic purposes and irrigation
- a cross-flow by drainage into a ditch where at least the upstream face is not lined.

In both cases, the reservoir is built in a depression so that runoff is collected, although areas in which the runoff concentration is too high are avoided because of the risk of damage to the reservoir during strong floods.

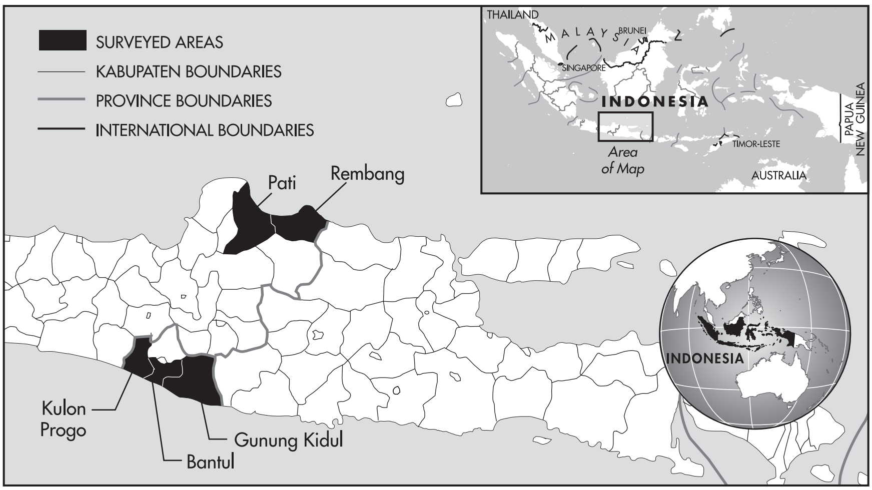
Farming Systems in Central Java

The study team investigated the use of on-farm reservoirs in two subdistricts in Central Java. The Bantul district, Selopamioro subdistrict, is rolling hillside with slopes of 20 to 40 percent some 100–300 meters above sea level. The dominant soil types are lithosol and inceptisol; annual rainfall averages 1,500–2,000 millimeters; the population density is 600–900 persons per square kilometer; and the average landholding size is 0.5–2.5 hectares. The dominant cropping system is a continuous rotation; the main annual crops of rice, maize, cassava, and peanuts are complemented by vegetable growing and animal husbandry. A large proportion of people have part-time jobs in urban areas, and emigration is substantial.

The terraces that are now a feature of the landscape were constructed in the 1970s under the Rembang Reforestation Project, and *Leucaena* was introduced as a forage crop. The Yogyakarta Upland Area Development Project (YUADP), which ran from 1990 to 1994, attempted to introduce the same technical packages as proposed in other upland regions participating in the project. The marked shortage of water in these areas led project managers to develop small hill reservoirs for supplemental irrigation of trees planted on terraces and for establishing vegetable crops.

The Gunung Kidul district, Ponjong subdistrict, of central Java is also rolling countryside with 20–40 percent slopes, but it is higher that Selopamioro

Map 3.1



at 200–600 meters above sea level. Dominant soil types are luvisol and lithosol; the average annual rainfall measures 1,500–2,000 millimeters; average population density is 400–500 persons per square kilometer, and the average landholding size is 1–2 hectares. The dominant cropping system is a continuous rotation, and the main annual crops—rice, maize, cassava, and peanuts—are complemented by vegetable growing and animal husbandry.

Because of soil conditions and landholding pressure, one of the first ecological crises in this area occurred in the 1930s. The traditional terraces constructed using tree trunks and stone walls date back to this period. The Rembang Reforestation Project only extended the construction of terraces begun in that period.

Although the team also made field visits in Rembang district, the farming systems there are not discussed here because this zone is not part of the upland regions. However, the technical information collected there is used to enrich our study of upland reservoirs.

Upland Reservoir Operating Method

The upland reservoir in the village of Umbelrejo in Ponjong subdistrict was built by the YUADP project in 1993. It is fed by a spring and has a capacity of 180 cubic meters (12 × 5 × 3 meters). The total cost, including labor, approached Rp 4 million. The borders were cemented to reduce water loss; the geological substrate is breccia and tuff. The water is used for trees (*melinjo, petai, nangka,* and *mangga*) planted as part of the project and to develop vegetables on terraces (onions, beans, tomatoes, and pimentos). About 10 farmers use the reservoir. The project provided a pump and pipes.

A study carried out from May to September 1994 showed that the reservoir can supply 4 cubic meters a day during the dry season, with the impounded volume decreasing from 86 to 61 cubic meters during the same period. The total exploitable volume was 673 cubic meters, supported solely by the underground supply. This water was used to irrigate nearly 3,000 square meters of vegetable fields (Mazwar, Id, and Hafif 1995). If one assumes that 4 millimeters is lost to evaporation every day, the average application during the period forms one-third of the potential demand. Watering is carried out in the evening and supervised by a group manager.

Farmers built another reservoir in a nearby hamlet without direct aid from the project. Twenty farms grouped to collect the Rp 400,000 required to construct the reservoir, which is small (10 cubic meters) and taps a spring in the flank of a terrace. Water from the reservoir is intended primarily to cover domestic requirements; supplemental irrigation of onion crops is the only agricultural use allowed by the group.

The YUADP built another reservoir in the village of Selopamioro (Bantul district) with the help of a farmers' group (22 farms) that participates in soil conservation measures. The reservoir is entirely masonry, has a capacity of 200 cubic meters, and cost Rp 7 million (including labor). Its main characteristic is that the water supply is derived only from runoff and the direct impounding of rain. That strongly limits out-of-season use, especially because priority in this period is given to the forage and fruit trees planted at the edges of terraces. This technical defect, combined with a failing collective organization, means that a large proportion of the water is used for a rice field during the rainy season, and the volume available at the beginning of the dry season is very limited.

In contrast, a few hundred meters away, an individual farmer built two reservoirs on his terraces for his own use. They are not masonry, each has a capacity of 20–30 cubic meters, and they are supplied by underground seepage (seasonal in one case and perennial in the other). Of the 0.75 hectare of terrace, one-third is used during the dry season for growing pimento, melon, cucumber, and beans. Watering is carried out by hand.

Cost-Benefit Analysis

The construction cost of the Umbelrejo reservoir was nearly Rp 4 million. Some of the water is used for trees planted within the framework of the project, and the benefit is currently difficult to assess. For example, the production cost for supplemental irrigation of a quarter-hectare of onions is about Rp 77,000, and the gross return is Rp 380,000, thus giving a net return of Rp 283,000. Even if the capacity of the reservoir was increased slightly to make it possible to water half a hectare, the cost of the works would still be much too high.

In contrast, the individual reservoirs seen at Selopamioro, which did not cost more than Rp 100,000, are much more cost-effective. With the possibility of irrigating a quarter-hectare, the net return is close to Rp 300,000, which provides a satisfactory profit from the second year onward. Problems of community management are also avoided.

Several technical components of the program developed at Rembang should be retained. Syamsiah, Fagi, and Bhuiyan (1994) performed an economic study based on field surveys. The average construction cost of a 150-cubic-meter reservoir (measuring 10 × 5 × 3 meters) without masonry is estimated to be $49. The loss of production because of use of the land is about $7 (30 kilograms of rice in the first harvest plus 20 kilograms in the second harvest grown on 100 square meters). Melons grown on half a hectare give a crop of 200 kilograms a season, worth $195. Twenty banana plants grown at the edge of the reservoir provide extra income of $24. Finally, the reservoir can be stocked with fish during the rainy season, providing an income of $19. The authors thus conclude that the reservoir cold increase net income from a half hectare plot by 50 percent, from $427 to nearly $645.

This calculation is valid only if the reservoir is supplied by underground water. Otherwise watering half a hectare of melon with 150 cubic meters of water would seem difficult! Indeed, the same authors stress that a 100-square-meter reservoir with a capacity of 180 cubic meters requires a 311-square-meter catchment (runoff coefficient = 50 percent) to irrigate 0.28 hectare.

Conclusion

The best opportunity for maximizing benefits from on-farm reservoirs resides in the possible complementarity between the introduction of soil conservation measures and the construction of reservoirs. The latter can guarantee the viability of the development in the eyes of farmers, especially for trees planted on terraces (reduction of climatic risk). Reservoirs also make it possible to benefit by growing cash crops that are added to the annual cropping system (reduction of the economic risk).

The choice of site obviously should be determined by the best compromise between underground supply and losses from percolation and seepage. Depending on the type of soil and topography, potential slides of earth banks during the rainy season or cracking during the dry season should be considered. Sizing must be coherent with the characteristics of the supply catchment to avoid any violent overflows or excessive silting (Undan and others 1994).

The major management constraint resides in collective management when this is chosen by farmers, or worse still, imposed by a project. A few influential farmers may take control at the expense of the others. A second problem is maintenance work—regular scouring of the bed of the reservoir and repairs to the banks. In the Rembang region we observed that the necessary determination for maintenance work was often lacking. Nevertheless, many cases of satisfactory collective management were observed in the field, but no general lessons emerged.

Finally, numerous technical themes remain to be studied for better design and management of reservoirs. These are biophysical (reduction of water losses), economic (reduction of operating risk), social (the interest of program subsidies and impact on the role of women), and environmental (effects on the water cycle). The aim is to progress from "sound concept to the practical opportunity" (Bhuiyan and Zeigler 1994).

4

Constraints to Adoption of Food-Crop Technologies in Upland Areas

Frederic Lançon

Improving the yield of food crops is a central issue for upland development projects. In our review of the existing literature during the first phase of the study, we found that almost 50 percent of the references about evaluation of new technologies dealt with food crops. The respective shares of wetland and dryland in the total harvested area, however, differ substantially from one crop to another (figure 4.1).[1] Lowland farming systems almost have a total monopoly on the supply of rice, with more than 90 percent of harvested area. Although soybean is considered an upland crop, more soybean is now harvested on wetland.[2] Wetland production of soybean increased dramatically as a result of development programs implemented in the 1980s that encouraged lowland farmers to increase their soybean area.

In contrast, most of the maize and groundnut crops are grown on drylands, while cassava is almost exclusively produced on dryland.

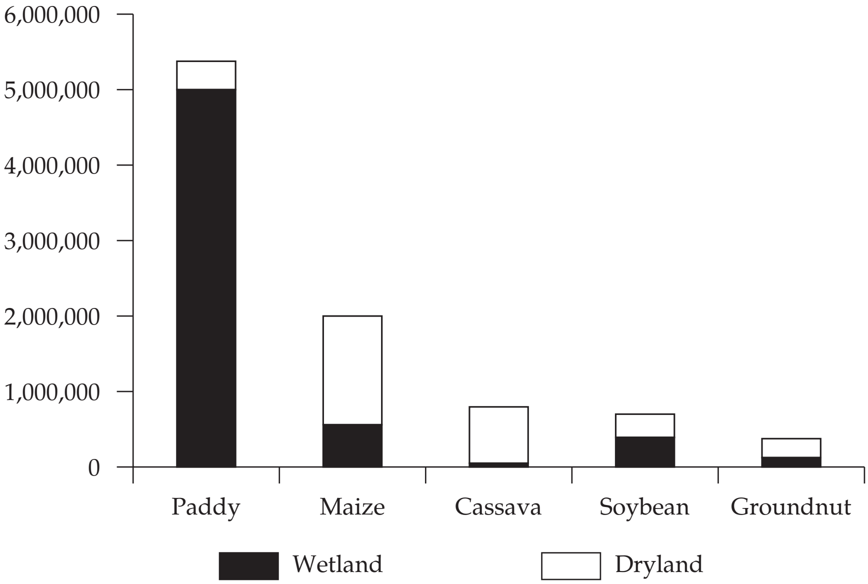
Justifying Technology Transfer

Two arguments have been advanced to justify the objective of intensifying food-crop production in upland farming systems:

Food policy—more precisely the sustainability of self-sufficiency in rice and other main crops—is the first argument. After the success of the Green Revolution based on intensified irrigated rice production, the Indonesian authorities were deeply concerned by the yield plateau reached at the end of 1990. Intensified production of food crops is also viewed as an efficient means to improve the welfare of upland farmers, as has been the case with lowland irrigated farming systems.

Another array of justifications emphasizes links between food-crop production and other components of upland development packages. For

Figure 4.1. Portions of Staple Food Crops Harvested from Wetland and Dryland Areas on Java, 1985–1990 average, hectares



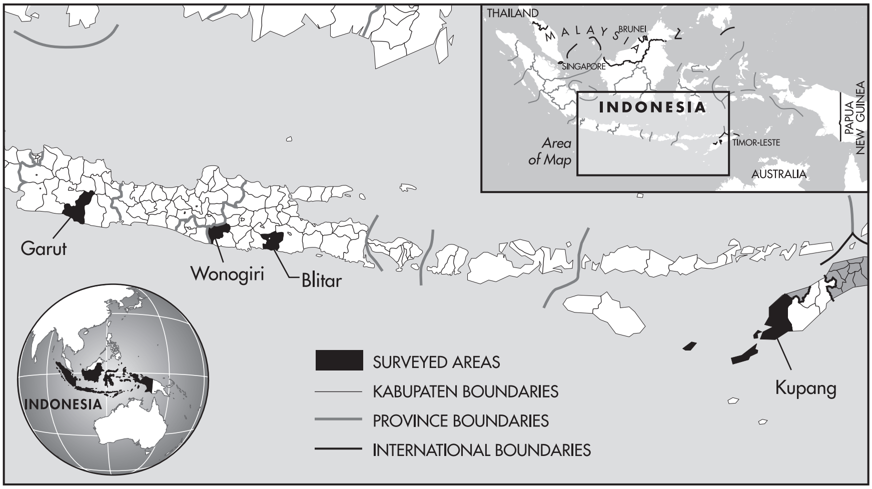
Source: based on Central Bureau of Statistics data on food crop production.

example, soil conservation measures may reduce the planting area per farm; therefore intensification is necessary to increase yields to make up for the lost cropping area. Harrington (1994, p. 185) points out that "Often farmers are unwilling to give up the 10–20 percent of land area taken up by the perennial intercrop, or are unable to supply the very considerable labor input that is commonly required." Along the same lines, introduction of new production techniques, for staple crops in particular, also aims to enhance the nutritional status of the household.

These two categories also lead researchers and extension officers to promote different approaches to adaptation of technology packages. Institutions in charge of technology development and transfer generally have tried to emulate the successes of the Green Revolution, starting with selection of improved varieties for upland ecologies (resistance to drought stress, in particular), followed by development of a technology package that includes chemical fertilizers, pesticides, and new cultural techniques. The second group of objectives naturally leads researchers to promote a farming system approach, where links are used as a stimulus to promote the adoption of new technology.

Of course this characterization is oversimplified, and in practice most of the projects we reviewed combined both approaches to some degree. Development of a new technology, however, tended to be restricted to introducing a new variety, with its accompanying package; less attention was paid to

Map 4.1



the agroeconomic environment in which this package was introduced. That is why we propose a different perspective to technical innovations for food crops. In addition to our own fieldwork, this chapter also draws upon other sources selected from the literature to provide a more comprehensive picture of issues related to the dissemination and adoption of technical innovations for food crops in upland farming systems.

Rice, maize, and soybean use most of the resources for food-crop development in upland areas. These crops have been developed using the same strategy, starting with the development of varieties adapted to upland farming conditions, which are then incorporated into a package that includes fertilizer, pesticides, and appropriate land preparation. The results of these programs vary.

Limits of an Upland Green Revolution Based on Food Crops

The introduction of more productive upland cultural practices for rice aims at sustaining rice self-sufficiency. Hence, this objective has a high priority for the Indonesian authorities. However, despite the emphasis researchers and extension services have placed on this issue, there has been no technical breakthrough comparable to the one that occurred for irrigated rice. In his review of the status and prospects of upland rice in Indonesia, Fagi (1996) ticks off the different factors that hamper the improvement of upland rice yields:

- *Bioclimatic factors.* Of the 1.12 million hectares of upland rice areas in Indonesia, less than a quarter are on fertile soil with a long growing season; more than half of all upland rice areas have infertile soil but a long growing season.

- *Cultural practices*. Soil tillage; weed control, particularly for shifting cultivation areas; and sloping topography and light moderate soil textures cause low water-holding capacity.
- *Socioeconomic constraints*. Improved technology often requires more labor than is available in the typical farm family.

In addition, Fagi points out that diverse environments and cultural practices under which upland rice is produced make the task of breeders and agronomists much more challenging than it was for lowland irrigated rice. Researchers have to design several different technology packages, each adapted to local conditions, rather than a single package. In the case of lowland irrigated rice, the artificial stabilization of the biophysical environment made it possible to concentrate research programs on the development of fewer varieties.

To overcome these constraints and speed up the development of upland rice cultivation, research and extension services propose to intercrop rice with other crops. The favored approach is alley cropping during the establishment of perennial crops.

Upland farmers have another response to the constraints that limit an increase of upland rice yields—they simply progressively transformed their dryland plots to rainfed, flat plots, bounded with dikes, where irrigated rice cultural practices can be applied. This transformation, using a local source of water such as a river or spring to produce rice, is described well by Levang (1993) in his case study on a transmigration area in South Sumatra. Even if the initial investment is considerable, farmers know that it is worthwhile because it will allow them not only to increase rice yields, but also to reduce significantly the risk of yield variation and crop failure. Another case of transforming dryland into wetland has been observed in Central Java in Wonogiri district, where farmers invested in hand tractors to facilitate the transformation.[3]

Innovation Adoption for Maize Production

Maize production is more representative of upland farming systems than is rice production. The large diffusion of maize in upland areas is attributable to its better performances in an agronomic environment often characterized by low moisture and soil fertility. In his study of the maize commodity system in East Java, Yonekura (1996) observed that maize is cultivated twice, especially by small farmers, when the dry season is long. The shorter cycle of maize compared with other secondary crops such as soybean and groundnut also makes it more appropriate for adjusting the cropping pattern to rainfall distribution.

In contrast to common upland cultural practices, maize is no longer intercropped in the subdistrict of Pace but grown as a monocrop. This is a clear sign of intensification induced by the rapid increase in demand from the booming poultry industry.

Cost and return data for major staple crops in Pace subdistrict confirmed that no crops can compete with rice in terms of return on labor or current inputs (seed, fertilizer, pesticides, and water pump irrigation) during the wet season when water is available. However, maize grown during the driest period of the year gives a higher return than rice produced during the early dry season when water availability is reduced. The high returns from soybean cultivated during the early dry season can be explained by the very low level of inputs and labor required. However, the yield remains low, probably because land preparation is inadequate.[4] Farmers are interested in soybean production largely because of trade policy, which is favorable to soybean prices.

The progress on intensifying maize production is stressed by Indonesian researchers, who note the high rate of improved varieties that are disseminated.[5] A World Bank report (1992, p. 22) on development prospects for Indonesian agriculture said that substantial growth in maize production is expected over the next two decades.

The mission had an opportunity to confirm these expectations during its visit to one site of the East Java Rainfed Agriculture Project in Panggurenjo subdistrict, Blitar district. Interviewed farmers confirmed that two years after the end of the project, almost all farmers in the hamlet we visited (around 60 households) applied the recommended technology for maize production—Arjuana open-pollinated improved variety, fertilizer, and pesticides. This very fast adoption is explained by per-hectare yields of 3 metric tons, compared with 500–700 kilograms using former practices. One of the main constraints faced by farmers, particularly the poorest ones, is the cash required to buy seed and fertilizer at the beginning of the season. According to the interviewed farmers, these constraints were solved during the project by establishing a revolving fund managed by the group of farmers cooperating in the project. Apparently this credit organization survived after the end of the project, especially for buying inputs in bulk at a lower price. As in the Green Revolution experience in irrigated lowland areas, credit for inputs is a key factor in the adoption of new technologies.[6]

Limits of an Integrated Approach

In several projects that emphasize sustainable management of natural resources, technological packages for food crops have been introduced as a component of a broader objective—to change farmers' cultural practices to favor more environment-friendly behavior.

One component of the Nusa Tenggara Agricultural Project aimed to transfer a new technology to rehabilitate areas overrun by *Imperata cylindrica* in the village of Camplong II in Kupang district on Timur Island. The soil in this area is mainly uplifted marine limestone corals; however, 25 percent of the area controlled by the village is more fertile and was progressively covered with *Imperata* under a shifting cultivation system. To restore this arable brown soil, the project proposed a package that included more intensive plowing using available animal traction to contain the return of *Imperata.*

The initial land rehabilitation was accomplished with tractors, followed by an animal traction training program where the first demonstration plots were established. The project recommended an alley cropping system, where rows of trees including coconut, mango, and cashew are planted every 10–15 meters, with the space between tree rows reserved for food crops. This component of the package was based on intercropping maize as a subsistence crop, complemented by groundnut, soybean, and mung bean as cash crops. To supplement farmers' fodder resources, multipurpose trees (*Sesbania grandiflora*) and grasses (*Pennisetum purpureum*) were planted along tree rows.

One year after completion of the testing and demonstration phases, very few farmers among the 200 who participated in the project had been able to adopt the proposed technology. Animal plowing did not control weeds as efficiently as expected, while the introduction of soybean and mung bean with high input technology did not succeed because of adverse climatic conditions. For the few farmers who adopted the recommended technology, groundnut was the most successful cash crop. The farmers replaced soybean and mung bean with bottle gourd, which is less sensitive to drought.

The simultaneous introduction of different innovations is one of the main difficulties with this type of innovation transfer. It has the advantage of giving farmers some latitude in selecting components of the package for adoption, but it also makes management of the transfer much more difficult. Even more fundamentally, the recommended package seemed to be far more expensive than farmers could afford. For example, farmers who did not follow the recommendations after completion of the project explained that they could not afford to buy the required quantity of inputs, even though they recognized that the proposed technology was more effective in terms of yield.[7] When the project ended and no more free fertilizer was supplied, farmers returned to their former cultural practices.

The limited size of fertile soil plots may also be a factor in explaining the low rate of adoption. Only farms over a certain size could afford to adopt even part of the package. These farms were operated by farmers with administrative functions (such as village chief or village secretary), who thus were given access to additional fertile land officially belonging to the village as payment in-kind for their services.

Limits to More Sustainable Cassava Production

A project in Malangbong subdistrict, Garut district, West Java, is another example of the difficulties faced by upland development strategies based on introducing new food-crop technologies. This farming system, located in a mountainous area, is based on cassava. The crop is produced both on terraces and on newly cleared areas on steep slopes.

The boom in cassava production is largely fueled by market incentives provided by export of cassava pellets for animal feed in Europe, as well as by a fast-growing Indonesian animal feed industry. During the 1990s, cassava also became an important raw material for small-scale food industries and for the chemical, paper pulp, and wood industries.

Cassava has a very bad reputation in terms of natural resources management. Intensive, continuous cultivation is often associated with loss of soil fertility and erosion (Howeler 1994). These effects are not directly caused by cassava itself but by the cultural practices and the agroeconomic environment in which it is grown. Because cassava can be grown on very poor soil and does not require much in the way of seed, fertilizer, and pesticides, it can be grown by the poorest farmers. These farmers have no incentive to maintain soil fertility because it is not important for cassava compared with other crops.

The Upland Farmer Development Project tried various approaches to reduce the planting density of cassava grown as a monocrop. The project recommended improving existing terraces by inverting the slope of the bench to reduce erosion and facilitate riser maintenance.[8] To justify the required investment (and reduce cassava planting), the project proposed development of food crops with several tree crops planted on the terrace risers.

The project started to introduce a new upland rice variety, Jatiluhur, but dissemination of this package faced many constraints.[9] There have been some successes; one farmer said the new variety was interesting because it had a shorter maturing period compared with the upland rice variety currently planted in the area. An alternative package recommended intercropping maize with cassava at planting time at the beginning of the rainy season, when rice cannot be intercropped with maize. According to the farmer, maize is the most interesting crop in this agroeconomic system. In particular, he found it convenient to be able to grow two maize crops in a row on the same plot, compared to cassava and rice that can be harvested only once a year. This multiple cropping provides regular income and consequently facilitates cash management at the farm level. He even started to buy hybrid maize seed from a private trader.

However, enthusiasm for cassava cropping alternatives is probably limited to a few farmers. The dissemination of this rice or maize-cassava package seems very limited, and cassava monocropping remains the dominant pattern. Labor is the main constraint prevnting adoption of the new package. This area is well connected to the main urban centers in West Java, and a majority of heads of household leave the village for several weeks at a time to work in Bandung or Jakarta.[10] Moreover, the introduction of more intensive cropping technologies requires continuous monitoring of the plot. This is particularly true for pesticide treatments that are efficient only if they are applied at the right time. The part-time off-farm activities of household heads dramatically hamper their ability to follow the recommended technology properly.[11] Hence cassava, requiring much less attention, remains one of the most dependable crops for these farmers.

In many households in Malangbong subdistrict, women are in charge of daily farm management. This situation, which is becoming more and more frequent in upland farming systems, brings new challenges for the transfer of innovations. Extension services must consider that women are their target group rather than the male head of the household. Women are often more involved in crop management operations such as fertilizer or pesticide applications, while the head of the household participates only in operations that require heavy labor such as land preparation and harvesting. In addition, women cannot totally assume their husbands' agricultural tasks because they still need time to prepare meals and perform other domestic tasks; hence the proposed innovations must not be too labor intensive. For example, the dissemination of white mulberry (*Morus alba*) for silkworm feeding under the guidance of a social forestry program and in connection with a Korean silk company is interesting. Leaf harvesting can be done on a daily basis at a regular time, can involve family teenagers, and can fit well into the labor allocation pattern.

The last constraint that contributes to the low adoption rate of recommended packages to substitute for cassava monocropping applied not only to food crops, but also to introduced tree crops—property rights in the area are uncertain. The land was owned by big plantations during colonial times and was taken over by the army after the war of independence. Still the official owner of the land, the army has tolerated settlement of farmers. One can easily understand that in such a land tenure situation, farmers are reluctant to make long-term investments to improve the farming system and its sustainability.

Conclusion

Except for maize, upland farming systems do not provide many examples of successful dissemination of food crop innovations. This ambiguous outcome of a decade of efforts made at both the research and the extension stages has many causes.

Whatever the agroeconomic environment, farmers cannot be persuaded to change their practices if the new technology does not bring significant improvements without increasing the risks too much. In addition, upland farming systems are often confronted with labor shortages that limit their ability to shift to more intensive technologies.

At a more macroeconomic level, one must also consider connections between upland and lowland agriculture. The success of the Green Revolution means food is cheaper not only for the urban population but also for upland farmers. If the market can provide the food requirements for their families at an affordable price, upland farmers will be less interested in innovations for food-crop production. Intensification of food crops in upland areas faces a dilemma—more inputs and more labor are required, and innovation adoption can be justified only if food crops are produced as commercial crops generating more cash income. However, improvement in market access for upland farmers means that they also have more opportunities to consume lowland food crops. In remote and isolated areas, farmers do not have enough incentives to make substantial modifications in their cultural practices for food crops. Similarly, food crops do not seem to play the catalytic and integrating role that their promoters expected for sustainable upland farming systems.

Notes

1. Even if wetland and upland definitions do not coincide exactly with lowland and upland farming system definitions, these data provide a good basis to compare the share of both farming systems in food-crop production.

2. The gap would probably be even higher in favor of wetlands if total production is taken into account, since yields are on average higher under irrigation than with dryland cultivation.

3. Observations made during a visit to a former study site of the Soybean Yield Gap Analysis Project in 1995.

4. In particular soybean grown after rice requires a good drainage system to reach potential yields of 1.5–2 metric tons per hectare (CGPRT, 1992).

5. During our visit, Dr. Sumarno, head of the East Java Institute for Agricultural Technology Assessment, in Karangploso, confirmed the high rate of dissemination of improved maize varieties.

6. The establishment of a similar system during the Soybean Yield Gap Analysis Project in the village of Eromoko, Wonogiri district (Central Java province) played a critical role in the adoption of improved technology for soybean production. The main soybean growing season is the early rainy season from October until December, when rice production starts. With cash resources at their lowest level at the end of the dry season in August, farmers are unable to invest in the inputs required to apply the recommended package (Lançon 1994).

7. For example, with maize, the recommended technology generates a yield two to three times higher than that achieved by using current farmer practices (200–400 kilograms per hectare).

8. In this area, bench terraces were established in the mid-1980s during a reforestation program implemented under the supervision of the Ministry of Forestry.

9. In addition to the constraints already mentioned in the first paragraph of this section, farmers explained that the taste of this new rice does not meet consumer preferences; thus marketing is less profitable.

10. Typically, the team spent at least two hours in the village and the surrounding area before meeting a farmer.

11. The same situation prevails in lowland areas near main urban centers. Sophisticated cultural practices for soybean intensification are rarely adopted by farmers who rely more and more on off-farm activities to make their living (Lançon 1994).

5

Introduction of Vegetable Production

Frederic Lançon and Ibrahim Hasanudin

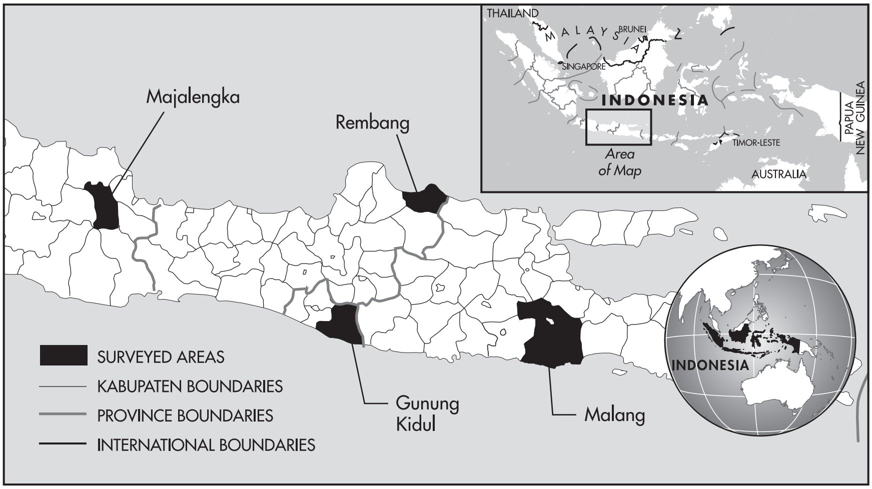
In his comprehensive review of the vegetable subsector in Indonesian agriculture, Ferrari (1994) points out that even though the share of vegetables in overall agricultural production is minor because volumes are small compared with rice and secondary crops, this subsector offers a route to achieve development objectives and diversify agriculture (1994, p. 6).[1] The dynamism of this agricultural subsector is particularly important for the development of upland agriculture. At various sites vegetables provide a new income opportunity for upland farmers and in some cases even earn the major part of household income. This chapter focuses on the process of vegetable adoption in different agroeconomic settings. It also draws upon an indepth study carried out in Majalengka district (West Java) by a team from the Coarse Grains, Pulses, Roots, and Tuber Centre (CGPRT) and Indonesian counterparts under the guidance of Hayami and others (1991).[2]

Commercial Vegetable Crops in Java

Some vegetables such as yard-long beans and chilis have probably always been a traditional component of Indonesian diets in both rural and urban areas.[3] They have been grown for a long time in the traditional gardens of most households, even in urban and suburban areas. These crops were traded locally because the transportation infrastructure was inadequate for moving perishable vegetables to faraway markets.

The first boom in vegetable production was brought about by a combination of accelerated urbanization in Java, improved communications infrastructure, and diversification of the urban diet, which has gradually included more vegetables usually grown in temperate climates. In his extensive review of highland society living on the upper part of Mount Bromo, Hefner (1990) recalls that upland farmers took advantage of a new road in the 1920s and grew cabbages and potatoes for Surabaya consumers.

Map 5.1



Farming systems in other upland areas in West Java (Cipanas, Lembang) and Central Java (Dieng) also became highly specialized in vegetable production. The development of vegetable markets was interrupted by the recession of the 1930s, followed by World War II and the turmoil of the first decades of the newly independent Indonesian state. With the economic recovery of the late 1970s and the economic boom of the 1980s, vegetable consumption increased and has once again become an attractive source of income for upland farmers. This increasing integration of upland vegetable systems is corroborated by Hayami and his colleagues in Majalengka district (Hayami and others 1991), who describe two marketing channels—local trading, as well as supplying major urban centers such as Bandung and Jakarta.

Vegetables in Upland Farming Systems

Vegetable production varies in farming systems and can be differentiated by considering the share of vegetables in the total cultivated area and thus in farmer income. Patterns differ from the most specialized to the most diversified farming systems.

The most specialized upland farming systems are located in the highest upland areas and grow onion, garlic, cabbage, and potato, a result of natural comparative advantages and disadvantages. Rice cannot be grown in these areas, and the traditional staple foodstuff is long-cycle maize (five to six months), but agroecological conditions are particularly suitable for vegetable production. The high level of humidity makes it possible to grow vegetables all year, and the volcanic soils are very fertile. In fact, these areas are located on volcano slopes or saddles and benefit from a regular supply of volcanic ash at each eruption.

This broad category of specialized farming systems can itself be divided into subtypes according to the kind of vegetables grown and the amount of the initial investment. The first subtype includes traditional vegetable growers who have been specialized for a long time. The potato producers in Ngada village on the slope of Mount Semeru (near the city of Malang in East Java) are at an elevation of 1,500–2,000 meters and are a perfect illustration of this subtype. This area is characterized by the most fertile, but also most eroded, soil in the world. This soil is pure ash on steep slopes where high rainfall maintains continuous erosion. The steepness of the slopes does not allow construction of terraces. To take advantage of the soil's high fertility, farmers diversified their original cropping pattern based on long-cycle maize by incorporating potato. The average size of the farms is about one hectare; rarely does a farm exceed two hectares.

In contrast are the potato farmers in Ngawi village in the subdistrict of Pujon. They are located on the opposite side of Malang on the slope of the Panderman volcano at an elevation of 1,200–1,500 meters. These potato farmers are veterans of the war of independence who acquired land as a pension and reward for their army service. These lands were originally Dutch colonial tea plantations, and potato cultivation started in the mid-1970s after a small road was was built on the volcano slope, making it possible to ship produce. Only the poorest of the veterans cultivate only their own land. Other smallholders extend their farm size by renting plots from absentee urban landowners. In this area, the slope is less steep than in Ngada village, and potatoes are grown on terraces. It is important to note that terrace risers of land owned by farmers are much better maintained than those of absentee landowners. Farmers take grass from the risers of absentee landowners' plots to feed small livestock in the farmyard, while they keep the grass on the risers of their own plots to control soil erosion and reduce the amount of labor required for terrace maintenance.

In the Batu subdistrict, which is in the lower part of this area at an elevation of 800–1,200 meters, the mission visited another type of farm that specializes in intensive production of high-value crops such as garlic and onions. This farmer was among the most advanced that we visited during the study. His production consisted entirely of garlic, shallot, stone leek, and potato. To control soil moisture and produce all year, he had equipped part of his land with sprinkler irrigation. The farmer owned about 6 hectares, which was far more than the average farmed by vegetable growers at other sites we visited, and he farmed probably 3 or 4 hectares more than he owned. He had close contacts with traders and sold to all the main urban centers on Java.[4]

These connections with traders reduced losses because he harvested only enough to fill required shipments. He also conducted his own trials to improve his techniques and had participated in several training courses. His success was revealed by the high level of education achieved by his children, some of whom had completed their education abroad. Although this type of farm is an exception in the upland landscape, it clearly shows that upland farmers are not always poor farmers, as is often stated in project justification.

Diversifying Vegetables and Cropping Systems

With the rapid expansion of markets in the late 1970s, production from specialized farms was not able to match the demand for vegetables; at the beginning of the 1980s, vegetable production began to develop in new places through a change of traditional cropping patterns. A typical case of production diversification through vegetable cropping was extensively analyzed in a study conducted in 1988 in Majalengka district in West Java (Hayami and others 1991).

Compared with rice-based farming systems in lowland irrigated areas, the cropping systems in unirrigated farming systems in Java have always been characterized by a high degree of diversification. They include rice during the rainy season, but maize, soybean, groundnut, mung bean, cassava, and sweet potato are grown on most of the planted area. These secondary crops are so strongly associated with upland farming systems that people often refer to them as upland crops (CGPRT 1994).[5] In Majalengaka, vegetables progressively replaced these secondary crops (figure 5.1). Although rice has been maintained in rainfed areas, the dry season is now dominated by various vegetables.

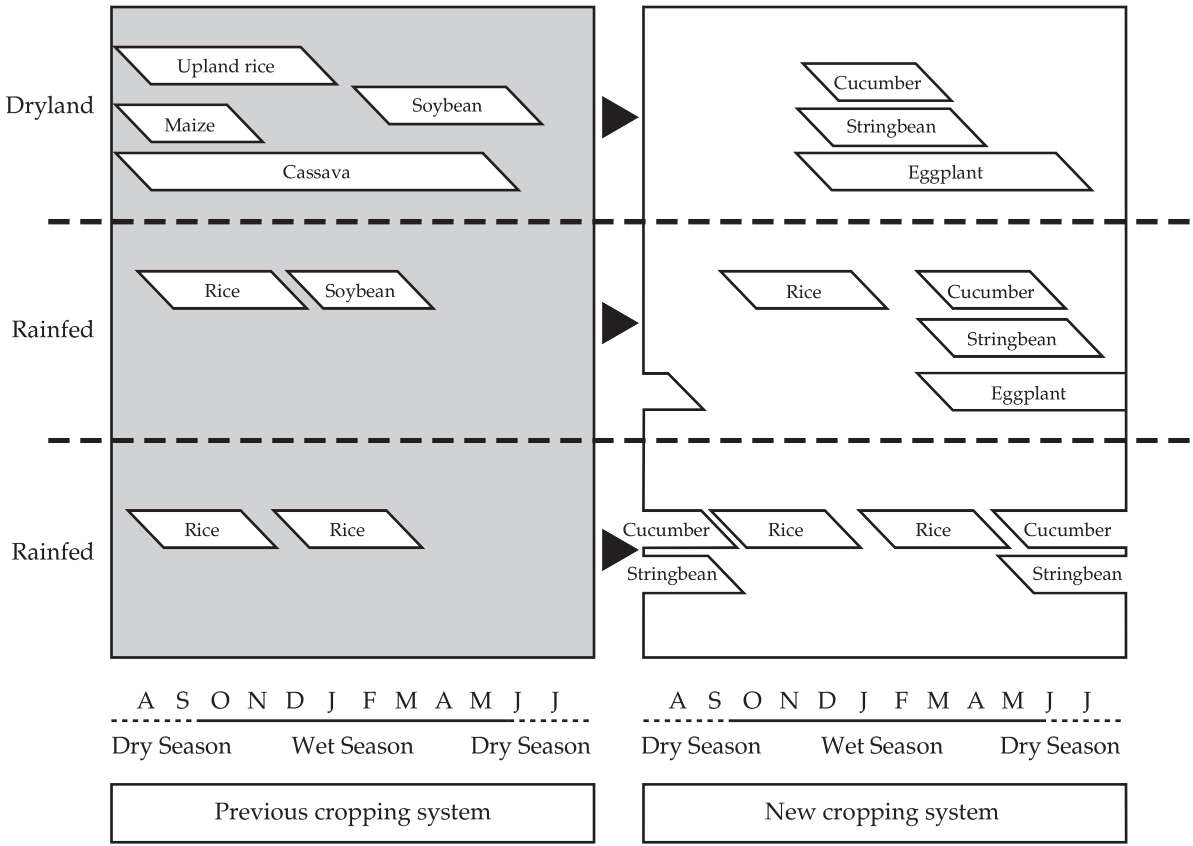
We reviewed different situations where farmers adopted vegetables as a secondary crop. In particular, vegetables have been introduced in connection with construction of on-farm reservoirs in Gunung Kidul district in Yogyakarta. These reservoirs enable limited access to water beyond the rainy season. Thanks to high returns per hectare, vegetables cultivated even on small plots near reservoirs can provide a significant amount of income. The mission observed this same trend on the northern dry coast of Central Java in the hilly part of Rembang district. Vegetables had not reached the same proportion in these areas as they had in Majalengka in 1988, but even though vegetable sales were not the main source of income, they were available during the dry season when farmers' cash reserves are at their lowest.

Innovation Costs and Returns

Vegetable cropping requires more capital and labor than staple food crops. Because they are very sensitive to insect pests and diseases, vegetables require more fertilizer and pesticides. Whereas a few hundred thousand rupiah are sufficient for a farmer to start growing maize, groundnut, or soybean, the cash cost for planting materials and chemicals is more than Rp 1 million per hectare for most vegetables, and several million for garlic and potato. Vegetables also require more labor concentrated within a limited period.

The data in table 5.1, from the study in Majalengka district, show that labor requirements triple when farmers shift from secondary food crops to dryland vegetables and double on rainfed land when rice is also grown. Female labor is extremely important for harvesting (Hayami and others 1991).[6]

Figure 5.1. Changes in Cropping Patterns for Different Categories of Land in Majalengka District



Source: Y.Hayami and others 1991.

Table 5.1. Labor Input for Different Cropping Patterns, hours, per hectare

Cropping pattern	*Male*	*Female*	*Total*
Dryland			
Secondary food crops (a)	1,311	907	2,218
Vegetables (b)	3,584	3,558	7,142
Variation (b/a)	2.73	3.92	3.22
Rainfed			
Rice + secondary food crops (a)	1,514	902	2,416
Rice + vegetables (b)	2,743	2,381	5,214
Variation (b/a)	1.81	2.64	2.16

Source: Hayami and others 1991.

Sharp increases in both labor and input costs are more than balanced by increased income (table 5.2). The additional profit is lower on rainfed land where vegetable yields are lower because they are cropped during a drier period. On this land, farmers give priority to rice when water availability is at a maximum. These differences in additional income explain the lower adoption rate for vegetables on rainfed land recorded by Hayami and his colleagues.

Examining the distribution of added value, Hayami and his colleagues proposed to calculate labor income on the basis of customary labor wages for both men and women. The remaining part of the income (which also belongs to the producer) can be interpreted as the value of land rent under the respective cropping pattern, which increases considerably for dryland when vegetables are grown instead of secondary food crops. In an analogy to forest rent, Hayami and his colleagues suggest that what was once considered marginal land has now become superior land through the introduction of vegetables and thus offers rent to farmers (Hayami and others 1991, p. 48)

Figures collected during the mission show great variation in vegetable cash costs from one location to another and between the type of vegetables grown. For example, advanced farmers interviewed in Batu subdistrict estimated that production of one crop of garlic required an investment of Rp15 million per hectare to cover planting materials and chemicals, irrigation (pump and sprinklers), and labor (all labor is provided by hired farmworkers). Potato required a smaller cash investment, estimated to be about Rp 8 million–10 million per hectare.

In Gunung Kidul district, where farmers have begun to produce vegetables during the dry season, investments and income from one hectare of shallot were much lower than in Majalengka district. This lower return per hectare is the result of a low yield, probably due to the production period (dry season) and less intensive cultivation practices. However, the return (2.1 rupiahs received for 1 rupiah invested) is still much higher than that

Table 5.2. Costs and Returns by Cropping Pattern, per hectare of Harvested Areas in Majalengka District, 1988–89 Season, thousands of rupiahs

				Labor income		
Cropping pattern	*Output*	*Current input*	*Value added*	*Total*	*Women*	*Nonlabor Income*
Dryland						
Secondary food crops (a)	717	139	578	559	154	19
Vegetables (b)	5078	462	4616	1895	605	2721
Variation (b/a)	7.1	3.3	8.0	3.4	3.9	143.2
Rainfed						
Rice + secondary food crops (a)	1565	181	1384	762	153	622
Rice + vegetables (b)	2845	420	2425	1456	405	969
Variation (b/a)	1.8	2.3	1.8	1.9	2.6	1.6

Source: Hayami and others 1991.

from traditional food crops such as maize or soybean under the same conditions.[7] In addition, the shorter growing period for vegetables is particularly attractive to farmers.

Adoption Rate

The adoption rate must be considered in light of the type of farming system, number of years of experience in vegetable production, and agroclimatic conditions.

In highland areas, agroclimatic conditions are particularly favorable for vegetable production and the temperature is too low for rice. Under these conditions, vegetables do not have much competition, and the whole area is devoted to them. At these sites, the rate of adoption, in terms of both area covered (the continuous rate) and number of farmers (the discontinuous rate) is above 90 percent.

In Majalengka district, where farmers started to grow vegetables in the 1980s, the continuous rate of adoption varies according to land type. In drylands, 82 percent is planted to vegetables during the rainy season (the new cropping pattern shown in figure 5.1). In rainfed fields, the rice plus vegetable cropping system uses only 22 percent of the total rainfed area. Altogether, cropping systems that include vegetables cover 50 percent of the total area available for food crop production (Hayami and others 1991, p. 11). The discontinuous rate of adoption is probably close to 100 percent, that is, every farm grows vegetables either on dryland or rainfed land.

At the sites visited by the mission, farmers recently started to grow vegetables in connection with construction of on-farm reservoirs. Only a few farmers have been able to try these new crops.

Constraints and Adoption Factors

Agroclimatic characteristics are the first category of factors influencing farmer decisions to adopt vegetable production. For example, in highland areas the agroclimatic factor is crucial because not many of the usual tropical crops can be grown at these low temperatures.

At the other end of the spectrum, water is the first constraint that farmers must handle in upland dry areas, such as in Gunung Kidul or Rembang. In these districts, development of vegetables is determined by the capacity of farmers to provide water. For example, in Rembang a group of farmers has rehabilitated a huge reservoir with the intention of developing shallot and onion production. In that case, adoption of vegetables can be partially interpreted as the output of the investment in irrigation as a substitute for forest rent (see chapters 1 and 3).

In the Ngada area farmers observed a significant decline in potato yields, which they attributed to adoption of a new variety. However, despite the natural fertility of volcanic soil, this decline in fertility could also be caused by soil erosion, which had not been offset by additional fertilizer, but farmers are reducing fertilizer applications to maintain their margins. Hence, in the long term, intensive vegetable production may be constrained and less profitable even in a very favorable agronomic environment.

The physical suitability of the agronomic environment is not, of course, the only factor affecting development of vegetable production. Compared with staple food crops, vegetables require more inputs, including labor. The data in table 5.1 illustrate the magnitude of the changes in labor required to produce vegetables instead of staple foods. In highland areas specializing in vegetables, labor requirements can be satisfied by employing farm workers from more densely populated areas at lower elevations.

The ability of farmers to mobilize enough funds to launch production is another critical factor. Farmers sometimes mention lack of initial capital as the main reason for not starting to grow vegetables. Even in the highland areas, the smallest farm does not have enough capital to develop garlic production and must stick to the production of potato, which has lower capital costs. This constraint can be solved through credit and cash advances that are often provided by traders.

Trade always plays a catalytic role in the spread of vegetable production. These products are perishable and require an efficient organization to channel them to consumers. Development of roads has been the forerunner of vegetable development in Batu district, and one trader was the initial organizer of vegetable production in Majalengka district: "On his travels he observed commercial vegetable growing and consequently taught his neighbours how to grow them. At Majalengka, he himself tried to grow vegetables with introduced seeds and at the same time acted as a middleman to market them" (Hayami and others 1991, p. 10). To a certain extent, the new road substituted for forest rent (a similar case for ginger is discussed in chapter 6).

Production is very often closely integrated with marketing activities. In recent years food industries have become involved in this subsector. For example, Indofood is conducting research to develop production of a certain variety of potato in East Java. Japanese companies in joint ventures with Indonesian traders are developing production of vegetable soybean (or green soybean) in Central Java to supply the Japanese market.

With the urban market as the main factor, adoption of vegetables seems to prove the need for a substitute for forest rent or capital—fertilizer, irrigation, research in new varieties, or more simply, a road giving access to a new market.

Notes

1. The share of the vegetable subsector in the gross domestic product (GDP) computed by Ferrari increased only 0.2 percent from 1983 to 1989, from 1.3 percent to 1.5 percent, but this slight increase must be considered in light of the 0.4 percent decrease (from 15.0 percent to 14.6 percent) in the total food-crop subsector share of GDP during the same period (Ferrari 1994).

2. CGPRT is under the auspices of the United Nations Economic and Social Commission for Asia and the Pacific.

3. The definition of vegetables is not within the scope of this study. Indonesians do no consider some main secondary crops such as mung bean and soybean to be vegetables.

4. This farmer used a pager so he could be contacted more easily by traders, and he regularly sold to Jakarta, which is 1,000 kilometers from the village.

5. The common status of this group of secondary crops is also revealed by the common name under which Indonesian farmers called them *palawija,* in contrast to rice.

6. Vegetables are harvested at intervals, whereas food crops are usually harvested in one operation.

7. For secondary food crops under the same circumstances, the return to cash is less than 1.5 (CGPRT 1992).

6

Ginger and Annual Crops in Tree-Based Agriculture

François Ruf, Yoddang, and Syarifuddin

The innovation we examine in this chapter is the adoption and partial abandonment of ginger by small-scale coffee growers in the mid-elevation mountain region in Kepahiang subdistrict (in Rejang Lebong district, Bengkulu province, South Sumatra). Coffee smallholders have always grown annual crops such as rice, maize, cabbage, and tobacco. These annual crops may be cultivated on fallows independently of coffee farms but are also widely intercropped with young coffee seedlings. In relatively densely populated mountain regions where the land is scarce, coffee farms are regularly replanted. During the first two years without any coffee returns, annual crops with a ready market, such as ginger, play a major role in funding the investment in replanting (chapter 16). The income from these crops also supplements the income drawn from coffee and contributes to food security. While the farming system remains based on a perennial crop, it is fairly broadly diversified.

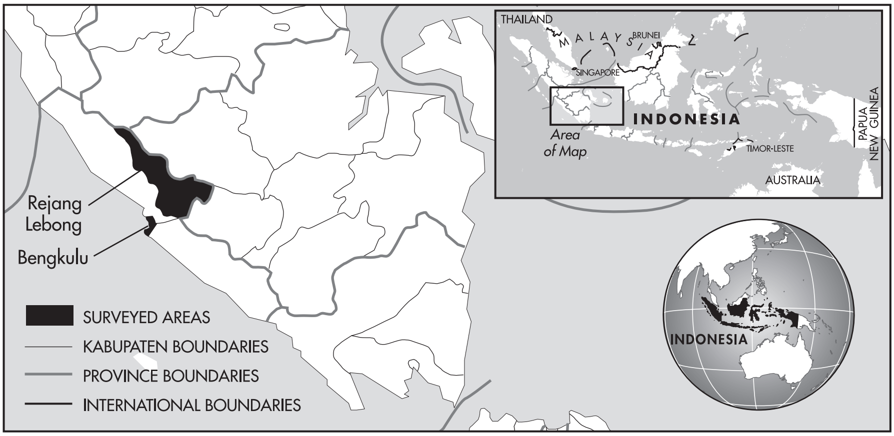
Why should adoption of this annual crop deserve a special chapter? Beyond the fact that we have qualitative data on that farming system for the period 1989 to 1998, the answer is that because of its many special features, ginger on family farms raises several major questions about the development of upland regions.

Export Crop

As an export crop, ginger stands out from the annual crops mentioned above, including vegetables intended mainly for large urban markets in the region. Even tobacco is primarily intended for the Indonesian industry, and very little is exported.

The narrow export markets for ginger are mainly Japan, the Middle East, Singapore, Hong Kong, Brunei, and Taiwan (which is also a producer). This

Map 6.1



market niche raises a question of communication. The smallholders at Kepahiang are two hours by road from Bengkulu and 12 hours from Palembang. How do they gain information about these markets? How do they adapt to strong price fluctuations? What are the historic, economic, and ecological conditions that affect the adoption of ginger in this small region?

Ginger is grown for its rhizome and multiplied vegetatively, so the quantity and quality of the plant material is extremely important. The "seed" can be any part of the rhizome. Yield is 3–10 times the quantity of seed, depending on soil type, maintenance by smallholders, and planting material. After primary forest clearing, yields may even reach 12 times the quantity of seed. Good-quality rhizomes for planting should be dried and stored under well-ventilated conditions for three months. Smallholders do not always have good storage and drying facilities for large quantities of material. In addition, if they do not plant ginger each year, they are dependent on outside suppliers. The middlemen have built large storage and drying installations and thus have substantial control over the seed supply. Under this set of conditions, smallholders are subject to strong capital and credit constraints for access to planting material.

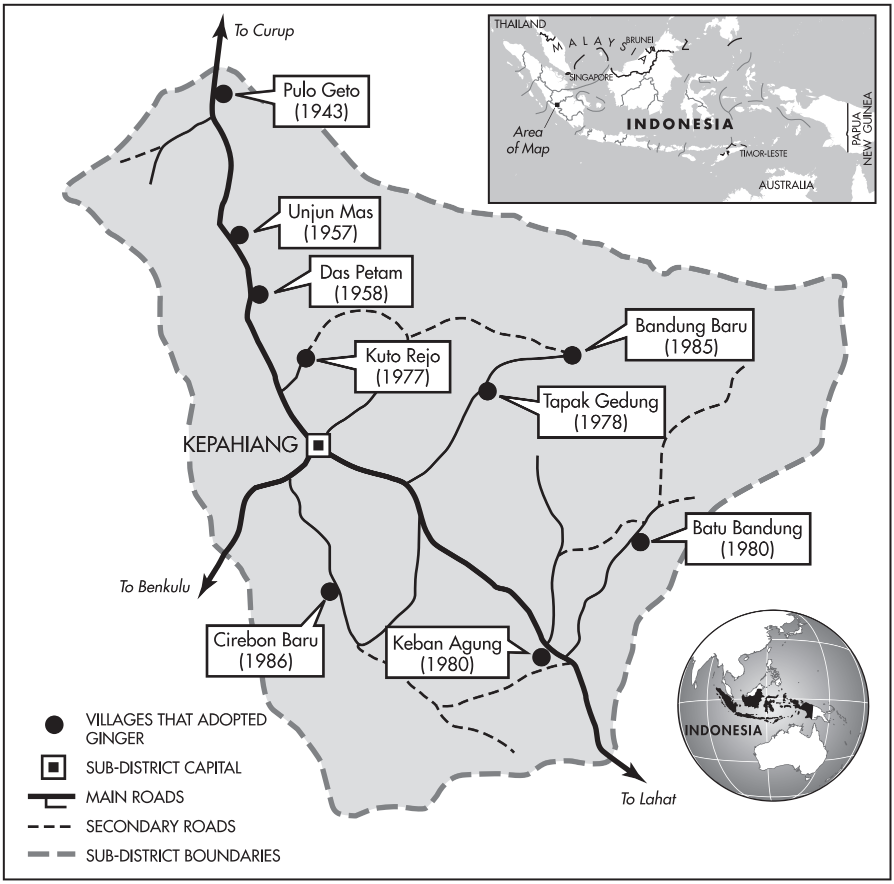
Ginger needs rich soil. Beyond the question of soil and climate of the Kepahiang region (recent volcanic soil from the Barisan mountains and annual precipitation of 2,500–3,000 millimeters), the prolonged adoption of ginger raises the question of soil fertility, which falls after clearing forest land.

Forest-New Crop Rent

Ginger is an excellent example of the forest-new crop rents given its phytopathology. Before 1992, production costs of ginger were low due to high yields obtained after forest clearing and due to the absence of serious pests and diseases. Since 1992–93, established ginger fields have been attacked by a new disease (spread by either a bacteria or virus). The leaves turn yellowish and rhizomes rot. A few villages such as Suro Bali have almost totally abandoned ginger because of this disease, but the ginger crops in other villages seem more resistant. What is the dynamic here?

One of the objectives of this chapter is to illustrate the interaction of forest–new crop rents and location rent.[1] The disease attack seems especially strong in fields close to villages and roads. In Batu Bandung, which is one of the last villages in Kepahiang subdistrict to be relatively close to a forest, ginger production has been shifting from the village neighborhood to forest plots that require a four-hour walk or half-hour ride in the dry season (Figure 6.1). To a certain extent, farmers are trying to escape from the disease and cash in the forest rent. This production shift and effects of forest-new crop rent are typically accelerated by migrations. North and northeast of Batu Bandung is the pioneer front of the subdistrict that spread between the early 1990s and 1997. Most migrants are motivated by coffee, but ginger benefits from the tree-crop shift in production.

Figure 6.1. Kepahiang Sub-district and Approximate Year of Ginger Adoption in Each Village



Farming Systems

Typical holdings at the subdistrict level are three or four hectares, nearly two of which are devoted to coffee. In 1991 ginger was grown on fallow as a monocrop or intercropped with other annual crops such as chili on about 70 percent of the available area. On some 30 percent of the land, it was rotated with coffee in replanting cycles.

Ginger Adoption

The very first ginger plants in the area are said to have been introduced in 1940 by a Chinese middleman., In 1943, however, a farmer named Ali Sunan, from the village of Pulo Geto received 50 kilograms of ginger from the Japanese army and was told to plant it. He reportedly harvested 550 kilograms. The army took 500 kilograms and left him the other 50.[2] The army then gave him 250 kilograms to plant in 1944 but never recouped the investment because it had to leave in a hurry when the American army arrived.

The harvest from the 250 kilograms was partly distributed to family and neighbors, but there was practically no market for ginger from 1945 to 1954. Ali Sunan's son remembers that it fetched half a rupiah per kilogram when white rice sold for three rupiah per kilogram.

About 1955, buyers started to come from Palembang, Padang, and Jambi, and the prices per kilogram of ginger and rice rose to Rp 1.5 and Rp 6 respectively. The buyers did not return from 1957 to 1959, which was the period of skirmishes between the Indonesian army and the independence movement, and the ginger crop went unharvested. The ginger market remained uncertain in the 1960s, with the price rising to an attractive peak relative to rice in 1962 before slumping, falling below the price of rice for the rest of the decade.

Middlemen and Exporters

In the 1970s and 1980s the market experienced strong fluctuations and interruptions, but buying by middlemen spurred a chaotic rise in the crop, which gained in importance after 1975.

Access to information about a market and adoption of a new crop is as much the business of traders as that of producers. The role of the trade information network was clearly seen in interviews with the first buyer-exporters of ginger. Before ginger, they worked in coffee exporting or other sectors such as textile factories in Jakarta. Some of Chinese descent had family contacts in Singapore, Hong Kong, and Taiwan and thus obtained information about production problems in Taiwan and Thailand, where the crop is highly seasonal, and opened up a market for Indonesian regions that can grow ginger all the year round.

A university economist well informed about ginger markets also seems to have played a role by encouraging local production for sale on the markets in Jakarta, Padang, and Medan. Middlemen reselling to exporters included local civil servants who invested their regular incomes in a sector in which capital is a requisite for funding planting material.

Diffusion of Ginger among Villages

How has ginger spread from 1943 to the late 1980s from one grower to another and from one village to another? The map (figure 6.1) of the 10 villages studied shows the north-south diffusion process along the road (paved in 1960). The dates mentioned there for launching the crop in each village should be considered as a guide. They are drawn from our sample of 57 planters and from open discussions with the head of each village. Even though they are approximate, these dates clearly show the spread of the crop.

In summary, ginger appeared in 1943 in Pulo Geto in the extreme north of Kepahiang subdistrict at the edge of the road, 10 kilometers south of Curup. From there, it followed the road and then moved away from it in stages from village to village. It does not appear to have reached Ujun Mas, the first village in our sample south of Pulo Geto, until 1957. It was brought there by a villager who had worked as a laborer for a member of the family of Ali Sunan, the first planter. The neighboring village of Das Petah planted ginger the following year.

The new crop was diffused among the already installed indigenous population. The first diffusion from the 1940s to the 1950s occurred before the first waves of migration (40 percent of the population in Kepahiang subdistrict are migrants, but indigenous residents are still in the majority).

In 1977, ginger plantations began to be appear in villages away from the road, operated both by Javanese migrants (in the village of Kuto Rejo in 1977) and by people from southern Bengkulu (Tapak Gedung in 1978). These villages were followed in 1980 by Keban Agung, the southernmost village on the Lahat road, and then by neighboring Batu Bandung.

Shortly after the road to Bandung Baru was paved in 1985, Javanese villagers there adopted ginger more as a garden crop intercropped with peppers and groundnut than in rotation with coffee. Coffee was developed at a distance from the village on cleared mountain slopes. Roads to all these villages are paved and can be considered satisfactory. This is of course an extremely important factor for a crop like ginger that is sold fresh and in substantial tonnage.

Table 6.1. Approximate Ginger and Rice Prices, 1950–70

Year	*Ginger (Rp/kg)*	*Rice (Rp/kg)*	*Ginger/rice price ratio*
ca. 1950	0.5	3	0.17
ca. 1955	1.5	6	0.25
1962	25	15	1.7
1965	10	20	0.5
1967	5	20	0.25
1968	10	25	0.4
1969	20	30	0.7
1970	32.5	32.5	1

Indeed, one of the last villages in the subdistrict to adopt the crop (in 1986) was Cirebon Baru, a village of Javanese migrants.[3] The road to the village was not paved until 1984.

Benuang Galing, the tenth village of our sample and inhabited mainly by migrants from southern Sumatra, grew only three or four hectares of ginger in 1990 and some ten hectares in 1992. Its remoteness, the state of the road, and the terrain tend to be problems. This village lacks a location rent for developing ginger. The hilly country and distances mean that coffee has an advantage. Indeed, occupation by men and coffee started in 1960 and coffee bushes have been felled and replanted ever since, although some ginger has been intercropped. Proximity to the road is not the only condition that hampered adoption of ginger in that village—the tight slopes of Benuang Galing and its lack of forest were also factors.

The case of Batu Bandung also demonstrates that location rent interferes with the forest rent factor and migrations. Production in that village, close to the road, started in the early 1980s when indigenous residents and migrants—who arrived in the early 1970s—cleared either secondary forest or their coffee groves and intercropped ginger with young coffee. This can be interpreted as an agroforestry system with 10-20-year-old coffee groves as a partial substitute for the natural fallow regrowth in a slash-and-burn system.

Production subsequently decreased in 1990–91, mostly because of the scarcity of secondary forest and coffee farms to be regenerated. Thus middlemen partially redirected their demand and credit operations, which influence where crops are planted, nearer to the roads. This redirection can be interpreted as giving location rent and capital—in this case fertilizer—an increasing role as a substitute for forest and agroforestry rents.

However, in the mid-1990s, in the village of Batu Bandung, farmers—primarily new migrants—cleared new forest plots farther from the village and road without fertilizer. The principles of forest rent and local shift of production fit the nutrient requirements of ginger. Although it is superficial, this approach to spatial diffusion clearly shows the main factors for development and possible recession of a crop like ginger.

Decline of Ginger

Since the mid-1980s, forest that can be opened to agriculture has been in short supply, and ginger production certainly suffered from that shortage of forest. Although the price tended to increase in 1990 and 1991, the production trend in the district seems to have declined. Although some middlemen promote fertilizer to help farmers grow ginger on fallows close to roads, their help and the price increase have not been sufficient to offset the shortage of forest land, the strongest determinant in ginger supply. Fertilizers bring nutrients that were formerly brought by slash-and-burn techniques when forest was abundant (wood-burning make nutrients ready to be assimilated by crops). Fertilizer, a major breakthrough, helps to reduce crop dependency upon forest, especially for such demanding annual crops as ginger and tobacco and for intensive tree-crop farming such as cocoa in Sulawesi (See chapters 14, 15, and 18).

Ginger production has been decreasing more rapidly since 1992–93, with the exception of the village of Batu Bandung, which still has forest relatively close. Disease, which increases risks and costs, is the main factor fueling the decrease. The best way to escape these risks is to clear forest in remote places, but available forest plots are scarce and very far away from villages and roads.

A second factor contributing to the decrease is a reverse in the coffee:ginger price ratio. In 1992 both prices were declining, but from 1993 to 1995, farmers benefited from the rapid recovery of coffee prices. This is one more illustration of the interaction between price factors and forest rent consumption. An economist could easily explain the decline of the ginger supply by a price change for ginger compared to coffee and other products. However, the relative recovery of the ginger price in 1996 and 1997 did not prevent the decline of ginger production (table 6.2). It helps to show that ecological changes (e.g., the disease outbreak and the relative decline of the forest cover) interacted with prices.

Smallholders responded to ecological and market changes as they had 10 years earlier in response to the market changes when they switched from tobacco to ginger. To take advantage of a price increase for chile, they moved from ginger, or ginger and chili, to chili and various market garden products. They also paid more attention to coffee in the late 1990s, especially in 1997 and 1998 when the financial crisis generated a windfall in nominal and real rupiah (Ruf and Yoddang 2001a).

Innovation Costs and Returns

The market is structured for two main types of ginger—ginger that takes nine months to produce and that is exported dry, a fairly traditional product; and the more recently introduced four-month ginger, which is exported dry to Japan.

Depending on the area available and soil types, the quantity of seed ginger required varies from 1 ton to slightly more than 3 tons per hectare, with an average of 2.6–2.7 tons per hectare. Yields vary by a factor of 3 to 10 times the quantity of rhizomes planted, according to the smallholder's maintenance, forest rent, soil type, fertilizer, and above all the quality of the planting material. Smallholders are quite explicit about the impact of forest rent on ginger and coffee yields (table 6.3). Although farmers may be a little optimistic about ginger yields in absolute terms, they clearly get a higher yield by clearing forest rather than a 10-year-old coffee farm or grassland fallow.

Substantial capital is required to purchase seed ginger, and variations in price lead to strong financial risks. For example, in 1989 the selling price of ginger was only Rp 180 per kilogram and Rp 200 per kilogram for the seeds. In 1991 the price of nine-month ginger rose to Rp 800 per kilogram; in 1992 the price fell below Rp 300 per kilogram before rising to Rp 450 and Rp 500 for the seed. This variability in price and ultimately in yield brings uncertain margins for the farmer (tables 6.4 and 6.5).

Table 6.2. Coffee and Ginger Prices and Ginger Production in Rejang Lebong District

Parameter	*1988*	*1989*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
Coffee price (Rp) (a)	1600	1250	1194	1157	1439	4943	4446	2773	2594
Ginger price (Rp) (b)	320	370	533	374	364	563	605	928	1154
b/a	0.20	0.30	0.45	0.32	0.25	0.11	0.14	0.33	0.45
Ginger production (t)	14,597	12,760			8,945	5,403			4,022

Source: Biro Pusat Statistics 1989–1998.

Table 6.3. Farmer Estimates of Ginger Yields, multiples of the amount of seed planted before the virus outbreak

	After forest clearing		*After coffee farm clearing and replanting*	
Village	*1st cycle*	*2nd cycle*	*1st cycle*	*2nd cycle*
Suro Baru	8–10		6–8	
Das Petah	8–10	4–5	5–7	2–3
Keban Agung	11		8–9	7
Batu Bandung	10–11	4–5	7–8	
Tapak Gedung	10	5	6–8	4
Bandung Baru	8		6–7	
Cirebon Baru	6-8		4–6	
Benuang Galing	8		6	

Source: Author's surveys, September 1997.

Table 6.4. Components of 9-month Ginger Costs and Profits, per hectare in 1989 for a yield of 3.5 times the amount of seed planted

Expenses/ha (excluding labor)	*Rupiah (1989)*	*U.S. dollars (1989)*
Planting material (2,200 kg × Rp 200/kg)	440,000	240
Fertilizer	0	0
Total	440,000	240
Gross revenue/ha (7,600 kg × Rp 180/kg)	1,368,000	760
Net revenue/ha (excluding labor)	928,000	520

Source: Author's surveys, September 1997.

Table 6.5. Components of 9-month Ginger Costs and Profits, per hectare in 1992 for a yield of 5 times the amount of seed planted

Expenses/ha (excluding labor)	*Rupiah (1992)*	*U.S. dollars (1992)*
Planting material (3,000 kg × Rp 500/kg)	1,500,000	750
Fertilizer	300,000	150
Total	1,800,000	900
Gross revenue/ha (15,000 kg × Rp 450/kg)	6,750,000	3,375
Net revenue/ha (excluding labor)	4,950,000	2,475

Source: Author's surveys, September 1997.

The net margin, excluding labor, varied from $520 per hectare in 1989 to nearly $2,500 in 1992. Expenses for land rental were negligible, adding Rp 50,000-100,000 to the cost. These revenues could have been improved even more if ginger had been planted the preceding year so the planter did not need to buy seed.

These are average revenue figures. Harvesting and transport costs increase considerably for remote fields where the crop must be carried to a road (the average additional cost for a yield of ten tons per hectare from a field one kilometer from the road is Rp 1 million per hectare. If a smallholder decides to use the *bagi hasil* sharecropping system when he is short of capital, he loses half the harvest in return for credit in the form of seed ginger and fertilizer.[4] When the *bagi hasil* system is applied to the case described in table 6.4, the net margin, excluding labor, is reduced to $1,700 per hectare. This is still very attractive if it is not further reduced by transport costs.

In 1991–92, the price of coffee fell to $0.60 per kilogram, and even on plantations in good condition with yields of 1,000–1,500 kilograms per hectare, the gross revenue from coffee was $900 per hectare at best, hence the increasing interest in ginger (before it was affected by the new disease).

Diffusion at Farm Scale and Rate of Adoption

If adoption of ginger is defined as the planting of a minimum of 0.1 hectare at least one year in three, nearly half of the planters in the subdistrict had adopted the crop in the early 1990s. Nevertheless, geographical analysis of diffusion by village revealed a strong differential, mainly according to distance from the road. The rate of adoption in a given year was probably about 20–30 percent of farms, with fluctuations related to the price ratio between ginger and coffee and to labor and land opportunities (rental or the availability of land following removal of coffee).

An average of 0.3 hectare is devoted to ginger on family coffee farms in a given year. Another stratum of holdings, limited in number but representing a large proportion of the cultivated area, seems to be formed by middlemen who rent and purchase land in order to grow several hectares of ginger.

Factors of Rapid Adoption

Once the plant material has been introduced, the "available capital" factor plays a fundamental role in a farmer's decision to start planting ginger because of the seed ginger constraint. One solution is sharecropping *bagi hasil.* The capital criterion is somewhat difficult to illustrate because differences in wealth and availability of capital are not great. Each village has a few villagers who have the necessary capital.

The availability of forest and old coffee farms ready to be cut down and replanted was a major factor for ginger adoption. Forest and, to a certain extent, old coffee farms bring the two basic required components—land availability and forest or agroforestry rent—that almost guarantee a successful growth and yield of ginger.

The road system was a factor in accelerating adoption of ginger. Transport costs considerably affect the producer price of produce with a high moisture content like fresh ginger. In comparison to dry produce such as coffee, the location rent conferred by the road is greater for ginger. The importance of transport costs has been calculated and clearly shows the rationality of concentrating ginger along a road suitable for motor vehicles, at least as long as insect pests and disease do not enter the equation.

Topography (flat land) and prices obviously play roles. Rising prices encourage the development of ginger at a slightly greater distance from the road or on slightly steeper land. Falling prices often bring the crop back to more favorable sites.

Factors of Recession

Factors influencing the decline of ginger adoption mirror the factors of rapid adoption. They are typical of a commodity cycle.

- *Available forest.* The shortage of primary and secondary forest is the structural factor.
- *Disease.* Diseases raise the risks and costs of production and make storage impossible. Thus even if a farmer intends to grow ginger the following year, he cannot keep tubers in reserve as planting material.
- *Lack of capital.* Even before the disease outbreak, ginger adoption was slowed by a lack of capital to buy planting material and fertilizer. Most farmers cannot grow ginger every year and have to buy their planting material or get it through credit and sharecropping arrangements. Since the outbreak, however, this constraint has increased dramatically. The disease makes the use of monetary inputs much more risky. In addition, it breaks the cycle of harvest-new planting by preventing farmers from storing seed.
- *Price.* Within a certain range, price changes do not appear as the only determinants of ginger supply. From 1986 to 1991, the price of ginger was increasing in current rupiahs and was sufficient to make the commodity attractive. However, the shortage of land and forest imposed a negative impact on ginger. From 1992 to 1995, the comparative price of ginger to coffee and production kept declining together, but in 1996 and 1997 the recovery of the price of ginger did not prevent the disease from reducing local production. Eventually in the late 1990s, most smallholders took advantage of increased prices for chili, planting it instead of ginger. Thus, the typical interaction among land, forest rent, and comparative prices once again explains a local commodity supply cycle.

Monetary Crisis of 1998

In September 1998 the price of 1 kilogram of coffee paid to the producer was about Rp 11,600, compared with an average price of Rp 2,600 in 1997. In the meantime, although ginger is exported, its producer price remained stable in current rupiahs. The ginger-coffee price ratio dropped to 0.09 in 1998, from 0.45 in 1997. Given the extraordinary price for coffee, At farmers in Kepahiang rapidly abandoned ginger. According to farmers interviewed in September 1998, very few of them were still planting ginger. One of them, a Javanese migrant, did not even harvest his ginger field planted after forest clearing in 1998. He consider the increased costs of harvesting (due to the labor costs rising from the skyrocketing price of coffee) and, more important, the increased transportation cost from the remote village of Batu Bandung. In most cases, transportation costs doubled (and this is one reason why coffee farmers benefiting from the windfall bought cars and invested in transportation services).

Even if a farmer had been willing to try ginger again on a fallow close to a road to lower transportation costs, and even if by chance the ginger escaped disease, making money on the crop would have been extremely difficult. After fallow, fertilizer is unavoidable for ginger, and fertilizer costs more than doubled in 1998–99.

Conclusion

For this type of produce and innovation, there are repeated reminders of the importance of capital as a limiting factor and hence credit as an accelerating factor. Anotoher important limiting factor is the distance of the ginger crop from the road (or in some cases the condition of the road). The case of ginger demonstrates a strong interaction among forest rent, location rent, and introduction of monetary capital.

- *1970s.* Ginger was primarily planted after forest clearing and benefited from the forest rent, good fertility, few weeds, no pests or disease, with resulting high yields, low production costs, and relatively high returns.
- *1980s.* Once the first forest plots were cleared, part of the ginger production moved to forest plots further away, but another part moved to areas close to a road. First, the increasing tonnage of the ginger crop required this adjustment to reduce transportation and marketing costs. Second, the credit provided by middlemen to buy fertilizer and plant ginger after fallow clearing, along with coffee cutting andreplanting instead of forest clearing, also made a contribution to make ginger planting on grassland fallow profitable.
- *1990s.* Despite the specific importance of location rent to a crop such as ginger, the role of forest-new crop rent strengthens over time. As usual, after years of introduction of a new crop, a disease developed.

Part of the phytopathology component of the forest–new crop rent was consumed. Since 1993, whatever the amount of fertilizer, it became increasingly difficult to grow ginger after fallow clearing and in association with the process of coffee clearing and replanting. with coffee replanting. The only way to obtain reasonable yields was to return to forest clearing. In 1997 the ginger supply came from relatively remote villages and plots. Until 1990–91, ginger was highly visible from the main asphalt road. No longer in 1997. Forest–new crop rent took over the location rent.

The ginger showcase brings other lessons:

- *Competition.* In a competitive situation, the comparative price of products plays a role in the decisions made by a trader in a manner fairly similar to those of a producer, especially because the fluctuation of margins is related to price.
- *Strife.* Although it is unfortunate for the people who have suffered, the history summarized above shows that a war or guerrilla movement may sometimes bring innovations.
- *Relationships.* On a more reassuring note, the case of ginger is a reminder that family links and employer-employee relationships contribute to the transfer of a crop or a technique. These links were particularly noticeable in the transfer of ginger from one village to another.
- *Adaptation.* The sustainability of upland agriculture does not mean that a specific commodity needs to be sustained at any cost. The Kepahiang case is a reminder that that rapid adaptation to environmental and market changes is necessary to sustain revenue. In this case, farmers moved from tobacco to giner to chili, while still gorwing coffee, the "safe crop" in the long run because of its strong international market.
- *Annual crops and tree-crop investment.* Finally, the advantages of annual crops such as tobacco until the mid-1980s, ginger until the mid-1990s, and chili in 1996–97, lie in their positive influence on decisions to replant tree crops, in this case coffee, to which they contribute financially.

Notes

1. Location rent is used in the sense of Van Thunen's concept — farm A close to a buying point has an advantage over farm B that is far away from the buying point. The difference in transportation cost of inputs and output between the two farms is the location rent. Because available forests are usually far away from roads and buying points, farmers who benefit from forest rent rarely benefit from location rent and vice versa (see Chapter 15).

2. Information gathered in talk with Ali Sunan's son, Alwi Hakim, of the village of Pulo Geto.

3. In the early 1950s, this village was part of an official transmigration project. However, in the late 1950s, most Javanese transmigrants left the village to escape risks related to a local uprising. Only six families came back in the 1960s. Since the 1970s, spontaneous migrants from west and central Java arrived and finally took over the land.

4. “Bagi hasil” means “sharing of the result” or “sharing of the product.” When applied to tree crops, this contract is usually set up between a plantation owner and a worker. The worker is in charge of the maintenance, harvesting, and post-harvest operations, and receives only one-fourth to one-third of the production. The main part is supposed to pay back for the land rent and the investment made in the plantation (See coffee and cocoa chapters). Here in the case of ginger, an annual crop, the main investment is the seed plus some capital to buy fertilizers. If that seed and fertilizers are provided from outside, in that case often by a middleman, the farmer becomes *bagi hasil* on his own land and has to share his ginger production on a 50–50 basis in exchange for the seed credit.

7

Tree Crops and Paddy Cropping Systems: Cocoa in Malinau

François Ruf and Yoddang

According to the forest rent theory, most cocoa farmers should plant their trees immediately after clearing the forest; however, many choose instead to plant after a four- or five-year fallow period. This short fallow option is taken only when a region has no available forest left, either primary or secondary, and when farmers enjoy strong location and fertility rents. A location rent is defined by the additional net margin related to the lower transportation cost for a product coming from a farm plot close to the marketplace compared with a farm farther away. A fertility rent refers to soils that have a natural fertility such as volcanic soils or alluvial plains, hence a lower production cost and a higher margin compared with less favored regions (chapters 1, 6, and 15). Otherwise, like most cocoa success stories elsewhere in the world, cocoa adoption in Indonesia means deforestation.

This chapter looks at one particular area, the Malinau regency (part of the Bulungan district in East Kalimantan province), to try to determine why some cocoa smallholders choose to clear short fallow rather than primary and secondary forest. The Malinau regency was still widely forested in the late 1990s. Most of the Dayak population lived in the mountainous hinterland. Local Dayak migrations to the river started only in the late 1950s and remain limited. Until recent years, a full day was required for a trip by wooden boat from Malinua to Tarakan on the coast. This may have hampered migrations from outside Kalimantan and saved the forest for a while.

What conditions are necessary for cocoa to be an agent of reforestation rather than deforestation when forest is still available? Surprisingly, cocoa adoption in the uplands seems to help promote rainfed and irrigated paddy fields in the lowlands and thus saves some forests from the spread of slash-and-burn for paddy. What are the conditions that explain such a scenario?

Sustainability of Slash-and-Burn

Although some smallholders still try to clear forest to grow paddy, most upland paddy growers generally depend on the fallow system. In Malinau they even manage to shorten the fallow duration to only three or four years, although Chabrolin (1965) observes that the "minimal" fallow period varies widely from one region to another. This is less than the 5–12 years often quoted in the literature and shows that slash-and-burn may be sustainable and a forest-saving technology. As long as population density remains relatively low, forest is not substantially destroyed by paddy slash-and-burn. Forest is cleared when a smallholder wants to increase his ownership or when a smallholder's son wishes to create his own farm. Forest remains relatively intact because the population does not grow very fast.

The main deforestation factor is clearly commercial logging, followed by migration, which is accelerated by logging activities. In Malinau the logging-related deforestation rate accelerated enormously beginning in 1993, but the process was still at an early stage in 1996.

Smallholders who embrace the slash-and-burn system recognize that they face more weed growth after fallow compared with a paddy field created after forest clearing. How can we explain their choice with respect to fallow?

In 1996, in terms of paid labor, clearing one hectare of forest cost about Rp 75,000 ($32) for slashing the undergrowth and about Rp 100,000 ($43) for cutting down the big trees with a chainsaw. Clearing one hectare of three-year fallow cost approximately the same for slashing (Rp 75,000), but only Rp 50,000 ($21.50) for cutting small trees. Slashing is easy for farmers to do themselves. The main problem is felling trees. Because farmers are now familiar with the chainsaw, they have little interest in using an ax to cut the big trees of primary forests by hand, as they once did. A chainsaw, however, requires cash, which is the main constraint for farmers. Farmers choose the *jakau* (fallow) because they can use an ax to clear the small trees and do not need cash for clearing.

Malinau smallholders stress that soils and climate are good enough so that trees can overcome weeds after 18 months of fallow. Deforestation, however, has just started. The forest atmosphere is still relatively preserved at the district level, so whenever farmers plant paddy and cocoa after a short fallow, they still benefit from some components of forest rent at a regional level. Farmers can thus afford to shorten the fallow duration to three years. Even after clearing a three-year fallow, the cost and labor requirements for weed control remain reasonable.

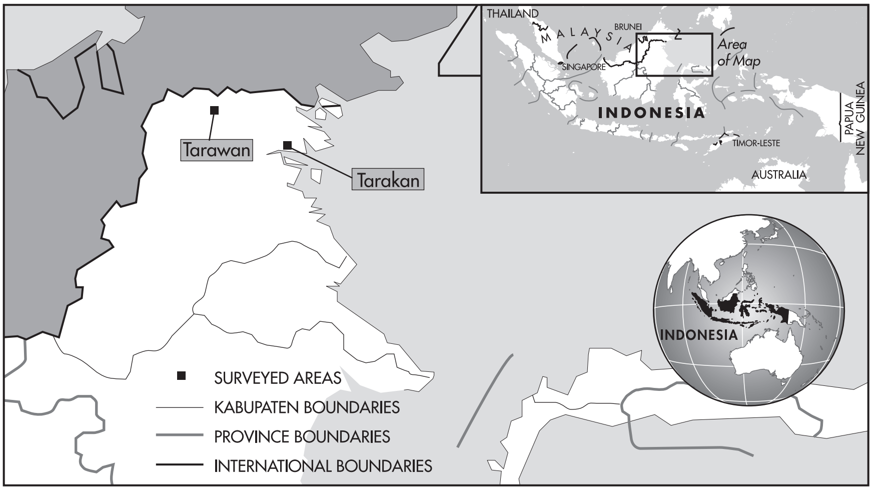
In short, slash-and-burn in a short fallow system and forest preservation appear to be two interdependent components of a sustainable shifting cultivation system.

Innovations: Cocoa Adoption and Rainfed *Sawah*

We investigated cocoa adoption in the hills as a conversion from paddy *ladang* into a more permanent tree-crop system.

In the early 1980s Malinau smallholders grew a few hundred coffee trees and a few productive clove trees, and they established a few acres of rainfed

Map 7.1



sawah in the lowlands. (*Sawah* is a paddy field that benefits from an irrigation network, while rainfed *sawah* is a paddy field with dikes. Rainfed *sawah* relies on rainfall and is less efficient than *sawah,* but the dikes allow some water control.) By and large, though, the Malinau smallholders remained paddy shifting cultivators. When cocoa started being widely adopted as a cash crop in the 1980s, it developed at the expense of forest and *ladang,* and fallow was thus converted to cocoa (plus some fruit trees).

The relative abundance of lowland acreage and 3,000 millimeters of annual rainfall enabled a high percentage of smallholders to maintain rice self-sufficiency by switching from paddy *ladang* to *sawah.* Although rainfed *sawah* technology in the valleys already existed, cocoa innovation accelerated the adoption of *sawah.*

In the case of Malinau, cocoa adoption thus led to a double trend of more permanent cultivation in uplands and lowlands. Cocoa and *sawah* adoptions were spontaneous, although both cocoa and rice had been noticed and encouraged by extension services in recent years. In the subdistrict, various cocoa projects were triggered in the 1990s, and some canals were built to improve the rainfed paddy *sawah* created by smallholders.[1]

Farming Systems

An example of the status of cultivated land in 1995–96 in the village of Tanjung Lapang was provided by the chief. With 7,000 hectares of forest and logging concession remaining plus acreage occupied by villages, roads, and rivers, the village covered a total area of 11,800 hectares. The village population was about 2,650 people, or 560 families, with an average family controlling about 7 hectares (table 7.1).

These figures reflect the relatively low population density but do not give a clear picture of land ownership. Part of the *jakau* (land under fallow) is

Table 7.1. Use of Cultivated Land in the Village of Tanjung Lapang, 1995–96, hectares

Crop	*Total area used*	*Area used by average family*
Permanent cultivation	1,125	≈ 2.0
Cocoa	525	1.0
Coffee	250	0.5
Paddy *sawah*	350	0.6
Shifting cultivation system	2,900	≈ 5.2
Cultivated paddy *ladang*	900	1.6
Jakau (land under fallow)	2,000	3.6
Land per family, plus forest reserves for some families	—	≈ 7.0

Sources: Authors' estimation based on interviews with the village chiefs and extension workers.

now included in a logging company concession, and frequent land conflicts occur. Farmers still consider this land to be their own and need it to maintain their self-sufficiency in rice.

One of the important features of the Malinau district, and Tanjung Lapang village in particular, is the ethnic structure of the population. Although most are Dayak people, they are not strictly indigenous. Especially in Tanjung Lapang, almost all Dayak are migrants from upstream regions of the Mentarang river, such as the Kerayan district. The first Kerayan people (or their parents) came to the Malinau region in the early 1960s and brought the rainfed *sawah* technology that then was adopted by other migrants some time after they adopted cocoa.

Indigenous people of Tanjung Lapang are called Tidung, and most left the village after selling their land or part of their land to the Dayak migrants.[2] Only two Tidung families are still in this village. Tanjung Lapang may thus be considered as a village of migrants even though 80 percent of the migrant families came from a comparatively short distance away. These families are Dayak Lundaya. They are indigenous in the sense that they are Dayaks, born in East Kalimantan, and share almost a common culture with the Tidung. However, they were not born in the Malinau regency and thus are considered as migrants by the Tidung. This indigenous-migrant concept is important for understanding how cocoa and rainfed *sawah* are expanding in the region.

The remaining 20 percent of families are migrants in the more classic sense because they come from other islands (Batak, Bugis, Irian, Java, and Timor). They are mostly employed by the logging company and are only part-time farmers. Some of them already own cocoa farms.

In Tanjung Lapang, all migrants were spontaneous, but in the neighboring villages some transmigrant schemes contributed to the rapid changes in the region. Three main factors pulled migrants to the region:

- *Logging.* In the 1980s and 1990s a number of migrants were attracted to this region by salaries offered by logging companies, five of which are still operating in the Malinau subdistrict.
- *Land.* In the early 1960s migrants were drawn to the area by the available land and relatively rich soils along the river and by the school and other new modern facilities, which did not exist in their mountain villages.
- *Forest products.* As long as forests are not destroyed, nontimber forest products such as rattan and *gaharu* (used in Chinese medicine and cosmetics) remain extremely attractive. Chinese and Bugis traders guarantee a price to any volunteer gatherer, including migrants.

These three main incentives are extremely important for understanding and anticipating regional changes. For example, one negative impact of logging is destruction or exodus of wildlife (deer, wild pigs, birds), which used to be the main source of protein and sometimes a source of cash for Dayak people. This is a lost part of the forest rent that smallholders must overcome. One way smallholders compensate is by planting cash crops such as cocoa and using the proceeds to buy fish (for the protein) imported from the sea coast and other basic goods.[3]

History of Cocoa in the Region

The first cocoa trials in the region are said to have been conducted in the early 1960s by at least two Dayak smallholders who used cocoa pods smuggled from Sabah in Malaysia to start a few dozen trees. That was the very first step of the local cocoa story. However, since there was no ready market in Malinau, cocoa adoption did not spread—until 1978, when Perminaseng, a Dayak migrant farmer from the neighboring district of Mentarang, planted 3,000 trees (about 3 hectares). A friend planted 1,800 trees (about 1.8 hectares), and a Chinese manager of a logging company planted 20,000 trees (about 20 hectares). Thus, from scratch, three people developed about 25 hectares of cocoa. This seems like a spectacular start considering they were working in a remote area with no established market. However, this seemingly massive initial adoption is not uncommon in cocoa or, for that matter, in other tree crops. Excellent information on existing markets in a neighboring country or region and the need to produce a minimal tonnage to create a market are the two key factors explaining these spectacular starts.[4]

Perminaseng got the information about growing cocoa from his uncle during a trip to Sabah in 1976. His uncle, a supervisor at a cocoa estate near Tawau (the Malaysian city and port at the border between Indonesian East Kalimantan and the Malaysian Sabah province), advised him to plant cocoa and started to teach him how to make seedlings and how to plant. In addition, he promised to come to Malinau once the trees were planted to teach about pruning.

Perminaseng kept the idea in mind. Because he was not an influential leader, he had to find people to share the risks of launching a new crop and achieving a minimal tonnage. He found two people two years later. In the meantime, he became a civil servant in the education department. In 1978 he was thinking about how to smuggle pods from Malaysia when he found the 20–50 cocoa trees planted in Malinau in the early 1960s.[5]

The Chinese manager financed the purchase of pods from the owners of the 20–50 trees. Pods cost Rp 200 (8 to 9 U.S. cents) a pod (a high price), and Perminaseng supervised seedling preparation in 1979–80.[6] It was the second decisive step of the local cocoa story. With no cocoa market in Malinau, the three cocoa pioneers started lowering their maintenance. However, in 1983 Perminaseng's uncle visited for a week to teach him how to do the pruning. In the same year, a Bugis named Anwar, who was smuggling flour, sugar, and other food products from Malaysia to Malinau, noticed the relatively high price of cocoa in Tawau and started to buy cocoa from the three Malinau growers and smuggle it to Malaysia. This was an additional source of profit without additional cost because he was already traveling to Malaysia. Then another Bugis from Malinau started the same business the following year. This established a market and a price for cocoa in Malinau, which led to cocoa planting. This was the third decisive step.

The fourth decisive step occurred when Bugis cocoa traders/smugglers based in the Sebatic Islands started visiting Malinau in 1990 and then sending their boats to buy and transport cocoa. All smallholders took this as a clear signal that there was going to be a long-term market for cocoa in Malinau, despite the area's relative remoteness.

In short, smuggling and labor migrations were tools of innovation and new sources of foreign currency. This combination has played a vital role at all stages of cocoa adoption, which is a perfect example of endogenous innovation by farmers and traders, working within a community that seized outside opportunities offered by smuggling, labor migration, and family networks. The copying effect becomes an investment multiplier.

Innovation Costs

The first innovators needed only two to five pods to plant 50 trees. For the three later adopters in 1979, information costs were already covered by a trip funded for family reasons and by existing knowledge among the relatives working in Sabah estates.

As planting material was brought in, the three adopters just needed to buy it. As in most cocoa stories, they had to pay a relatively high price. The two first cocoa adopters profited from their innovation by selling pods at an equivalent of 5,000 Rp per kilogram (about US$8 a kilogram in 1979).[7]

After a possible further rise in the price per pod due to a sudden increasing demand for planting material, successive waves of followers benefited from a rapidly declining price due to increasing supply. In 1989–90, when the extension services launched a cocoa planting project, the seedlings were free.

As with most tree-crop adoption in wet tropical regions, farmers benefit from a relatively low opportunity cost for intercropping cocoa with paddy. At least part of the forest clearing and weed control costs are supposed to be covered by paddy. Although average forest and fallow clearing costs can be estimated, most clearing operations are done by family labor and mutual aid groups.

Except for rare cases of herbicide for weed control after clearing the three- to four-year fallow, cocoa planting is done without any monetary inputs. Except for some pesticides to control pod borer given within the framework of Dinas projects, most farmers do not buy any inputs. In contrast, however, in the Moluccas where pod borers have been a problem for years, pesticides are available in markets. This means that a minority of smallholders have already started spraying to fight the cocoa moth.

Although most smallholders still apply a no-cost strategy to all steps in cocoa adoption from planting to pod borer problems, spontaneous adoption of herbicides and pesticides is beginning. Here again, we have a clear effect from the proximity of Malaysia and the cocoa experience (see chapters 14 and 15).

Innovation Returns

As in other regions, yields range widely depending on soil, maintenance, and choices about monocropping or intercropping. In most cases, except near farmers' houses where cocoa trees may be "smothered" in a traditional fruit tree garden, cocoa has been adopted as a monoculture. Potential yields are about 2,000 kilograms per hectare. However, because of the relatively low orchard maintenance (no fertilizer, weed control, or pruning),[8] we estimate the average yield to be 1,000–1,500 kilograms per hectare before pod-borer infestation. Even at the relatively low price of Rp 1,800 per kilogram in 1996 (caused by the remoteness of Malinau and its low production), net income is approximately Rp 2,000,000 (US$900). By local standards, this is a windfall—one that is typical of cocoa success stories.

Pod borer infestation seems to have limited this windfall to only a few years; late adopters may have an even shorter period in which to realize such profits. Although farmers are quick to say their pods are 90 percent infested, the actual economic loss has not yet reached that level. Even in infested pods, parts of the beans are still saleable. We estimate the 1995 loss at around 50 percent. Because there are no monetary costs, even yields of 300 to 500 kilograms per hectare earn significant income for the Malinau smallholder.

Rate of Adoption

At Tanjung Lapang approximately 400 of the 560 families have already adopted cocoa. Most of the 160 nonadopters are employees of the logging company and newcomers. The average area for cocoa adopters is approximately 1.4 hectares. At Tanjung Lapang the smallest growers have some 400 trees (around 0.3–0.4 hectare), whereas the biggest adopter seems to own 4 hectares. In Malinau city, where Bugis and Chinese middlemen were among the first adopters, the largest cocoa adopter owns 25 hectares.

Abandon the Crop?

Were farmers discouraged when pod borers struck some relatively young orchards quite hard? The Dayak people still have alternatives to cocoa (see below), and they can abandon a new crop or activity as rapidly as they adopted it. For tree crops, abandonment of the innovation is not the absence of maintenance and harvest. As long as the pest does not damage the tree, the capital is still there. Cocoa is considered abandoned when the trees are cut down. According to this definition, only a small minority of smallholders have abandoned cocoa.

Impact of Cocoa Adoption at the Regional Level

For cocoa adoption, the relevant regional level is a sample of the four subdistricts that form the local cocoa basin. The entire regional production is marketed via the Sesayap river with Malinau city as a collection point.

The four subdistricts are Malinau, Lumbis, Mentarang, and Sembokung; the latter three produce far less cocoa than does Malinau. No production statistics have been seriously collected; because there are several middlemen from Malinau and Sungai Nyamuk, accurate tonnage estimates are problematic. Let us try an appraisal through two approaches.[9]

In 1995, according to extension services, the cocoa area of Malinau reached 3,200 hectares. In 1993 it might have been 2,500 hectares, with trees on 2,000 hectares already producing. Because the orchards were generally still very young, the average yield was estimated at 800 kilograms per hectare, or 1,600 tons. Because the other subdistricts follow far behind Malinau, the 1993 production of the entire region probably reached some 2,000 tons, possibly a little more. Then the pod-borer outbreak occurred in late 1994. Based on the distance of orchards from the main pod-borer areas, the loss of saleable beans was estimated at 30 to 75 percent. The new plantations coming into production were far from being able to offset the loss. The 1995 production was estimated at about 1,000 tons.

Interviews with the middlemen led us to the same conclusions: local production reached 2,000 tons or slightly more in 1993 and dropped to some 1,000 tons in 1995. The drop, however, was not irreversible. A number of smallholders and middlemen remained confident and optimistic. They believed in pest cycles and the efficiency of pesticides.

Factors of Rapid Adoption

Considering that the first real cocoa adoption started only in 1980, some 3,000–4,000 hectares in 1996 and nearly 80 percent adoption in the neighboring villages of Malinau is a nice score. In chronological order, a number of factors were important in this rapid adoption.

- Contacts with Sabah estates through labor migration, family networks, and active smuggling enabled farmers to adopt cocoa and smugglers/middlemen to start buying it.

- Northeast Kalimantan still benefits from a vast forest and relatively good soils suited to cocoa.[10]
- Motorization of local wooden boats started in the 1960s and developed in the 1970s and 1980s.[11] In addition, speed boats further reduced the Tarakan-Malinau journey from one full day to only four hours in the 1980s. Cocoa grown in Malinau can be shipped to Tarakan and then to Tawau (Malaysia) more efficiently.
- Local migrants from upstream Dayak districts were the main cocoa adopters.
- The decisive arrival of middlemen and boats from other regions in Malinau was a clear signal to farmers that the cocoa market was sustainable.
- Two to three Dinas projects helped farmers to set up a total of 400 hectares of cocoa between 1989–90 and 1995–96. As in Sulawesi, beyond the usually much appreciated supply of seedlings, these projects indirectly encouraged spontaneous adoption by displaying an official interest in a new crop.

These factors are almost universal in successful cocoa adoption stories. In this case, an additional factor, the role played by Indonesian Bugis, must be credited. Although they are a small population in Malinau, the Bugis play an important role as middlemen and exporters/smugglers to Malaysia. Having local Chinese collectors selling their cocoa to Bugis middlemen is not the least of the amazing aspects of the local historical development of Northeast Kalimantan.

Despite these factors and low land prices, compared to the Sebatic islands and Sulawesi, this adoption has not led to a real cocoa boom. Why?

Constraints to Adoption

Small Labor Supply

Local migration from Dayak mountainous districts into the cocoa growing region is limited by the relatively low population of Dayak.

As of 1996 Bugis based in Malinau did not call upon relatives to help them with their work in cocoa orchards, largely because of continued uncertainty about cocoa marketing and pod-borer prospects. As long as Bugis are not sure of success, they do not call their relatives, unlike the Bugis from the Sebatic islands, who do call relatives and friends.[12] Migration is considerably hampered when these family networks do not work.

This may change in the future for at least two reasons. First, if smallholders manage to control pod borer with pesticides, the conditions required for success will be present. Second, Bugis from Sebatic Island may want more land and may therefore move to new places such as Malinau.

Alternatives to Cocoa as a Source of Cash

Is it the right time for migrants to take up massive cocoa or other tree-crop operations? Probably not yet. Logging companies attract migrants, but these migrants are not yet fully involved in agriculture. They still have money to make from logging.

For nonwage earners, forest products remain a source of cash, and there is no need to invest. They still benefit from the precommercial agriculture stage by collecting natural resources without destroying them. When they need cash, they may go to the forest and collect rattan. If they make a deal with a person owning a chainsaw, they can also collect precious timber and sell it on the local market. As long as this is done by native people to cover their limited cash needs, natural resources are not substantially harmed.

Food Self-Sufficiency

The main objective of a Dayak shifting cultivator is still to achieve food self-sufficiency for his family. If cocoa will help him reach this objective, he will take advantage of this crop, but he will not try to maximize income by clearing forest and spreading cocoa plantations beyond the labor capacity of his family.

Risk of Pest Infestation

Because the cocoa pod borer may strike orchards, cocoa may not be a low-risk investment and is no longer considered as a guarantee of rice purchasing power. Some Dayak smallholders may thus give up their cocoa trees almost as rapidly as they planted the seedlings.

Access to Markets

Although access to markets should improve year after year (unless the Malaysian border starts being controlled, which would be a disaster), it will still take years before Malinau smallholders can really benefit from high producer prices.

Conclusion

The Dayak are "indigenous migrants," originally from Lundaya and other districts several days' walk up the river. Their cocoa-growing and rainfed *sawah* strategies are a blend of those common both to indigenous people, who tend to emphasize food security and heritage transfer (an environment-friendly strategy), and to migrants, who generally focus on income accumulation by tapping the environment and forest rents with little concern about destruction of natural resources.

Without any mass migration, shifting cultivation accompanied by some herbicide use addresses the main problem of short fallow. In addition, rice supplies are supplemented by a small amount of rainfed *sawah*, thereby substantially preserving natural resources and enhancing sustainability of these systems. Even though cocoa production has not enjoyed the same boom associated with logging and mass migration, several interesting innovations have appeared that considerably improved the standard of living of most of the population.

The remoteness of the region has long hampered private and state companies from setting up there, which has limited pressure on natural forests.

Malinau is now at a crossroads where continued migration could either remain environment friendly or result in heavy natural resource use. Increased logging will increase incomes in the region, a phenomenon under way since 1993. But extensive logging is detrimental to shifting cultivators and forest gatherers. It remains to be seen whether agricultural innovations will be able to keep up with the transformation of the ecosystem. It is also not yet clear whether the potential regional tree-crop development (cocoa cropped by smallholders and oil palm grown on large estates) could occur by establishing a balance between deforestation agents (common to tree-crop farming) and reforestation agents (not so common).

The region's assets include its proximity to the Malaysian Sabah, experience obtained on Malaysian estates, and the relatively free environment that facilitates product and population flows. These assets must be preserved and promoted. The regional dynamics are certainly enhanced by the limited informal taxation. As in the Sebatic islands, the dynamics in Malinau seem to confirm that free exchange along the borders could definitely benefit small merchants, entrepreneurs, and families who live by farming.

Notes

1. The cocoa projects include PKT (Pengembangan Kawasan Terpadu), a regional integrated development; BP3UTTM (Bagian Projek Pegembangan Usaha Tanaman Terpadu Malinau), a component of the regional integrated development project of Malinau; PIP (Proyek Intensifikasi Perkebunan), a tree-crop intensification project; and P2RT (Proyek Peningkatan Pertanian Rakyaat Terpadu), another tree-crop project with lighter means than the previous one.

2. Although Tidung people may be considered as a subgroup of Dayak, a number of them did not want to be called Dayak since they wished to be seen as city dwellers, not villagers.

3. This planting includes planting after *jakau* clearing as well as after forest clearing, which can be interpreted as a sort of reforestation, especially when smallholders intercrop various fruit trees.

4. Other examples: rubber trees in Indonesia (Gouyon and Levang 1993); cocoa in Indonesia; see also the Sulawesi case and its typical scenario. One local Bugis leader convinced a number of farmers to plant cocoa before there was any local market by guaranteeing land access to them and by testifying to what he had seen in Sabah (Ruf 1995c; Ehret and Yoddang 1996).

5. That is why some cocoa farms in the 1980s were still partially planted with amelonado types, while amazons and hybrids of upper amazons have totally taken over amelonado in other countries, including Côte d'Ivoire. This is also the case in some parts of Sulawesi where planting material was introduced from (then British)

Sabah in the late 1950s after a local uprising. Several types of cocoa were smuggled to Sulawesi, including old amelonado types. However, upper-Amazon types rapidly took over.

6. This relatively high price would mean that the two first local cocoa innovators who owned 50 trees already understood the upcoming value of cocoa beans. Rumors about the good prices received for cocoa were coming from the Sebatic islands (close to Tawau).

7. In 1979, the international price in New York was about US$2 a kilogram.

8. Beyond local economic alternatives to the cocoa intensification option, the lack of pruning also means that the Malaysian experience still has to be transferred to Dayak smallholders. Although most of them have relatives working on Sabah estates, the latter apparently still have a limited influence on them compared to the Bugis (see chapter 14).

9. The Sungai Nyamuk village, on the coast of half-Indonesian, half-Malaysian Sebatic island is the strategic point before the Malaysian border and Tawau market.

10. The remoteness of Malinau and upstream regions and the total absence of infrastructure, except for the river and a lawn airstrip built by missionaries, may account for the relatively low deforestation rates compared with other regions of Kalimantan. However, in the 1990s, logging seemed to make up for the delay quite rapidly. The logging company has tremendously accelerated deforestation since 1993.

11. The increasing use of motor boats is also partially related to labor migration to Sabah, including the Dayak. Boat motors are the main items brought back by Dayak from Sabah to their villages, followed by sewing machines (personal communication from Geneviève Michon, Institut pour la Recherche et le Développement (IRD)/ International Centre for Research in Agroforestry (ICRAF) ecologist). Purchase of both items may be interpreted as nonagricultural innovations that make family incomes more diversified and thus more sustainable.

12. We estimate that 80 percent of the Bugis cocoa planters on Sebatic Island were formerly workers in Sabah (not only in cocoa estates) before coming to this island. About 20 percent came directly from Sulawesi.

8

From Alley Cropping to Cashew Farms

François Ruf and Frederic Lançon

Flores is an island at the heart of the small archipelago between Bali and Timor. The eastern part of this archipelago is an Indonesian province called Nusa Tenggara Timur, and Flores is part of it. This chapter examines the adoption of cashew as a new tree crop in the Sikka district, an already densely populated and cultivated region of Flores. Cashew can be viewed both as a mean of reforestation for degraded *ladang* and as a source of relatively safe and sustainable income.

Although cashew has been grown casually for years in Flores, especially in the eastern part, its introduction as a tree crop can be considered innovative because it is now produced using a more intensive method—higher planting density. According to farmers, some trees were planted in the 1970s, but they did not trigger much interest since there was no market. Cashew was truly launched as a cash crop on a larger scale in the early 1980s, at least on the coast. For example, in the village of Krigna, cashew was said to be unknown until 1982, when extension services promoted it for the first time. In the hilly part of Sikka district, its introduction and promotion seem to have started only in 1990. In some other parts of Flores and more generally in Nusa Tenggara, cashew expansion may have started a few years earlier. These observations and farmers' statements seem to agree with the available statistics (table 8.1). Up to the mid 1980s, cashew acreage remained marginal in all of Nusa Tenggara.

Around this period of the early 1990s, extension services introduced cashew as a component of an alley-cropping system—planting cashew along terrace lines and maize and other food crops on the terrace plains. However, the narrowness of the terraces and farmers' enthusiasm for cashew does not leave much space for food crops. In fact, the alley-cropping system is effective only during the first two or three years when the cashew trees are young and small. Most of the cashew adoption does not follow the alley-cropping system but rather monocultural farm plots.

Table 8.1. Planted Area of Major Tree Crops in Nusa Tenggara Province ('000 ha)

Crop	*1975*	*1980*	*1987*
Coconut	7.4	9.2	14.1
Coffee	1.3	5.0	3.7
Kapok	0.3	3.8	3.1
Cashew	0.5	0.7	3.0
Candlenut	—	1.1	2.1
Cloves	0.1	0.1	0.4
Cocoa	0.0	0.1	1.1
Cotton	0.0	—	0.2

Source: Barlow and others 1990.

Tree Crops in Farming Systems

In Sikka the farming system is dominated by shifting cultivation of food crops on 85 percent of agricultural land (Barlow and others, 1990), along with old and new projects aiming at introducing terraces and hedgerows intended to reduce erosion and make food-crop systems more sustainable and less dependant on a long fallow.

Tree crops in Sikka are dominated by coconut. In his report on soil conservation experiments, Metzner (1976, p. 105) noted that "the people try to compensate for the disadvantage of the relatively short rainy season by cultivation of perennial crops. Since the beginning of this century, intensive coconut planting occurs up to an altitude of 660 metres; Sikka is now the most important copra producer of the province."

The production of coconut, however, is declining. In the 1980s observers noted the lack of replanting and thus a coconut aging trend that would unavoidably lead to lower production (Barlow and others 1990). This trend was confirmed by people we met during our mission. Sikka coconut production is no longer exported to oil processing plants in Ujung Pandang. The market is reduced to some exports to East Java where some local coconut oil producers try to survive (they face strong competition from cheaper palm oil).[1] In addition to a low replanting rate, a pest outbreak has also reduced production. This constraint has not been solved despite massive measures taken by extension services that organized aerial pesticide spraying.

Cocoa is the second largest perennial crop produced in Sikka. It was introduced during the 1950s, but its production is confined to the highest part of the district where there is sufficient moisture. In the lowest part of the district near the sea, annual rainfall is less than 1,000 millimeters and concentrated in a three-month period. Cocoa can not be grown satisfactorily in this climate. With poor prospects for the expansion of traditional tree crops of the district, one can easily understand farmers' interest in increasing their cashew production.

In 1990, only 9 percent of the farms in Sikka district were involved with tree-crop production. Food-crop production was the main agricultural activity for most farms, and maize was the main crop. Households supplemented their incomes by selling small livestock such as chickens and pigs, along with handicrafts (almost every farm had a loom to weave *ikat*, the traditional material in eastern Indonesia).[2]

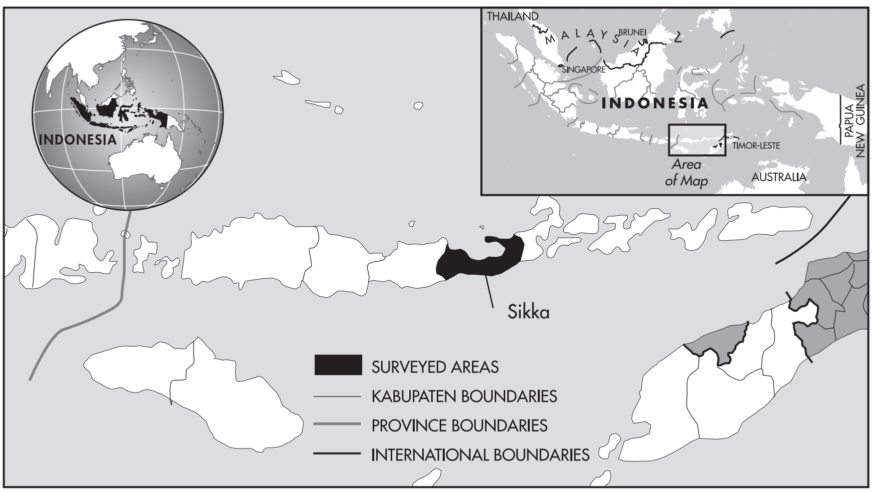
The total land controlled by each family was 0.5–3.0 hectares, with an average of 0.5–1.0 hectare devoted to food crops. However, at least a few farmers stated that they had 10 hectares or more. This also seems in line with the available statistics. For Nusa Tenggara Timur province overall, 15 percent of households owned 40 percent of the land.

If we consider that local shifting cultivation requires a minimum of three or four years of fallow, it is easy to understand why a high proportion of smallholders must find additional land. There is much sharecropping and land renting; however, land rents remain quite low and are often based on pledging a pig. This land pressure in the Sikka district also suggests dire constraints to adoption of new tree crops such as cashew.

Introduction of Cashew

In the villages we visited, cashew seedlings and recommendations for planting them were provided by projects, managed either by agricultural extension services or forestry services. In all cases, seedlings and their associated packages were distributed to farmers through the village chief. As a result, large numbers of farmers often adopted the new tree crop simultaneously. Even with only a few trees per household, this simultaneous adoption may have played a critical role in reaching a production level high enough to attract middlemen. The quality of the nuts themselves, which is related to the dry climate, also appeared to be another factor in the rapid development of marketing connections.

Map 8.1



The main objective of the forestry department's interest in cashew was to support reforestation. By chance, in connection with trends on the world market and rapid development of significant production volume, cashew prices rose and transaction costs were not too high. More and more smallholders began to plant cashew on their own without the support of official projects.[3]

Cashew was usually planted on existing terraces, intercropped with food crops but only during the first two years; in most cases, seedlings were provided free and even accompanied by a subsidy. If they owned land, and if the number of planted trees remained compatible with a fallow for necessary food crops, farmers adopted cashew at low marginal costs. If they wanted to plant beyond that threshold (approximately one hectare), the planting cost was much higher.

With a yield of 0.5–1.0 kilogram of nuts per tree, about 700–800 kilograms per hectare (without fertilizer), and a nut price of about Rp 1,700 per kilogram (compared with Rp 400 for a kilogram of maize), cashew was a very attractive opportunity for farmers. On the cost side, apart from planting operations, cashew requirements in labor are limited to weed control and harvesting, often done by women. In addition, the fresh fruit can be used to feed pigs.

Constraints and Adoption Factors

If the definition of adoption is ownership of a minimum of 10 trees, almost all farmers in Sikka who owned at least a backyard were adopters. If the definition is based on planting 300 trees or more, the rate of adoption varies from 5 to 50 percent according to land ownership, types of villages, and ecology.

Because the chief of the village controlled seedling distribution, the status and relationship of farmers with the chief sometimes influenced the rate of adoption. For example, in one village families whose parents were migrants to the small region were not given any seedlings. Most adopters interviewed owned between 100 and 1,000 cashew trees (0.1–1.0 hectare).

In terms of continuous adoption, the first constraint was land, with status in the village second, at least in the early stages of adoption. This later factor will certainly change later on when planting material will no longer be the limiting factor.

A very small land area obviously limited the number of trees but did not prevent adoption at the apparent expense of food security. Smallholders who own less than 1 hectare and who need to cultivate 0.5–1.0 hectare of food crops every year cannot theoretically adopt cashew. However, some do. By lowering (but not eliminating) the area for food crops, these smallholders take the risk that the tree crop will raise the family's purchasing power and thus become a component of food security.

Metzner (1976, p. 106) observed a similar tradeoff between food crops and tree crops for coconut:

> With the spread of coconut plantations, however, the area available for dry farming has been reduced; although annual crops are often planted between the trees, yields are lower when this is done. . . . The consequences were increasing dependence on food imports and on fluctuating copra price. In times of low copra price, the proceeds from sales of copra were often insufficient to cover the farmers' minimum food needs.

Besides these structural constraints, tree adoption has been affected by contingencies such as the 1992 earthquake. Many smallholders mentioned its devastating effects on terraces and on young cashew trees planted on these terraces. Adoption rates measured in number of producing trees were somewhat hampered by this earthquake.

The main factor leading to rapid adoption and an increasing continuous rate of adoption per household was an increase in the price of cashew. Since the early 1990s, even without subsidies, all households that owned enough land would have planted plenty of cashew. As usual, this new tree crop even triggered local migration and a search for new land to increase the planted area.

Civil servants and urban dwellers seem to form a nonnegligible contingent in this local migration and rapid adoption of cashew. This is related to the need for capital to buy land. In addition, in this case because family labor is not available, capital is required to pay workers for planting.

Conclusion

This overview of cashew dissemination in the Sikka district was limited by time. Beyond the failed attempt of promoting cashew for afforestation purposes followed by the successful one motivated by financial returns, it would be interesting to see if there are any other similarities between the development of cashew in Flores and other production centers in Indonesia such as South Sulawesi and in Africa. It would also be relevant to examine the world market to evaluate the extent to which the development of cashew can be supported in the medium term.

However, this rapid survey supports our views on the prospects and conditions necessary to develop more sustainable upland farming systems. The very first condition is to integrate tree crops in the upland farming systems.

Tree Crops in the Uplands

Many farms are limited to multipurpose trees such as *Gliricidia sepium*. While *Gliricidia* is supposed to fix terrace hedges and improve soil conditions as a leguminous tree (able to capture nitrogen in the air), it may also provide some fodder to animals. At a certain level of population density, tree crops are a fundamental component of upland farming systems. Their biological functions secure the sustainability of the system, but they must also be a reliable source of cash. Of course, finding a tree crop adapted to a dry agroecological zone is more difficult than identifying one for a more humid zone. If promising prospects for cashew markets are confirmed in the coming years, this crop may have a considerable impact on the evolution of upland farming systems in Flores.

Tree Crops and Terraces

The introduction of tree crops in already terraced land is an interesting innovation. It seems to be a more efficient option for generating a return to farmers' investments in land conservation than are packages that include only food crops.

Alley-cropping techniques can be adapted only to a transition phase during early tree growth. The increase of cashew area again raises the question of combining food crops and tree crops within upland farming systems. Farmers have a choice between keeping a low planting density of the trees in order to save enough land for food crops or using a more intensive cultural practice for the tree crop but then finding a way to compensate for their loss of food production. At the farm level, this compensation can be obtained either through a decrease in fallow duration (an increase in the cropping index) or by enlarging the area controlled through land rental and buying. The alley-cropping option proposed by the Upland Farmers Development Project to Sikka farmers did not seem to be sustainable.

Interaction of Tree and Food Crops

The future of the food-crop component of upland farm systems we saw in Sikka depends upon the prospects for tree-crop development. Beyond the farm level, if neighboring farmers are able to produce enough food-crop surpluses (in a lowland irrigated system), upland farmers rather easily take the risk of specializing in tree-crop production. This is the case with cocoa in Sulawesi, but the situation is different for cashew production in Flores. If the market is not able to ensure food security, farmers will be reluctant to reduce the area planted to food crops. In addition, perennial crop prices are characterized by trend inversions. As in the case of coconut in Flores, these cycles may threaten the food security of farmers who opted for intensive tree cropping.

However, tree crops and food crops are not necessarily in opposition. The income generated by tree crops may support the transition to more intensified food-crop production through investment in equipment (plows, pumps) and inputs (high-yielding varieties, fertilizer, pesticides). Of course, this shift assumes that efficient food-crop technology is available.

Conserving Natural Resources and Increasing Farmer Income

Even though the common interest in cashew development on the part of project managers (mostly reforestation of degraded land) and farmers (mostly a strategy to increase income) was not clearly anticipated, it would be interesting to identify other cases of such convergence to design adapted natural resource conservation strategies.

The introduction of such a profitable tree crop as cashew reverses the cause and consequences of the adoption process. It is no longer the pressure on the land that triggers the adoption of a new cultural practice, but the adoption of a new crop that stimulates an increase in farm size or even migration to a new location where land is still available. This mechanism is very often observed in the development of perennial crops, as in the case of cocoa. In the case of cashew in Flores, it is important to stress that this expansion is not achieved at the cost of deforestation but represents a modification of the management of shifting cultivation areas.

Replanting and Capital

Along with the adoption of cashew, grassland is converted to small orchards (also see chapters 9 and 15). As in most cases of replanting, farmers expected a better income by adopting this new tree. As in most cases of replanting, it was greatly facilitated by a supply of external capital, mostly in the form of seedlings provided by various extension services and projects.

In short, along with an attractive market, the supply of planting material, in a combination of integrated information and capital, is a key factor to successful integration of a new tree crop that can help to sustain upland farming systems.

Notes

1. A new technology launched in 1990 and a new market for coconut timber may revive or launch a new type of coconut industry. If new market opportunity does not induce replanting, however, the coconut timber industry will not be sustainable.

2. There were almost no cattle in the area surveyed.

3. The same story happened in West Africa, at least in Côte d'Ivoire, where colonial forestry services unsuccessfully tried to promote cashew in the 1950s as an afforestation tool, but here the tree was rapidly adopted in the 1980s when a cashew nut market appeared.

9

Coffee and Agroforestry Systems

François Ruf and Yoddang

The most important innovation studied in this chapter is the introduction of arabusta coffee. In 1981 the national extension service, Dinas Perkebunan, launched several PRPTE (Proyek Rehabilitasi Perkebunan Tanaman Eksport) projects to promote various tree crops in all Indonesian provinces. In coffee-producing areas—even minor regions—most projects concentrated either on robusta or arabica coffee, depending on the latitude. In a very limited number of districts, however, the directorate of Dinas Perkebunan also decided to try introducing arabusta, a famous hybrid of the coffees arabica and robusta not previously grown in Indonesia (except in Timor, which was then part of Indonesia).

Arabusta has the organoleptic quality of arabica and the sustainable yield of robusta. Robusta is less prone to diseases than arabica, a quality that arabusta is also said to retain. These qualities keep the price of arabusta comparatively high. However, the research team based in the cocoa and coffee research station of Jember in East Java judged that the planting material required further experiments and was reluctant to distribute it to villages. The directorate of Dinas Perkebunan thus tried it only in a limited number of districts, including West Sinjai, in the south of the South Sulawesi province. This is where the survey about coffee and agroforestry systems was conducted, in two villages called Tessililu and Arabica, in 1996.

Farmers were provided with a credit package, to be repaid within 12 years, that included

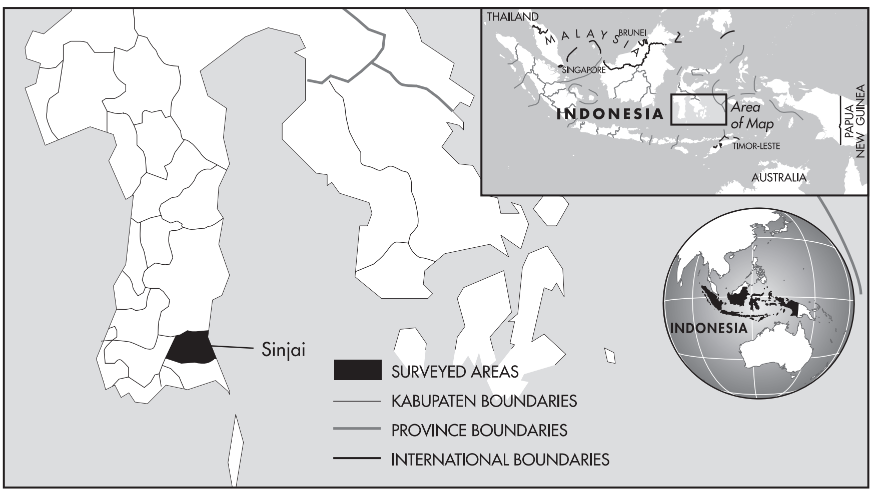
- Arabusta seedlings
- Fertilizer: 250 kilograms per hectare of urea and 150 kilograms per hectare each of tri super phosphate (TSP) and potassium chloride (KCI)
- Pesticides: Diazinon (3 liters per hectare)
- One hand sprayer for every 2 hectares
- Stems of *Gliricidia* and seeds of *Sesbania* and *Erythrina,* promoted as shade trees to protect coffee groves
- Cash (about Rp 100,000) to help farmers with some indirect terracing
- A land certificate (when credit was repaid)

In the two villages of Tessililu and Arabica about 230 farmers representing at least 20 percent of the heads of households adopted the package in 1981, including some terracing. Direct terracing was known by farmers and used for rice fields or even small robusta coffee plots. Because they already knew about terracing, the farmers agreed to construct some indirect terracing when planting arabusta coffee. Indirect terraces have spread with commercial tree-crop promotion, but not with food crops. (An indirect terrace is a small terrace wall of 20 to 40 centimeters, which is not wide enough to make the terrace surface horizontal. As a result the terrace profile remains oblique, but the terrace reduces erosion.)

Five years later, from 1985 to 1987, it was the forestry department's turn to propose seedlings to the villagers as part of a public reforestation project (Proyek Hutan Rakyat). This project involved wood tree seedlings such as *Albisia,* mahogany, *Lamtorogun, Sesbania, Gliricidia,* and *Eucalyptus.* The last was recommended for eroded soils and seems to be used for timber. However, this survey could not include any appraisal of its impact on farmers' revenues.

The forestry department also provided *Pennisetum purpureum* (elephant grass). This project came independently of the former one. There seems to have been no coordination between the agricultural extension services and the forestry department regarding their interventions in West Sinjai. Nevertheless, because coffee prices were rapidly increasing in current rupiahs, farmers took this new project as an opportunity to request additional arabusta seedlings to replace those that had died since 1981. Because West Sinjai smallholders were also spontaneously testing cocoa in the early 1980s, some cocoa seedlings were also provided. When various extension services propose projects, it is necessary and useful to listen to farmers about what they wish to modify in the proposal. Their own request in terms of planting material is extremely important. This is an obvious but often neglected point.

Map 9.1



History and Endogenous Innovations

Since the 1910s and 1920s, farmers in the Sinjai region have known arabica coffee as *kopi bugis* and have cultivated small quantities, which were sold to buyers in Ujung Pandang. Production was irregular and was satisfactory only once every three years.

Starting in the late 1920s, robusta coffee (locally called *kopi mereh*) was introduced. Old coffee bushes planted in the 1940s and 1950s can still be found today. Robusta coffee did not spread very much; the farmers who grew it consumed it or sold at local markets.

The clove boom hit the region in the 1970s and early 1980s, when prices skyrocketed to Rp 12,000 per kilogram and even higher (the price dropped to Rp 5,000 in 1992 and to about Rp 2,000 in 1996). Clove adoption was also accelerated by information circulating among former members of an independence movement, DI/TII, who used commodities such as copra, rattan, cloves, and pepper to fund their movement in the 1950s and early 1960s.[1]

In 1981, at the time PRPTE introduced arabusta, almost 70 percent of the steep slopes in West Sinjai were still under shifting cultivation. The *ladang*s were covered with maize, vegetables, or fallow. Less than 30 percent of the steep slopes was partially planted with trees such as cloves, robusta coffee, arabica coffee, and a few coconuts. At least since the 1950s, some farms also planted bamboo to be used for construction material.[2]

Formation of the Agroforestry System

In short, the evolution of farming systems on the slopes was roughly as follows:

- Before 1970, *ladang* plus a few surviving robusta and arabica coffee groves.
- 1970–81, *ladang* plus cloves mixed with surviving robusta coffee groves.
- After 1981, arabusta coffee mixed with cloves and robusta coffee (some robusta and arabica removed) plus *Gliricidia* and other leguminous trees plus spontaneous introduction of a few cocoa trees.

Fruit trees (orange, *rambuttan*, avocado, jackfruits, *langsat*, and others) are also present (and seem to have been present when arabusta was introduced in 1981), primarily in the orchards close to houses where the coffee-clove-cocoa system has turned into a typical Indonesian agroforestry garden. Cocoa and various leguminous trees completed the overall agroforestry system.

Except for the few surviving robusta and arabica coffee trees, the agroforestry system was clearly built from scratch in less than 20 years. Most cloves were planted on *ladang*. Arabusta coffee seedlings were planted below the established cloves and then spread on other *ladang*. In other words, cloves and arabusta, enabling the conversion of *ladang* into tree-crop farms and then into a commercially oriented agroforestry system, looked like perfect reforestation tools.

West Sinjai smallholders did not have any special experience with intercropping and agroforestry systems. They did not receive any recommendations from extension services but built their systems out of necessity and through their own experiments.

First, they tried to introduce arabusta seedlings between cloves at relatively low density. Even though they had to clear some *alang alang* regrowth between clove trees, they saved time on land clearing and weed control compared with what they would have spent clearing *ladang* covered only with *alang alang*. Once the clove stock area was intercropped, they had to turn to *ladang*, controlling *alang alang* by intercropping young arabusta seedlings with maize and vegetables during the first two years.

Arabusta orchards could thus be hosts to new tree introductions such as cocoa, fruit trees, and *markisa* along with jackfruit, banana, avocado, and various leguminous trees. Smallholders were asked about the main factors that led them to choose agroforestry instead of monocropping. The answers were quite explicit:

- *Low density*. Farmers said they saved money and time by using available land under established trees at low density.
- *Weed control*. They also saved time and money on weed control, explaining that they only weeded once a year but harvested three crops annually.
- *Proximity*. The plots were also close to the farmers' houses, which saved them "commuting"" time. In most cases, an alternative choice of clearing a new fallow meant having to walk for some distance from the house to the plot.
- *Income.* Labor returns per farm plot are more regular within a year because each tree crop, and possibly each food crop, produces at different periods of the year.
- *Lack of land.* Even if farmers are ready to accept a longer distance from the house to another farm plot, they lack opportunities to procure land. If they acquire more land, it is usually in small plots, and agroforestry techniques are suited to small plots.
- *Erosion control*. Last but not least, smallholders speak about agroforestry systems as an efficient way to control erosion. Although they cited the *Hutan rakyat* concept (reforestation by smallholders) used by the forestry department to promote its reforestation projects, we believe that smallholders are not just repeating official ways of thinking. They would not intercrop trees only for erosion control, but they know that it may help.

Success of Arabusta Coffee in West Sinjai

Why did arabusta coffee spread much better than other coffee varieties and any other tree crop on the slopes of West Sinjai? Why did arabusta coffee happen to be the main trigger for converting *ladang* and *alang alang* into agroforestry systems?

The first explanation is agronomic. Arabusta, introduced from Timor, proved to be better suited to the local ecology than arabica and robusta. Although arabica has an export market in Ujung Pandang (exporting to Japan), it is prone to diseases, and its production varies enormously from year to year. The relatively stable production of arabusta catches the smallholders' attention.

The other explanations are related to market and price factors. First, the favorable agronomic factors were combined with the relative certainty of having a market made arabusta of interest as an export commodity, unlike robusta coffee, which has not always been salable in Ujung Pandang.

Second, price increases in the mid-1980s following the introduction of arabusta in the early 1980s enabled early adopters to cash in as soon as the young coffee trees started producing. Their success was immediately taken into account at the village level and triggered followers. This pattern is similar to that in Flores with cocoa adoption in the 1970s and cashew in the 1980s and 1990s. We also believe that the arabusta price in Sinjai may have benefited from the reputation of Toraja—arabica coffee that is exported to Japan from Ujung Pandang with a high premium. Because arabusta from Timor tastes more like arabica than robusta, it is possible that some arabusta was mixed with exported arabica coffee.

Farming Systems and Households in 1996

On average, a household in the villages of Tessililu and Arabica in West Sinjai owns half a hectare of coffee and agroforestry orchards and half a hectare of rice terraces, but the size commonly ranges from half a hectare to three or four hectares, and some families do not own any rice terraces (table 9.1). In this case, they usually take rice terraces as sharecroppers. The range may be higher for Arabica village, where village heads and absentee landowners

Table 9.1. Survey Data on the Population and Farming Systems in Two Villages of West Sinjai, 1996

Parameter	*Tessililu*	*Arabica*
Population	4,400	2,500
Village area (km)	23.9	17.5
Appr. population density (pop/km)	184	143
Number of families	800	450
Average family size	5.5	5.5
Rice field terraces (ha)	500	275
Coffee and agroforestry (ha)	400	300
Protected forest (ha)	20	300
Rice field terraces per family (ha)	0.60	0.60
Coffee and agroforestry per family (ha)	0.50	0.65

Source: Author interviews with farmers and village chiefs.

reduced the 450 hectares of protected forest by 150 hectares, which they distributed among themselves. According to certain smallholders, if the holdings of relatively rich absentee owners are excluded, the average land ownership of rice terraces per household drops to 0.2 hectare. People consider themselves indigenous (Makassar, Konjo) and not migrants.

Sources of Cash

In 1981 the main source of cash in West Sinjai was still food crops (beans and sweet potatoes were sold, while paddy, maize, and cassava were eaten by the household). In the late 1980s, although they were not fully adapted to 1,000 meters elevation, cloves became the main cash crop (the density varied widely from 1 to 70 trees per hectare, mixed with robusta coffee and other trees). Arabusta coffee took over as the main cash crop only in 1993 or 1994. The collapse in the price of cloves in the 1990s accelerated the adoption of arabusta.

After coffee and cloves, the third source of cash is meat-oriented livestock farming (two head of cattle per household on average, along with a few goats and poultry). The other sources of cash are quite diversified and include cocoa, vegetables, and various fruit trees.

Innovation Costs

The basic principle of building capital from scratch by planting trees remains as true as ever. The tree crop is mostly dependent on labor, with limited capital, and a few years later a tree-crop farm is an asset and represents capital. It can be sold or used as a collateral in a pledging transaction.

In the case of West Sinjai, planting seedlings on land with already established trees or that already had been cleared for maize did not require too much labor; the package provided by the PRPTE scheme covered most of the investment costs; smallholders, all native to the village, used their own farm plots. From the farmers' point of view, the investment cost to be considered is what they had to repay for the PRPTE package, that is, capital plus interest. Theoretically the cost was about Rp 470,000 ($211) a hectare.

Innovation Returns

Under the West Sinjai environment and without any fertilizer, one hectare of 10-year-old arabusta coffee yields approximately 350–400 kilograms, slightly more when trees are younger. With fertilizer, one hectare yields about 600 kilograms, and if conditions are right, up to 1,000 kilograms. During the 1990s, the average price was about Rp 1,500 ($0.67) a kilogram. Thus one hectare of unfertilized trees would yield a net return of Rp 600,000 ($270). Labor is excluded because it is primarily family labor. From the farmer's point of view, the innovation cost was covered in the first year of production, approximately three years after adoption and planting. The return from arabusta is further enhanced by additional income drawn from intercropped trees such as cloves and food trees, and possibly from cattle that benefit from the *Gliricidia* and other "anti-erosion" trees turned into fodder trees.

One of the clearest achievements of these coffee agroforestry systems is new housing. Paddy terraces and *ladang* maize cannot help "average farmers" build houses other than ones with bamboo walls and *alang alang* roofs. Farmers with paddy terraces use field material to build housing, while coffee farmers can afford to buy construction materials. In the 1990s, apart from field shelters, few *alang alang* roofs could be found in West Sinjai; most *alang alang* roofs had been replaced by sheetmetal roofs. Even if coffee prices plunge again, at least arabusta has provided some return in the form of family houses. This is a sustainability factor. Farmers who invested and improved their daily life on site now have less incentive to migrate to pioneer fronts.

Rate of Adoption at Village and Regional Levels

If the definition for arabusta adoption is to have planted more than 200 arabusta trees (approximately 0.25 hectare of agroforestry system), approximately 20 percent of the smallholders of the two villages of Tessililu and Arabica adopted it within the first year. The PRPTE package, including cash advances, was certainly a strong incentive for this first massive adoption. In the 1990s, except for the landless, almost 100 percent of the families in the two villages adopted arabusta coffee, most generally under the agroforestry system. According to available data, most of these smallholders own between 200 and 2,500 arabusta trees (0.25–3.0 hectares), with the number of trees dependent on the amount of land available to each household.

The two villages may have produced some 200–250 tons of arabusta coffee in the late 1990s. According to official statistics, West Sinjai district produced about 1,000 tons of coffee, all recorded as robusta coffee.

Factors of Rapid Adoption

The relatively rapid adoption of arabusta—which also meant rapid development of coffee orchards, agroforestry, and to a certain extent terracing—can be explained by a combination of good interventions and opportunities.

- *Adaptation.* Because of the unexpectedly good adaptation of the cultivar to the local ecology, the planting material proved to yield more regularly than arabica. This is evidence that extension services are sometimes right when they introduce a cultivar that research agencies claim has not been tested enough. One of the best ways to test a cultivar is to distribute it to smallholders. The only precaution is to stress clearly the need for experimentation to smallholders.

- *Chief's skills.* The skills of the local PRPTE project chief, who personally knew about arabusta coffee (apparently from an experience in East Timor), were a factor. He took the initiative to show farmers movies on arabusta, and more important, took one farmer leader to a village that was already producing arabusta.
- *Few cash crops.* From an immediate point of view, the low incidence of cash crops in West Sinjai is an advantage for promoting a commercial crop. Farmers are more keen to adopt a new cash crop if they do not have a well-established one yet. Marginal production of robusta coffee cultivated in West Sinjai hardly caught the attention of traders.
- *Importance of existing markets.* One difficulty in launching a new tree crop or even a new cultivar is to make sure that it has a market. The introduction of arabusta was risky. In this case, the export price of arabusta probably benefited from the neighboring Toraja (special arabica) market. Arabusta coffee was probably mixed with Toraja coffee due to the high export price of the latter.
- *Price increase.* By chance, when arabusta groves started bearing berries in 1983–84, the international price increased, and the 1983 and 1986 currency devaluations in Indonesia also increased the price relative to maize and other food crops.
- *Capital and other factors.* The capital provided under the PRPTE package was a factor in the rapid adoption of arabusta trees.
- *Land certificates.* Finally, was the land certificate provided by the PRPTE project a determining factor? In PRPTE projects involving coconut adoption, the grant of land title was a factor, mostly because the smallholders were migrants who had potential conflicts with indigenous people. In Sinjai, most farmers were native to the area, so not much attention was paid to land titles. Because there were few land conflicts, farmers did not feel the need for titles.

Farmer Constraints

The main constraints of this agroforestry system are the dependency of arabusta coffee on inputs and difficult market access. After some years smallholders discovered that arabusta coffee was highly dependent upon fertilizer. Most fertilizer has not been subsidized since the mid-1990s, about the same time that coffee prices dropped; in 1996 farmers in West Sinjai were showing less interest in arabusta. Production was lower, because of the lack of fertilizer and the lack of interest, which in turn may have had a negative impact on prices if traders thought that it was not worth sending trucks to buy the West Sinjai supply. Five hours of mountain road (with very degraded asphalt) may lead to market difficulties if a small region does not produce enough supply to attract regular traders.

Agroforestry Systems: From Constraints to New Opportunities

Although the coffee to fertilizer price ratio may lead to a dire slump in arabusta production, introduction of arabusta has helped to build an agroforestry system with some terracing in the two villages we studied. This is an opening for further innovation, for example, as terraces are built and *Sesbania* and *Gliricidia* trees are sometimes planted at the edge of the terraces. Other trees may be adopted in the future.

Conclusion

These two villages in West Sinjai proved that farmer communities are quite able to maintain and develop sustainable tropical agriculture on a sloped area decades after deforestation. Farmers managed to build a few direct terraces devoted to paddy cultivation and to cover the slopes with coffee-based agroforestry and some light indirect terracing, in a pattern similar to the case of cashew in Flores (described in chapter 8). The seemingly successful combination of light indirect terracing and leguminous trees with a commercial tree crop can also be interpreted as a form of replanting and reforestation (see chapters 8 and 15). Farmers adopted replanting for reasons similar to those in the cashew case—an expected higher income, a shortage of forest land, and opportunities for external capital.

Among the lessons drawn from this development, it is interesting to note that once again it happened through a combination of necessity and chance. First, farmers spontaneously started innovating by necessity. Apart from a few cloves and arabica coffee, they did not have many commercial tree crops. Second, the approach of the extension services was rather good. The audacity of introducing a risky coffee planting material proved to be the right strategy.

Both of these approaches eventually came together, driven by:

- the declining price of cloves
- the increasing price of coffee due to an international price rebound from 1981 to 1984, and more importantly, the 1983 and 1986 currency devaluations in Indonesia
- the amazing ecological adaptation of the cultivar
- its unexpected immediate market
- the uncoordinated but rather useful succession of interventions and supply of planting material by agricultural extension services and the forestry department.

Smallholders' knowledge about using different official sources of planting material is also worth noting. In other words, by expressing their wishes, smallholders managed to coordinate previously uncoordinated interventions by various extension agencies, which is possibly the right approach. Some room might be left to chance, but the best place to coordinate their approaches is in the field, in collaboration with farmers.

Further research is needed, including determining complementary aspects of agricultural and forestry extension services, along with an appraisal of the economic impact of wood species such as eucalyptus.

Notes

1. The stated aim of the DI/TII (Darul Islam/Tentara Islam Indonesia) uprising was to build an independent Muslim state in Sulawesi. The movement's chief was Kahar Muzakar, who played a leading part in booting the Dutch out of the island after the second world war. His reputation of cleverness is immense among Bugis people and especially among the DI/TII direct members. Kahar Muzakkar had the strategy to fund his movement by agricultural commodities such as clove, pepper and cocoa. We collected many live testimonies of confidence and solidarity among forum DI/TII members that accelerated the adoption of these commodities, especially cocoa (Ruf and Ehret 1996, Ruf and Yoddang 2001).

2. Including the construction of bamboo towers made by the DI/TII rebel movement in the late 1950s and early 1960s to monitor the army's mountain incursions.

10

Vanilla on Coffee Farms

François Ruf, Yoddang, and Syarifuddin

Vanilla was introduced in 1979 in Kepahiang, a subdistrict of the Rejang Lebong district in the Bengkulu province, one of the three provinces of Southern Sumatra. It was abandoned in 1997.

Although the subdistrict was dominated by native people from Bengkulu, Balinese migrant families from Suro Bali village were the first adopters of vanilla and remained the main adopters until the 1990s, planting the creeper either as a monocrop next to coffee or intercropped with it.

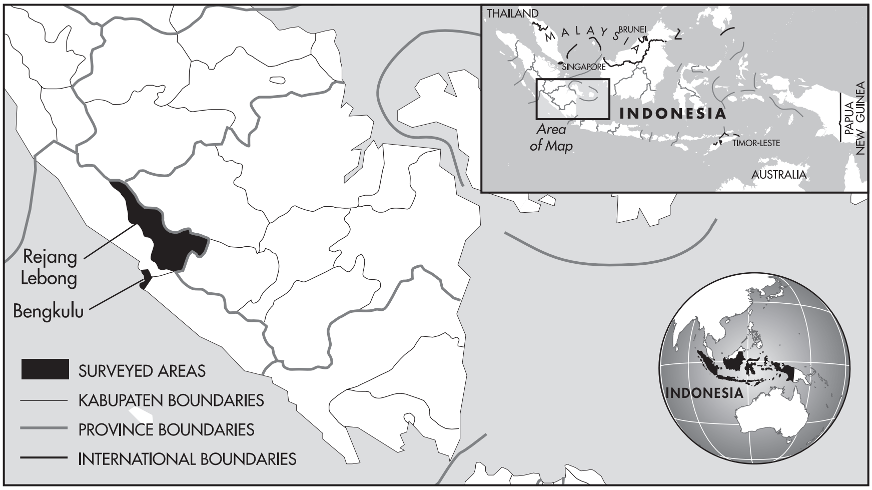
This chapter looks at the role of migrants in innovation and technology transfer and at the rapid abandonment of a promising innovation. What led to this innovation cycle of adoption and abandonment? Adoption of vanilla enables us to explore a basic role of extension services in accelerating the adoption rate of an innovation launched by one smallholder. It also allows us to see what happens when extension workers do not anticipate new problems. In addition, we describe a showcase of accelerated consumption of forest and new-crop rents, which is related to the decision to abandon an innovation in the context of an attempt at diversification and agroforestry.

The first step in this process was adoption of vanilla in an already established coffee farming system. The coffee was shaded by *Gliricidia,* a strategy that certainly falls in the category of agroforestry. The vanilla creepers used the *Gliricidia* trees as stakes. What are the factors determining adoption or nonadoption of agroforestry practices? Did agroforestry systems affect the adoption and abandonment of vanilla?

Study Method

Although our observations were limited to interviews with 11 farmers from this Balinese village in Bengkulu, they were interviewed first in 1991 and again in 1997 and 1998. The spread of vanilla in that village was limited to 30 farmers (half the village) and some 8–10 hectares, but this microdevelopment highlights several interests that deserve a short chapter.

Map 10.1



Farming Systems

The coffee-based farming system of Kepahiang is reviewed in chapters 6 and 16. On the subdistrict level, the average landholding per family is 2.4 hectares, with 1.2 hectares planted to coffee. At the Balinese village level, the coffee area seems steady at 1.4 hectares.

The first Balinese migrants arrived in Kepahiang in the late 1960s from neighboring districts. They were leaving official transmigration schemes that failed because of poor soil conditions and an obligation to grow food crops. The soils were good in Kepahiang, and the migrants were free to grow tree crops, but they had to find land.

Balinese migrants used the *bagi tanah* contract (land sharing) with indigenous landowners, under which the landowner devotes one piece of land to the newcomer. The latter clears the land and plants coffee. When the coffee trees bear fruit, the produce is usually shared equally.

Because these systems were not developed at the expense of forests, but rather on old coffee plantations abandoned and then sold by indigenous owners to the Balinese migrants, the latter replanted coffee, intensifying production at the same time (a process of increasing the gross and net margins per hectare). In other words, as coffee planters, Balinese migrants played a role in maintaining regional upland agriculture and income almost as soon as they arrived. The success of the first Balinese migrants attracted more migrants in the late 1970s.

Agroforestry or Monoculture

If agroforestry is defined as the intercropping of at least two tree species, a combination of coffee groves and *Gliricidia* is already an agroforestry system. Vanilla enhances and confirms the agroforestry status of the plot.

Creepers on live stakes such as *Gliricidia* are agroforestry systems, while creepers on dead stakes are monocropping. The vanilla in our study area always uses live trees as stakes, thus vanilla in Suro Bali is always agroforestry. Accordingly, we cannot compare monoculture and agroforestry choices but rather degrees of agroforestry. The question is, under what conditions do farmers choose "light agroforestry systems" (vanilla plus *Gliricidia*) or "heavier" ones (coffee plus *Gliricidia* plus vanilla)?

The main factor is the availability of land. If a smallholder in the village owned fallow land, he chose the vanilla plus *Gliricidia* system. If all his land was occupied by coffee, he used the space between the rows. At least in Suro Bali, it is that simple.

The second factor is labor. Already existing shade trees on coffee farm plots can be used as live stakes for vanilla. Farmers save the labor and cost of planting stakes for vanilla, a factor that demonstrates that *Gliricidia* is a key component of the agroforestry system. Coffee farms without shade are defined as monoculture and are less suited to vanilla intercropping.

These agroforestry systems remain flexible, however, and farmers can change the crops depending on circumstances. Two years after a virus outbreak in the vanilla creepers, smallholders in Suro Bali returned to a system of coffee plus *Gliricidia,* letting the vanilla creepers rot. In this case the shade trees provided the flexibility in the system.

Step by step, farmers replaced some of the *Gliricidia* and vanilla trees with coffee. The new coffee farms kept part of the *Gliricidia.* The shade tree is the basic tool of conversion from one system to another.

This is the paradox in which agroforestry makes tropical agriculture more sustainable, not by fixing it, but by enabling its rapid change and adaptation to ecological or market changes. At least in this case, agroforestry had no positive impact on the degree of the disease infestation, but it allowed the planters to adapt their farming system to new ecological conditions.

However, unbalanced commodity prices can induce farmers to return to pure monoculture. The high price for coffee in 1998 led farmers who had intercropped coffee, *Gliricidia,* and vanilla a few years earlier to cut down not only the vanilla but also the shade trees. The objective was not to eliminate the virus-infested vanilla but to increase the light available to coffee to maximize its yield. In that case, the agroforestry practice was limited to a short cycle before giving birth to a new monoculture cycle.

History of Vanilla Adoption in Suro Bali

In 1979 Made Sukiyasa took four cuttings of vanilla from his native village in Bali and planted them in Suro Bali. From 1979 to 1985, nobody seemed to monitor this experimental plot. During these seven years, the innovator himself did not substantially extend his vanilla plot. Because the normal life span of a vanilla plantation is 7–10 years, he might have decided to observe a full cycle before going further. More likely he just kept his plot experimental since there was no local market. That is also why other farmers did not follow his example.

In 1986, however, after a few years of convincing yields and hearing a radio broadcast providing information on vanilla, Made Sukiyasa decided to extend the plot. He visited Taba Rena village in the neighboring subdistrict of Curup and obtained 300 vanilla cuttings. Then he looked for further planting material and asked Balinese staff from the local extension services for help. He was advised to go to the neighboring district of Bengkulu Utara in the subdistrict of Arga Makmur, where some vanilla was already being produced.

He then extended his plot and was immediately followed by three other Balinese smallholders, including the chief of the village, who was given 50 cuttings by Made Sukiyasa. More wished to follow in 1986 but gave up because planting material was unavailable.

In 1989 Made Sukiyasa took the opportunity of a family trip to Bali to sell his first 12 kilograms of vanilla. The price was Rp 80,000 ($44). Other farmers in Suro Bali also looked for confirmation about the vanilla market and prices from their relatives in Bali. As usual, this first sale and clear price information, which Made Sukiyasa reported to his fellow smallholders, triggered much interest. However, everyone was still short of planting material.

In 1990 extension staff bought 10,000 cuttings from Made and others at the price of Rp 200 per cutting ($0.10). In 1991 they bought another 5,000 cuttings. Some of these were distributed to 27 smallholders who were interested in growing vanilla, and the reminder were used to set up an experimental plantation.

Innovation Cost and Returns

About 3,000 cuttings, each one meter long, are required per hectare to establish a vanilla monocrop plantation. Smallholders often plant at a higher density if they do not lack planting material. Vanilla comes into production after three years, and in the Kepahiang environment, the yield per hectare of a monocropping system seems to vary from 2,000 to 3,000 kilograms of fresh pods or 500 to 600 kilograms of dry fruit. The 1991 price was Rp 12,000 ($6) a kilogram for fresh pods and Rp 60,000 ($30) for dry. This represented a potential of US$15,000 per hectare or more.

This spectacular output also requires a no-less-spectacular amount of skilled labor. Each flower needs to be artificially pollinated. Balinese do not view this operation as so difficult, probably because they have some experience in hand pollination; however, it is extremely time consuming, and returns per day of labor are less spectacular.

According to figures supplied by smallholders, prices remained relatively attractive in 1992 but started declining in 1993 when coffee prices started rising (table 10.1).

Table 10.1. Vanilla and Coffee Prices, 1991–96

Year	*Vanilla (Rp/kg)*	*Coffee (Rp/kg)*
1991	12,000	1,190
1992	9,500	1,160
1993	6,500	1,440
1994	5,500	4,940
1995	5,500	4,450
1996	5,500	2,770

Adoption and Abandonment

In Suro Bali village, the adoption rate for vanilla reached 50 percent at its peak, around 1992–93, with 30 of the 60 families in the village growing the plant. At the peak, the average area planted was 0.3 hectare per family, with a relatively wide range of 0.04–0.70 hectare.

As the 1990s progressed, the price started to drop. In 1996 the price was still about Rp 5,500 per kilogram of fresh pods ($2.35 due to the rupiah depreciation), but there was no longer any supply. The vanilla price decline and the price ratio of vanilla to coffee played a role in that drop, but farmers said the main factor in their decision to abandon vanilla was the outbreak of disease. By 1998 the villagers of Suro Bali had totally abandoned vanilla.

Three factors in this innovation cycle are examined below: constraints before wide adoption, factors that accelerated adoption, and reasons for abandonment.

Constraints to Adoption

Not surprisingly, Balinese farmers needed to be convinced by market and price information before adopting a new crop. The best way to be convinced was to have a real sale of the new product by one of the innovators. This was decisive proof. In other words, one innovator was allowed to take the risks and handle the information costs—a classic example of information free riding and copying.

Once farmers were convinced by the technical and market information, one of the major obstacles to rapid adoption of a new crop was the planting material. This was a problem both for the Balinese of Suro Bali and for non-Balinese farmers in surrounding villages, who never adopted vanilla.

Finally, any shortage of family labor hampered vanilla adoption. Beyond the lack of information and the need to master hand pollination, labor is one reason that most indigenous people did not adopt vanilla. This crop is labor intensive and thus developed when households had a relative surplus of family labor compared with the labor requirements for coffee. Most non-Balinese migrants who had larger-than-average coffee farms were short of labor and also did not know how to hand-pollinate vanilla.

Factors that Accelerated Adoption

When asked about their motivations for adopting vanilla in 1991, almost all Balinese smallholders mentioned attractive prices, suitable climate and soils, and expected high income.

These smallholders were right about climate for a few years. The creeper requires abundant rainfall, about 2,000–3,000 millimeters a year, and a high relative humidity. Vanilla also needs drainable soils with a high humus content, and it likes volcanic soils. Kepahiang met most of these criteria. In addition, vanilla thrives on hills cleared of forest but not burned over. Because vanilla was introduced either close to the house or intercropped with coffee groves, there was no burning in the village of Suro Bali.

More curiously, some Balinese smallholders also mentioned easy maintenance as a criterion for vanilla adoption. Two reasons account for this response. First, Balinese experience with the plant was important. Second, the crop requires skills and labor, but less hard work than land preparation and planting in *sawah* and weed control below coffee groves. Part of the labor, such as flower pollination, can be done by wives and children. It might be one of the reasons why some Balinese family chiefs consider vanilla an easy crop.

The high prices of the late 1980s and early 1990s offered potential income of several thousand dollars per hectare. Vanilla is one more example of a positive supply response by migrants to increasing prices. In addition, coffee prices started plunging after 1988, and the low price of coffee was clearly a factor during the "massive" adoption of vanilla in 1990. Farmer decisions were influenced by comparative prices and trends.

Before comparative prices and expected income, however, the key was a combination of information from migrants and radio, personal relationships between a farmer and an extension staff member from the same culture, and the ability of the extension services to support smallholder initiatives, especially by providing planting material.

Reasons for Abandonment

All farmers said that the disease outbreak was the reason they abandoned vanilla. Beginning in 1995 segments of vanilla creepers turned yellow, then black, and finally rotted. By 1996 almost all vanilla creepers were infested. Some farmers started replanting but failed because the new cuttings were immediately attacked. In 1997 almost nothing was left. The extension services introduced chemical products used on maize and other crops, but all failed.

All farmers insisted that a price of Rp 5,500 ($2.35) would have remained attractive without a disease infestation. However, the vanilla price was cut by 50 percent between 1991 and 1994. Even more important, during the same period the price of coffee increased by 300 percent. The kiss of death for vanilla came in 1998, when coffee prices jumped to Rp 12,000 per kilogram from Rp 2,600 the year before.

Conclusion

The vanilla situation is another illustration of innovation and technology transfer related to migration. Vanilla development on the island of Bali was a direct and easy source of information for Balinese migrants based in Sumatra.

Vanilla adoption illustrates how agroforestry can make tropical agriculture more sustainable by enabling its rapid adaptation to ecological and market changes through diversification and replanting. This is the principle of a tree-crop portfolio (chapter 11).

In addition to three determinants of replanting identified in previous chapters (shortage of forest land, availability of capital, and higher expected income), the case of vanilla underscores the need to reduce labor at the replanting phase, perhaps through innovation. Agroforestry can be nothing more than a strategy to save labor and land, especially at the replanting phase.

11

Intensive Orange Production

Frederic Lançon and Ibrahim Hasanudin

A wide variety of orange trees traditionally has been grown in many upland agroeconomic systems as one component of the home garden. In recent years, however, orange production has been growing rapidly, and oranges are playing an increasingly important role in several upland farming systems investigated by the study team.

Orange production and dissemination follow different patterns. Within traditional tree-fruit production systems, the proportion of orange trees increases through replanting of existing local varieties or new varieties. Orange tree development is also a component of a multiple tree package recommended to farmers in connection with reforestation or soil conservation programs.

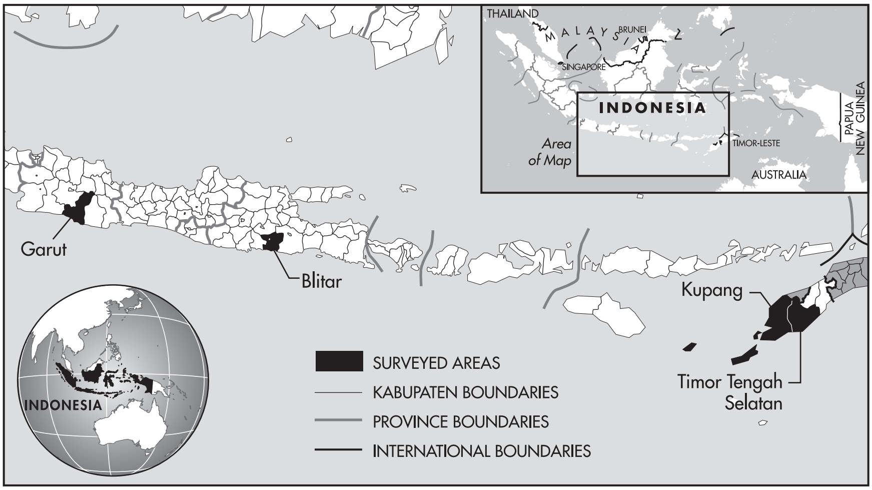
In such cases, orange trees are usually simultaneously planted with other species such as mango, lemon, and fodder trees. The objective is to reduce environmental damage by substituting income-generating tree crops for annual crops. A third pattern involves converting an entire unit of land into an exclusive orange orchard.

The rapid spread of orange trees corresponds to an even faster growth in the national market driven by changes in consumer diets, especially in urban areas. Various actors such as large-scale farmers, traders, and government agencies are involved in the dissemination of planting material and cultural practices.

Farming Systems in Mountainous Areas

Even though orange trees are not a common feature of specific farming systems, historically some locations have a reputation for being orange production zones. For example, the Garut district in the southern mountainous zone of West Java province is well known for its orange production. One variety of orange, *jeruk garut,* is named after this district.

Map 11.1



In East Nusa Tenggara province, orange production started during the 1920s in the subdistrict of Molo Utara on the slope of Mount Mutis above 1,000 meters. According to farmers interviewed in the village of Tunau, orange production started before World War II under the initiative of Chinese traders from Kupang, the main town of West Timor.

During the first decades of this century, cattle grazing was the main farm activity in this area as it was in many other farming systems of Timor Island. Food crops were mainly grown for home consumption, and fruit trees represented only a minor, but regular, source of income. In those times, each farmer was able to graze around 20 head of cattle.

Between 1960 and 1970, the system shifted from a cattle-oriented system to a more diversified farming system. This change was caused by several factors. A disease outbreak in 1965 sharply reduced the size of herds. Population increased, thus gradually reducing the available land and leading to intensive exploitation of grazing areas. In 1994 the population density in the villages of the subdistrict was estimated at 1,587 inhabitants per square kilometer, far above the province average of 50. Based on the total village area and the number of households as reported by the village chief, the average farm size was about 1.5 hectares; rarely was a farm more than 2 hectares. In many places this intensification of land use led to a complete disappearance of trees and bushes, damaging the sustainability of the fodder supply per unit of land. At the beginning of the 1970s, the government took action, starting a reforestation program in the most degraded zone. This decision institutionalized the limits on exploitable land and sped up the development of new farming systems. To facilitate this transition, the government launched a soil conservation program on remaining land still exploited by farmers; the program included the establishment of bench terraces combined with planting fruit and fodder trees.

Land limits led to a combination of all farming system components—annual crops, tree crops, and livestock production—on the same unit of land.

Nowadays cattle production is limited to two animals per household, with animals kept within a plot to facilitate feeding operations and to enable direct use of manure. As in many other sites where terraces have been developed, *Leucaena* was the main fodder tree, if not the only one. To overcome pest attacks against this crop, farmers started producing new fodder plants after 1986. Animals are now fed with leaves of *Sesbania grandiflora* and *Pennisetum purpureum*. Twenty-five percent of farms no longer raise cattle but still produce forage that is sold to livestock traders who need the feed to maintain animal weight during trading operations.

To sustain their income, farmers intensified their annual crop production, taking advantage of rainfall patterns that make it possible to grow two crops in a row. The first rainy season is devoted to the production of maize, a subsistence crop planted in November and harvested in March (long-cycle varieties are adapted to the elevation). The second rainy season (between May and September) allows farmers to grow commercial crops such as garlic and red beans.

The share of tree crops in farmers' income is expanding rapidly. During the 1970s, farmers increased the production of already-known tree crops such as candlenut, orange, and banana. The tree-crop portfolio is adjusted according to market development. For example, apples were one of the most important crops during the 1970s but were abandoned in the mid-1980s because the price paid to farmers was too low. In recent years, farmers started planting avocado and replanted orange trees despite spider attacks that are difficult to control.

These changes show that this type of farming system is flexible enough to adjust rather quickly to new market opportunities and to increasing limitations on land resources. However, it should be noted that this intensification process has reached a limit and is no longer able to match the needs of an expanding population. The farmers we interviewed underlined the increasing flow of young people leaving villages to find income opportunities in Kupang and other industrial centers of the archipelago.

Crop-Livestock Farming Systems Where Shifting Cultivation Still Prevails

The study team visited two sites in the western part of Timor Island where farmers used crop-livestock farming systems with shifting cultivation. The sites were the village of Bosen in the Molo Utara subdistrict in the district of Timur Tengah Selatan and the village of Kotabes in Amarasi subdistrict in the district of Kupang. These farming systems are characterized by the importance of cattle as one of the main income sources. Although farmers acknowledge increasing population pressure on the land, the population density is still low, ranging from 52 inhabitants per square kilometer in Molo Utara to 59 inhabitants per square kilometer in Amarasi.

Annual food-crop production still depends on opening plots left fallow for a period of three to 10 years, depending on the total area covered by the farm. A single three-to-four month rainy season makes only one crop per year possible. An open field is usually cropped every two to five years. The first year, maize or sometimes rice is planted as a monocrop, and the following years maize is intercropped with legume and tuber crops.

Besides recovering fertility, one of the main tasks of fallow is to provide fodder for livestock. *Leucaena leucocephala* has been the major source of animal feed. Amarasi is well known for the rapid and overwhelming dissemination of this tree following the regulation set by traditional authorities during the 1920s. According to this regulation, any *ladang* returned to fallow must be planted with *Leucaena*. With this system, a significant share of the subdistrict has been covered with *Leucaena,* allowing rapid intensification of cattle production and hence significant improvement in the welfare of the local population.

In the village of Bosen where population growth has been slower, *Leucaena* was introduced later in the 1970s as a component of soil conservation programs, including the development of ridge terraces. At both Amarasi and Bosen, fodder production has been severely affected by outbreaks of the psyllid *Heteropyslla cubana.* This reduction in the fodder supply has only been partially compensated by the introduction of new plants such as *Sesbania* or *Pennisetum,* the planting of which was imposed by local authorities in the case of Bosen. However, the disruption the psyllid outbreak caused in the functioning of these systems and the increasing population pressure on land are challenging their sustainability.

To strengthen their incomes, farmers are developing the tree-crop component of the farming system, even though *ladang* systems still prevail. Originally, within these farming systems tree crops generally had a subsistence crop status, except for particular species such as candlenut and betel vines. In Amarasi, the local name for a permanent garden explicitly refers to this subsistence function. They are called *kebun mamar* (garden for eating). The development of cash tree crops is occurring through various scenarios. In Amarasi, they are introduced within reforestation projects that impose rehabilitation of degraded *Leucaena* forests through terracing and planting fruit trees. In Molo Utara orange tree introduction has been promoted by a trader from the subdistrict who has developed a nursery of 100,000 seedlings.

This woman owns a plot of 6 hectares cropped with her nursery plants. The plot also serves as a demonstration plot. Planting materials have been adapted through budding of improved imported varieties on local and more pest-resistant varieties. In Kotabes trees have been planted recently, but it is too early to reach any conclusions about the success of the introduction. In Molo Utara, one farmer who planted earlier already considers that oranges are his main source of income. Even though the orange dissemination process is just beginning, the prospects are very promising in these areas.

Dryland Farming Systems without Fallow

Orange trees not only are affecting isolated upland areas, but also highlight a striking development in the southern part of Java Timur province. This hilly area is characterized by its limestone soil, where fertility is low (Carson 1989, p. 10). Rainfall can reach 2,000 millimeters a year, which is concentrated from December to February. For four or five months. there is less than 60 millimeters of precipitation. These areas are more populated compared with the "upland standard"—population density is more than 350 inhabitants per square kilometer.

In these systems, food-crop sales are the main source of regular income. When farmers have irrigated fields, rice is the main subsistence crop; otherwise maize is cropped for both household subsistence and the market. In the past decade, cassava has been a major cash crop, but this market is shrinking with declining export opportunities. Livestock is also an important source of cash, even though the number of head per household is rarely more than three or four, but this source of income is quite irregular and constrained by fodder resources.

This area has been the target of two important land conservation projects because it is located along the Brentas River, which supplies a major irrigation network in the central part of the province. These two projects, the Upland Agriculture and Conservation Project (UACP) and the East Java Rainfed Agriculture Project (EJARP), the second of which is nearly completed, have followed the same standard approach, combining terracing with intensified fodder and food production. These projects also provide farmers with various fruit trees such as mango, jackfruit, gnetum, and coconut. The team visited two sites in the district of Blitar—one site within the EJARP project intervention zone in Panggunrejo subdistrict, and the other in Binangun subdistrict in the former UACP intervention area.

These two projects have had a visible impact on farmer practices. The development of terracing on the EJARP site was striking. The number of households involved in terracing increased from 25 to 60 within four years. An improved local variety of maize that is open pollinated is widely grown, whereas the dissemination of hybrid maize is lagging. The coexistence in the same area of two successively implemented projects gives some insight into the long-term impact of this type of project. Terraces are still widely visible in the UACP area, but the most striking phenomenon is the rapid development of orange orchards.

Judging by the number of new concrete houses built near traditional teakwood houses, this orange boom has already substantially improved the standard of living. This development is actually an extension of orange production areas in the neighboring district of Tulungagung, where production started several years ago. In this area, orange trees are very sensitive to pests, and their life span is rarely more than a few years. Tulungagung producers, looking for new areas to expand their production, started to hire plots in Panggunrejo in the early 1990s. Considering the high return offered by this crop, local farmers started to emulate Tulungagung orange producers. Despite the unavoidable decrease in production after five or six years, the return on investment is greater than the return on maize. The orange boom is so enticing that some young people who left the village a few years ago to find a job in town or in industrial centers have returned to the farm.

In the EJARP project, oranges have not yet expanded as much as in the UACP zone. EJARP staff were not keen to disseminate orange trees because of their high susceptibility to disease. Project managers were afraid they would lose farmer confidence in the project if they provided low-quality planting material, and research has not yet found technical solutions to the disease problem. However, farmers have already started to plant orange tree seedlings that they bought from private suppliers.

Innovation Cost and Returns

The study found that cost and returns for orange trees varied according to the agroeconomic conditions where they are grown and the type of cultural practices used by farmers.

As with other fruit trees, the initial investment can be adjusted to farmer resources—farmers can plant a few trees or several hectares of trees. At the different sites, seedlings cost as little as Rp 500 up to Rp 2,000 for the improved variety. Crop maintenance is more or less intensive depending on the size of the orchard and the availability of efficient pest treatments. The only site where farmers were able to provide some figures was in Panggunrejo (table 11.1).

As reported by farmers, we assume for our calculations that the average life expectancy for orange trees is about six years. They start producing after three years, and the second year of production gives the highest yield. The average cost for fertilizer and pesticides is around Rp 400,000 a year.

Table 11.1. Estimates of Orange Tree Cash Costs and Returns, per hectare

Year	*Input*	*Cost (Rp)*	*Yield (kg)*	*Return (2,000 Rp/kg)*
0	Planting 300 trees at a cost of Rp 1,500 each	450,000	—	—
1	Pesticide and fertilizer	300,000	—	—
2	Pesticide and fertilizer	400,000	—	—
3	Pesticide and fertilizer	400,000	—	—
4	Pesticide and fertilizer	400,000	1,500	3,000,000
5	Pesticide and fertilizer	400,000	4,500	9,000,000
6	Pesticide and fertilizer	400,000	1,500	3,000,000
Total		2,750,000		15,000,000

Source: Interviews with farmers in Panggunrejo.

Because we did not have any reliable sources to estimate the opportunity cost of labor and the average value of land rent, we excluded these items from our estimates. In addition, it should be noted that farmers provide labor only for crop maintenance activities (fertilizer applications and spraying) because oranges are usually marketed under *tebasan* contract. With this type of arrangement, traders are in charge of organizing harvesting with their own team of farm workers. This arrangement allows the farmer to avoid the most labor-intensive part of orange production.

The return on investment is high enough, about five times the total cost, to assume that orange production is a very profitable activity. The quality of the material used to build new houses, such as painted tile, is further evidence of the high return from orange production. On the eastern Indonesian islands, the returns to orange production are probably lower, but this crop is not yet produced in a very intensive specialized system as it is in the Java Timur subdistricts.

Rate of Adoption

The rate of adoption for orange trees must be considered in different ways depending on the status of this tree in the farming system. Where orange production has been a component of complex agroforestry systems, the discontinuous rate of adoption is very high, with each farmer having at least 5–20 trees on several plots. This is the case in Tunau village on the slopes of Mount Mutis in Timor.

When oranges are produced more intensively—for example, where a whole plot is exclusively devoted to orange production—the continuous rate of adoption (that is, the area planted with oranges) is a more relevant indicator. In this case, it is also essential to consider how many years earlier orange production started. For instance, the share of village areas planted with oranges is much higher in Panggunrejo where the boom started six years ago than in Binangun where the EJRAP project restrained farmers from planting orange trees until recently. In Panggunrejo, one farmer has already planted more than one hectare of oranges on his five hectares. In Binangun there are not yet any plots entirely converted to orange production. Although we did not have any means to approximate the continuous rate of adoption of orange trees in Panggunrejo, we estimated by direct observation that at least along the village road, one-third of the area had been converted to orange orchards. Although fewer orange trees were planted on land farther from the road (marketing is becoming more costly), the orange boom definitely has a structural effect on the farming system.

Constraints and Factors for Adoption

At the farm level, no obvious constraints prevent farmers from planting orange trees. As shown by the diverse situations reviewed by the mission, this crop is very versatile and can be introduced in different farming systems, either as a monocrop or as a component of a more diversified tree-crop system. This flexibility allows farmers to adjust the initial number of trees to their investment capacity and risk level. Poorer farmers may limit their production to 5–10 trees, while the richest may begin by planting a few trees and then increase their orchard size to hundreds of trees. However, we did not observe any farms that are entirely specialized in orange tree production. We can thus assume that orange trees will be monocropped only by households with enough capital to maintain diverse sources of income.

The agroecological niche in which orange tree production started several decades ago no longer seems to be a constraint. Orange tree production is developing under a wide variety of agronomic settings. On the technical side, the major constraint is diseases, against which farmers have not yet mastered chemical controls, but the high rate of tree mortality after six or seven years is well known by farmers and does not seem to keep them from planting.

The high attraction of oranges despite these risks is closely linked to the dynamism of the market, which ensures a high return on production. Accordingly, market access is a key factor in the adoption and development of orange trees. Roads are critical, of course, but so too is an efficient marketing network. The importance of marketing in the adoption process is also underlined by the role of the trader or farmer/trader in the dissemination of this fruit tree. Even though official channels provide seedlings in some cases, the main channels for planting material are traders. Sometimes they even contribute to the development and adaptation of new planting material.

In the long run, it seems quite likely that an economic factor is also a major constraint to development of orange production. As often observed with agricultural commodities, a steady increase in orange production may lead to oversupply and price decreases. This issue also depends upon consumers' choices between local and imported production and the opening of new markets for Indonesian producers, such as juice, processed foods, and exports. This evolution will probably require more investment at different stages of the commodity chain as well as in orange quality.

Orange tree production is an effective means for upland farmers to improve their standard of living without putting natural resources at stake, but successful adoption, at least as a component of the farming system, requires solid capital in the form of planting material, fertilizer, and pesticides. Once more we see that monetary capital plays a major role in replanting and diversification.

Fruit tree production has always been a feature of upland farming systems, but production has developed rapidly in recent years—and not only orange production. It is important to point out the rapid development of mango production in areas such as the Probolingo district in Java Timur and the northern districts of Java Tengah. In these areas, fruit trees are intercropped on ridges with rainfed paddy, or even sometimes entirely replace the rice of the first Green Revolution.

12

Improved Rubber Agroforestry Systems

Eric Penot

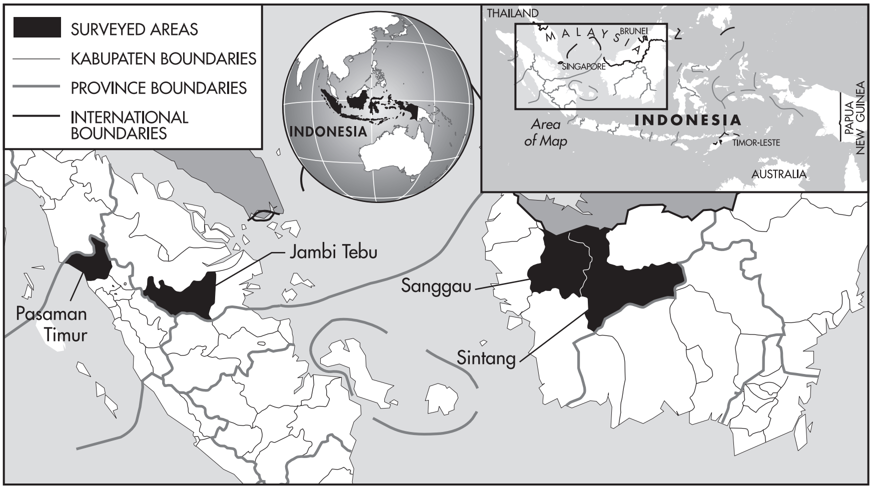
The innovation discussed in this chapter is the introduction of rubber (*Hevea brasiliensis*) to the plains of central Sumatra and Kalimantan, its adoption by farmers, and their adaptations to local farming conditions.

Rubber was introduced to Indonesia around 1900 in northern Sumatra and initially cropped on private estates. The demand for natural rubber led to a market boom, which has been sustained by permanent demand for the commodity (around 6 million tons is consumed worldwide each year).

In the 1910s and 1920s Sumatra was sparsely inhabited, with only one to four inhabitants per square kilometer. Shifting cultivation was the common practice; the typical pattern involved slash-and-burn of primary forest, one or two years of upland rice, followed by a long fallow. Fallow periods began to decrease (from 30 years to 10 years or fewer) when land began to be less available. Replanting after clearing old jungle rubber is the most common feature in the traditional rubber-growing areas. In pioneer zones (Barisan mountains, buffer zones, remote areas), however, jungle rubber may be planted on secondary forest and more rarely on primary forest. Basically the trend is replanting in the central plains and new planting in the hedges of traditional central areas.

In the early 1900s when rubber was introduced, farmers saw an immediate opportunity and began to collect seeds in surrounding estates that were flourishing. Rubber was cultivated intensively on estates, with fertilizing and continuous weeding requiring a great deal of labor. Local farmers as well as spontaneous migrants adapted their own systems according to their limited resources of cash and labor, planting rubber trees with paddy after traditional slash-and-burn. They let the rubber trees grow with the secondary forest, planting the rubber trees at a higher density than on the estates to compensate for trees lost to competition and degradation. Indonesian farmers have called this system jungle rubber (*hutan karet*).

Map 12.1



The rubber tree is a forest species in its natural habitat in the Amazon basin in Brazil, so rubber proved to be very adaptable to this "new" environment. Farmers profit from this rubber cropping system because it requires no inputs and low labor and because it provides a certain amount of income diversification because the system also produces fruits, nuts, and timber for housing, as well as nontimber forest products such as rattan, medicinal plants, *gaharu* resins,[1] and local vegetables. Gouyon (1995a) has described such a rubber cropping system in South Sumatra.[2] De Foresta (1990, 1992a) described rubber cropping as part of a complex agroforestry system.

Production per hectare of unselected rubber seedlings is very similar in both estate and jungle rubber systems with a annual yield close to 500 kilograms per hectare. In the case of jungle rubber, the advantages are quite clear: there is no cost of establishment (unselected seeds have no value, and no fertilizers are used); the labor investment is low (only a few days are required for rubber planting because land has already been cleared for upland rice); and no maintenance is required during immature periods. Biodiversity conservation, soil conservation, and water management can be added to the list of environmental benefits. Nontimber forest products provide income diversification, a feature highly appreciated by farmers who generally do not like to rely on one crop or product only. The main constraint is the delay in production (Gouyon 1995a). Rubber trees are tapped after 8–10 years, compared with those in estates, which are tapped 5–6 years after planting. Jungle rubber has a relatively low yield per hectare compared with plantations planted with clones.

Farmers are still relying on unselected rubber seedlings for jungle rubber, while estates have now all adopted improved planting material (grafted clones). The estate plays a role, often indirectly or involuntarily, in disseminating plant materials because workers collect seeds.[3] Clonal seedlings are plants coming from seeds collected in plantations planted with clones. They do not have the same characteristics as the clonal parents. Clones are grafted stumps where the grafted material has been selected.

Rubber clones provide the highest yields and the strongest secondary characteristics. Clonal rubber yields between 1,400 and 1,800 kilograms per hectare on estates in Indonesia and among the best farmers participating in the Smallholder Rubber Development Project (SRDP), such as in Prabumulih SRDP area in South Sumatra.[4] Other improved rubber planting material can be clonal seedlings (seeds from plots planted with one clone) and polyclonal seedlings (seeds from an isolated garden planted with several selected clones). In Indonesia only one estate (Lonsum) is able to produce polyclonal seedlings (BLIG).[5] Polyclonal seedlings, which were in favor on estates in the 1950s and 1960s, have generally been abandoned for clones that are more homogeneous and adapted to high production levels. These clones (particularly those of the third generation that have been available since the 1970s) have good secondary characteristics such as disease resistance. Clonal rubber is therefore the first important innovation to be adopted by farmers.

In the 1970s the Indonesian government began to debate ways to support the smallholder rubber sector. The Malaysian and Thai governments offered such support to their smallholders much earlier (in the 1950s in Malaysia). In Indonesia, which produces 50 million tons of rice each year and needs to feed more than 200 million people, rice self-sufficiency was—and still is—the central focus of agricultural policy. Unlike Thailand and Malaysia in the 1950s, traditional rubber-growing areas in Indonesia are not located in politically sensitive regions.

In 1990 around 80 percent of the smallholders in Malaysia and 65 percent in Thailand had been reached by various rubber schemes. The model chosen by all three governments for smallholders is directly derived from the estate model: monoculture of rubber with a high level of labor and inputs, and no intercropping during the immature period (except cover crops). The objectives were to maximize returns to capital and labor, as well as to develop a simple rubber monocropping system that could be widespread in vast areas without major adaptation to local conditions (adaptations were generally limited to choice of clone and level of fertilization). This model has proven efficient but costly (around US $1,500 per hectare in Indonesia). So far, only 15 percent of Indonesian rubber farmers have been reached by projects,[6] and only a portion of them (approximately 70 percent) have full production plantations.

As a general rule, farmers participating in these projects were provided with a credit package that was supposed to be repaid within 15 years. The package included the following components:

- clonal rubber plants
- fertilizer during immature period (the first five years)
- pesticides for diseases
- cash to help farmers with some terracing if necessary (about Rp 100,000)

Table 12.1. Rubber Planting Distribution among Various Projects, 1970–98

Category	*TCSDP 1990–98*	*SRDP 1980–90*	*NES 1978–90*	*PRPT 1980–90*	*GCC/ARP 1974–80*	*NSSDP/ WSSDP 1973–79*	*Total*
Area (ha)	69,000	101,149	168,571	15,697	112,600	20,019	487,036
Percent of total area	14.2	20.8	34.6	3.2	23.1	4.1	
Class A & B plantations (percent)[a]	80 (est)	89	60	39	< 25	80 (est)	
Planted area effectively under production in 1998 (est.)							
Productive area (ha)	55,200	90,023	101,143	6,122	28,150	16, 015	296,653

a. Class A & B groups rubber plantations that have been correctly implemented and are productive.
Source: Gouyon 1995 and Penot 1999.

In addition in two government-funded projects aimed at settling migrants in virgin areas, farmers were given land certificates and a wage for the first five years.

Rubber generally contributes between 80 and 90 percent of rubber farmers' incomes (SFDP/GTZ 1990; Gouyon 1995b). Rubber farmers that do not participate in these projects generally have 2–5 hectares of jungle rubber no matter where they are located. Old jungle rubber plots with very low yields cover vast areas. Project farmers generally have 1 to 2 hectares of clonal rubber in addition to their jungle rubber.

Innovations

The innovation adoption process can be divided into three categories:

- endogenous innovations in the jungle rubber system by nonproject farmers
- endogenous innovations in the rubber monoculture estate-like systems by former project smallholders
- rubber agroforestry systems developed by research project farmers combining their own innovations with those of outside research agencies.[7]

Questions about clonal planting material to be produced by private nurseries are a broader policy issue and are discussed later.

Endogenous Innovations by Nonproject Farmers

On their own, farmers have adapted the estate model into a complex agroforestry system where secondary forest is allowed to grow rubber. Planting density of rubber is increased, sometimes up to 2,000 plants per hectare, to compensate for expected losses due to competition with other trees. There are no extra costs for this dense planting rate because seeds are freely collected from old jungle rubber.[8]

The use of cheap but locally adapted planting material is already an innovation in itself. Farmers seized an opportunity, rubber, and integrated it with the traditional system. Beyond this primary adoption, one can observe five innovations introduced by farmers in the jungle rubber system: type of planting material, planting techniques, number of manual weedings, chemical weed control, and agroforestry techniques. So far, these are the only innovations that have been introduced in the jungle rubber system without any external help.

PLANTING MATERIAL. Clonal rubber stumps are relatively expensive and are simply not available to farmers in many remote rubber-producing areas. The first endogenous innovation was to collect seeds from existing nearby clonal estate plantations. At the very beginning during the 1910s and the 1920s, estates and farmers were using unselected seeds. Estates planted the first generation of clones in the late 1920s and the 1930s, and the seeds collected by farmers on these clonal plantations were in fact clonal seedlings (generally from the GT1 clone, the most widely planted one), which were then planted in jungle rubber. The production increase compared to that of jungle rubber was low, but yield could reach 700–800 kilograms per hectare (Dijkman 1951). The proportion of jungle rubber seedlings that are clonal seedlings is thus unknown after several generations of jungle rubber (the life span of the system is 30–40 years). The word *collect* means harvest of seeds with or without authorization from estate owners. Except for those seeds coming from specific polyclonal gardens such as BLIG, these seeds have no market value, so estates do not object to allowing surrounding farmers to collect them.

AN EXOGENOUS AND FAILED INNOVATION. In the Pasaman area in West Sumatra, farmers have adopted BLIG rubber planting material. Both East and West Pasaman areas were surveyed by the author, who concluded that BLIG, which is susceptible to *Colletotrichum* leaf disease, is not suitable for those areas. Its yield potential (probably around 1,000 kilograms per hectare per year) is also questionable, but there may be scope for BLIG in some areas that are remote and without leaf diseases.

PLANTING TECHNIQUES. Farmers began to plant rubber trees in rows in the 1980s to facilitate tapping and improve returns to labor.

NUMBER OF MANUAL WEEDINGS. Since the mid-1980s or so, the trend has been to weed once a year, at least during the first years of the immature period, with a selective cutting to conserve interesting timber and fruit trees as well as some species such rattan. In contrast the estate model calls for 8–12 weedings a year during the first four years. With annual weeding, tapping of rubber trees may occur in the sixth or seventh year after planting, instead of the 8–10 years without any weeding.

CHEMICAL WEED CONTROL. Deforestation often creates a niche for *Imperata* grasslands, maintained year after year by burning the savanna. In West Kalimantan *Imperata* can be very aggressive and jeopardize virtually all crops if weeding is not adequate. Rubber growing in a field invaded by *Imperata* suffers from the competition, and production may be delayed until the eighth or ninth year, thus destroying some forest rent.

Manual control of *Imperata* is possible, but it requires an amount of labor generally not compatible with farmer strategies. Farmers recently adopted the herbicide Roundup (glyphosate). Applied at a rate of 2–5 liters per hectare, it suppresses *Imperata* and enables paddy to grow. The per-hectare cost of Rp 40,000–100,000 is compensated by saving labor. Herbicide is also used to control weeds in the rubber rows during the paddy crop or during the first four or five months after planting. The cost is then Rp 25,000–50,000 per hectare using only half a liter per hectare (all prices are before the 1998 financial crisis).

Farmers are as sensitive to returns to labor as they are to yields per hectare and total revenue, and every innovation that dramatically reduces or saves labor has a good chance of being adopted if the cost is reasonable and within the range of benefit for a given crop. This is the case for Roundup. It is very efficient with rubber and probably for all tree crops (see chapter 15 for its use with cocoa and cloves); Roundup is probably less efficient for upland rice and annual crops considering the risks of crop failure. Innovations with limited improvement in returns to labor have little chance of being adopted if other opportunities exist (for example, if a farmer can choose between rubber and palm oil or pulp trees). All these advantages seem to overwhelm the possible negative effects of herbicides on the environment. In addition, the residual effect of herbicides such as Roundup is extremely limited.

AGROFORESTRY TECHNIQUES. Another innovation is to intercrop rubber with food crops during the immature period. Some farmers have intercropped for several reasons—the presence of a market for some products (chili and pineapple for Palembang in South Sumatra), the necessity to grow food crops if land is scarce (as it is in transmigration areas), or the tendency of some farmers to go for continuous upland food cropping in an intensive way (that is the case of the Minang Kabau farmers in West Sumatra and the Kapupaten of East Pasaman (Pasaman Timur). Intercropping was tremendously limited in project areas before 1993 because it was forbidden by estates and project management. Various research programs in several countries have shown that intercropping, in fact, favors rubber growth and does not have any negative impact on rubber.[9]

Asked about the main factors that led them to choose agroforestry systems instead of monocropping, smallholders gave the following answers:

- lack of capital to afford the complete "estate-rubber" package and lack of labor required in this system
- saving time and money on weed control
- higher returns to labor per farm plot during the rubber immature period
- availability of land, which enables a relatively extensive rubber cropping system.

Smallholders speak about agroforestry systems as an efficient way to control erosion and as a sustainable source of income through biodiversity with timber and fruit species. Local Dayak and some Javanese transmigrants also consider rebuilding biodiversity in *Imperata* areas as an important means of future access to fruits and seeds for replanting their fields or home gardens.

A Well-Adapted Crop: Jungle Rubber Adapted to Pioneer Farmers

Jungle rubber was very well adapted to the situation that farmers faced at the turn of the 20th century. At least six conditions were necessary for jungle rubber to replace shifting cultivation with a sustainable rubber cropping system able to feed 1.2 million farmers in Indonesia in 1990:

- land was plentiful, unspoiled, and thus offered forest rent
- direct sowing of unselected rubber to the forest environment in a complex agroforestry systems was possible
- a reservoir of labor was available in Java
- a sustained demand for rubber and a pricing policy that almost always favored farmers with continuous incentives for further area expansion and production increases
- there were no other alternatives until the 1980s
- jungle rubber conserves soil fertility and biodiversity, enabling the renewal of the system every 30–40 years. There seems to be no major technical problem with replanting rubber and oil palm, unlike cocoa.

The first five conditions are quite similar to that of the cocoa boom in Indonesia and probably to most tree-crop commodity booms based on forest rent and migration (Ruf, 1995a, c; Gouyon, 1995b). However, for jungle rubber alone, it has proved sustainable on more than 2.5 million hectares with two or three cycles of replanting during the 20th century. Indonesia is still very well placed in the world market, with low labor costs and the capability to increase production significantly if more farmers move to clonal rubber. The demand will be maintained for the next 20 years because there is no substitute for synthetic rubber for at least 25 percent of the total market (natural rubber contributes 35 percent of the total demand).

Limits to Adoption for Nonproject Farmers

The system cannot be maintained except in remote and pioneer zones because:

- other perennial crop alternatives emerged in the 1980s and 1990s such as oil palm, cinnamon (in Jambi and West Sumatra), and recently, pulp trees
- off-farm opportunities have appeared with industrialization and trade development
- jungle rubber yield per hectare is limited and every farmer now knows that rubber clones enable double or triple production (a very positive outcome of SRDP/TCSDP), which means that these farmers must adopt clonal rubber.

Farmers generally plant up to 4 hectares of jungle rubber. Planting area is limited by labor and not by land, except in areas where land is now fully used such as in South Sumatra around Palembang. A farmer can tap 600 trees a day, or about 1 hectare. If the farmer taps every two days, he and his wife can handle 4 hectares of jungle rubber. Further expansion requires sharecropping if nonhousehold labor is available (Javanese transmigrants, for instance).

The continuous expansion of the rubber area is still under way through both planting in new areas and replanting old jungle rubber areas. Smallholders now account for 84 percent of the total rubber area (DGE 1993).

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 alternatives. The future of this system is to include clonal rubber to boost rubber production, meanwhile conserving agroforestry practices that provide income diversification, efficiently use farmers' limited resources, and maintain environmental and biodiversity advantages. This will be developed in the third stage of innovations with Rubber Agroforestry Systems (RAS). These systems use on-farm experiments, based on participatory research, to test the capacity of clones to be intercropped by various animal and perennial crops, especially fruit trees. CIRAD and ICRAF are conducting these experiments in Sumatra and Kalimantan.

Innovations in Monoculture Systems by Former Project Farmers

The estate model rubber projects have been well described in the literature. In two areas a major endogenous innovation in SRDP plantations is the planting or selection of trees in original monoculture plots in North Sumatra (southern part) and West Kalimantan (Sanggau area). Farmers select fruit and timber species between the rows of rubber.

Farmers have long been told by the Indonesian extension service Dinas Perkebunan that clonal rubber should be cropped in monoculture and were generally forced to maintain clean rows in projects (at least during the immature period of rubber) to destroy any emerging vegetation. In West Kalimantan SRAP (Smallholder Rubber Agroforestry Project) has chosen GT1 as the main clone to be planted. Unfortunately, this clone is very susceptible to a leaf disease (*Colletotrichum*), leading to severe defoliation and most likely a decrease in production. Defoliation was so severe—as much as 75 percent for most of the year in some areas—that *Imperata* began to come back in rubber plots along with secondary forest regrowth.

In at least one village in Sanjan (Sanggau area in West Kalimantan), some farmers began to select timber and fruit trees among the emerging vegetation, first to shade and suppress *Imperata*, but then to obtain production from these trees, which included *meranti,* teak, and *nyatoh* for timber and durian, *pegawai, rambutan, duku, petai, jengkol*, jackfruit, and *cempedak* (a type of wild jackfruit) for fruit. The same trend has been observed on both SRDP plantations in the southern tip of North Sumatra province. This innovation is remarkable for two reasons: first, because farmers always thought that is was possible to intercrop trees with rubber but did not know which trees could be combined with rubber without decreasing production (and neither did researchers), and second, because they now ignore rules discouraging intercropping.

Farmers are also combining unselected rubber trees with newly planted cinnamon (*Cassiavera*) in the Muara Bungo area, in the village of Muara Buat, in hilly areas close to the Barisan mountains, and in the immediate vicinity of the Kerinci National Park (pioneer and buffer zones). The success of cinnamon in the Kerinci area has spread to more traditional rubber areas, in particular the Barisan mountain piedmont, as well as to the plains where cinnamon is not traditionally grown. It is too early to assess this innovation, but official services are now also experimenting with combinations such as rattan in other provinces, and this innovation can be expected to spread rapidly.

COST. There is no cash cost for the associated trees because plants are collected from the surrounding jungle rubber. Planting cinnamon is more costly; 2,500 plants per hectare cost Rp 50,000–125,000. Relatively limited labor is required for tree planting or selective cutting if trees emerge from existing vegetation regrowth.

RETURNS. Fruit trees produce within 10 years, timber is used by the grower or sold, and cinnamon is harvested 7–8 years after planting.

ADOPTION AT THE VILLAGE AND REGIONAL LEVELS. Only preliminary observations have been made in some selected areas, in particular in the village of Sanjan, Sanggau area, West Kalimantan, and North Sumatra (Penot, CIRAD-CP, personal observations unpublished, 1993-1995). A further and more systematic survey should be done to quantify the trend in all projects. In Sanjan village, a rough assessment shows that at least 10 of the 50 SRDP project farmers are selecting and growing associated trees.

ADOPTION BY INDIGENOUS PEOPLE. In Sanjan, adoption is fairly good because Dayak farmers already have traditional agroforestry practices with jungle rubber and the *tembawang* system—a fruit- and timber-based complex agroforestry system (Schueller and others 1997).

CONSTRAINTS ON ASSOCIATED CROPS. From an institutional point of view, there are no constraints to associated fruit and timber trees to rubber as soon as project officials have no more authority on farmers' plots. From an agronomic point of view, problems of competition between rubber and associated trees may appear after 10 to 15 years for fruit trees and 15 to 20 years for timber trees, according to planting density. So far no scientific data are available on this kind of competition, and no experiments have been conducted.

The planting density of associated trees observed in Sanjan suggests that farmers are aware of this potential threat, and planting density (of associated trees) is fairly low at 100–200 trees per hectare (compared with a per hectare average of 550 rubber trees), with a limit on tall trees with a canopy above rubber trees such as durian.

RATE OF ADOPTION. The SRDP and other estate-model projects can be considered successful, with effective rate of plantations in production at up to 80 percent compared with PRPTE projects in previous years at 24 percent.[10] It is quite clear that these estate-model projects had an indirect positive effect on surrounding farmers in project areas, providing significant information to these farmers about clonal rubber (in particular in South Sumatra around Prabumulih and in the western part of West Kalimantan in the Sambas, Anjutan, Sanggau, and Sintang areas).

CONSTRAINTS ON ESTATE MODELS. The estate model has several constraints. One constraint is cost, which ranges between $2,000 and $4,000 per hectare depending on the specific project with which the farmers were involved. At that rate, it will require 160 years to reach all farmers (Tomish 1992). To reach more farmers, new low- to medium-cost technologies must be identified and implemented. In projects with oil palm, credit is provided to solve the problem of smallholders' limited capital.[11]

Another constraint has involved the targeting of the project. The SRDP development approach has been successful because the project deals with traditional rubber farmers who have access to clonal rubber. The NES (Nucleus Estate Project) approach has been less successful because of the government's very heavy pressure on rubber smallholders, in particular concerning credit reimbursement (see Levang's analysis of Batumarta NES in South Sumatra, 1989). In addition, the targets were transmigrant Javanese farmers with no tradition of rubber production. It is quite clear that local farmers have more incentive to intensify their rubber cropping systems through access to clonal rubber under certain conditions and are more open to innovations than transmigrants because they feel rubber is now a traditional crop

A third constraint is access to the estate model. Access is limited for non-project farmers by the cost and availability of good quality planting material and cheap phosphate fertilizers. Clonal rubber is one of the inputs necessary to upgrade jungle rubber. The purity of the clone is questionable in both government projects managed by the tree-crop extension service, Dinas Perkebunan, and local private nurseries.[12] Other important constraints include traditional credit mechanisms, which are not adapted to long-term loans required for plantation funding, and lack of information. Dinas Perkebunan, in particular, is often unable to provide current information about the latest efficient and adapted techniques. These constraints lead to a search for new rubber agroforestry systems as alternatives to both the jungle rubber system (low productivity and low cost) and the estate system (high productivity and high cost).

Rubber Agroforestry Systems Developed by Farmers

Since clonal planting material is now more available in some provinces than in the past, particularly in North and South Sumatra provinces as well as in West Kalimantan province, innovative farmers have begun to intercrop rubber with other perennials such as fruit and timber trees. These improved rubber agroforestry systems are very promising for income diversification (rubber, fruits, timber, food crops). They are also more sustainable and less susceptible to fire risks. Some examples in West Kalimantan have been well documented (Schueller 1997). Such systems have been developed in areas where social and technical pressures from rubber projects were lower. Up to 40 percent of project farmers have developed such strategies in West Kalimantan.[13] Among them, some 10 percent have developed complex agroforestry systems, with more than 200 fruit and timber trees associated with clonal rubber without any decrease in rubber yields. These developments are illustrated in the following example of participatory on-farm research for improved rubber agroforestry systems.

An exogenous component comes from the Smallholder Rubber Agroforestry Project, which conducts farm experiments under real conditions. A participative approach is essential. Improved rubber agroforestry systems are explored as alternatives to traditional jungle rubber and classical rubber development schemes based on estate technology. The main challenge is to test various improved planting materials and appropriate levels of inputs and labor to see which combination produces the best growth and yield in agroforestry systems, and which are most appropriate and affordable for smallholders (Barlow 1993; Penot 1995a). The objective of this research program is to improve the system's productivity by optimizing labor and minimizing use of inputs while keeping the benefits of agroforestry practices.

Even though agroforestry systems are very similar to the practices farmers currently use, it seems necessary to link innovations with an analysis of existing farming systems. The aim is to combine the advantages of clones with those of jungle rubber. The capital invested in improved agroforestry systems (based on the uses of clones) is higher than that for jungle rubber, but at the end of the rubber cycle, there is value not only from the rubber trees, but also from fruit trees and timber trees. Unfortunately, the rights of farmers to cut and sell their trees are not clearly established. Tree tenure is very limited and at least 74 percent of the land in Indonesia is still considered forest land under the responsibility of the Ministry of Forestry. Preliminary results show that risks, in terms of inputs, labor, crop failure, and the establishment phase, are lower with agroforestry practices (Penot and others 1997).

A network of on-farm experiments has been developed with 100 farmers in three selected provinces—Jambi and West Sumatra in Sumatra and West Kalimantan in Borneo. All innovations tested in this program have been discussed with farmers to improve adaptability and suitability of technologies according to farmer resources and requirements. The experiments are designed to minimize inputs and labor while conserving agroforestry practices and their advantages: income diversification, income during immature period of rubber through intercropping, and maintenance level of biodiversity and the environment.

SRAP is using a participatory approach for on-farm experiments with three main kinds of rubber agroforestry systems. Each is being tested for its suitability to local agroecological conditions, for labor and cost requirements, and for the optimal 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.[14] These clones must be able to compete with the natural secondary forest growth. Various planting densities and weeding protocols will be tested. This will identify the minimum amount of management needed for the system, a key factor for farmers whose main concern is to maintain or increase labor productivity. The biodiversity is very similar to that of jungle rubber, quite high, and relatively close to that of primary forest.

RAS 2 is a complex agroforestry system in which rubber (550 trees per hectare) and perennial timber and fruit trees (92 trees per hectare) are established after slashing and burning (De Foresta 1992b). It is relatively intensive, with annual crops intercropped during the first three or four years, with an emphasis on improved upland varieties of rice; various amounts of fertilizer are used as well as dry season cropping such as groundnut. Several variations of crop combinations are being tested, including food crops and tree crops such as cinnamon. Several planting densities of selected species are being tested according to a tree typology, in particular *rambutan,* durian, *petai,* and *tengkawang*. Biodiversity is limited to the planted species (between 5 and 10) and those that will naturally regenerate and be selected by farmers.

RAS 3 is also a complex agroforestry system with rubber and other trees planted within a framework similar to that of RAS 2. The difference is that it is established on degraded land covered by *Imperata cylindrica* or in areas where *Imperata* is a major threat. Labor or cash for controlling *Imperata* with a herbicide are the main constraints. In RAS 3, annual crops, generally rice, are grown only during the first year, with nonvine cover crops (*Mucuna*, *Flemingia*, *Crotalaria*, *Setaria*, and *Chromolaena*), multipurpose trees (wingbean, *Gliricidia*), or fast-growing trees such as pulpwood (*Paraserianthes falcataria, Acacia mangium,* and *Gmelina arborea*) grown immediately after rice harvesting (several combinations are being tested). The objective is to provide a favorable environment for rubber and the associated trees to grow, thus suppressing *Imperata* growth and limiting the weeding requirements. The association of nonvine cover crops and multipurpose trees for shading is aimed at controlling *Imperata*. Expected biodiversity should be similar to that of RAS 2.

COST AND RETURNS. A complete cost-benefit analysis of rubber agroforestry systems has been published (Penot 1996a). The main conclusion is that returns to labor are improved compared with those of the estate model. Benefits are also higher due to the other crops.

ADOPTION AT THE VILLAGE AND REGIONAL LEVELS. So far these systems are still under experimentation. In 2001 they were five or six years old and at the end of the critical immature period. An impact survey implemented in 2000 shows that the systems have been widely accepted and replicated by local farmers. Three-fifths of SRAP farmers have replanted on their own an average

0.6 hectare of RAS systems, generally RAS 2 (Trouillard 2001). There is a strong demand from neighboring farmers who want to join the project (the scale of the project is currently limited to 100 farmers each with a rubber plot between 0.3 and 0.8 hectare, a sufficient plot size to reflect reality). The development of village budwood gardens and local nurseries has given local farmers cheap access to improved planting material (which accounts for half of the total input cost of establishing a rubber agroforestry system).

ADOPTION BY INDIGENOUS PEOPLE. The systems are based on farmer demand and include some of the previous innovations developed by farmers themselves. So far, preliminary assessment of adoption by farmers seems to be slow, but with a real trend. In 2000, 24 farmers in trial villages had developed RAS systems on their own.

In the meantime, the context has dramatically changed as many farmers have access to recent oil palm plantings (2 hectares per farm) through projects from local private estates. Although oil palm seems to be promising, most farmers still also wish to plant clonal rubber. The 1997–2000 economic crisis reminded smallholders that farms relying on only one tree crop are fragile. Such a situation leads to new strategies oriented toward diversification where farmers consider oil as a complement to, rather than a substitute for, rubber. Nevertheless such opportunities reinforce the need for more productive and more affordable rubber systems based on clones. RAS systems seem to be the right alternative at the right time.

CONSTRAINTS TO ADOPTION. Farmers are aware that clonal rubber requires more weeding and inputs than unselected seedlings in jungle rubber, even in an improved agroforestry system, but they sometimes underestimate the minimum necessary requirements (which are currently being tested at different levels). One of the main constraints is the ability of farmers to integrate a minimal amount of inputs and labor into their current practices; this amount is higher than that for jungle rubber (very low) but lower than that for the existing estate model. The current research is aimed at identifying a level that will be acceptable to farmers.

The main constraints to adoption include a lack of:

- capital and credit
- good technical information about RAS and relevant training (especially on grafting techniques)
- good quality planting material
- relevant recommendations at the province level, particularly about leaf diseases

The low availability of clonal rubber planting material is still a serious constraint. The main hypothesis is that income from new oil palm plantations will provide the necessary capital for farmers to invest in clonal rubber that will be grown primarily in rubber agroforestry systems

Production of Planting Material by Private Nurseries

In South Sumatra province a strong demand for clonal rubber and the presence of a research station (Sembawa) that can provide information and budwood has led to the spread of private nurseries. More than 500 nurseries were operating there as early as 1991 (Gouyon 1993). The same trend has been observed in North Sumatra province (Barlow 1993) and to a lesser extent in West Kalimantan province (Schueller and others 1997) and Jambi province (Penot 1997). In all cases farmers took the opportunity to begin production of rootstock in nurseries and later grafted the rootstock with budwood from the extension service or surrounding projects. Few nurseries had their own budwood gardens. In South Sumatra, North Sumatra, and Jambi provinces, local Malayu farmers set up nurseries. In Jambi the market is still weak, although the demand is big. In West Kalimantan recent surveys show that only Javanese transmigrants took the opportunity to develop nurseries in order to supply the growing demand from the extension service and surrounding projects or private medium-sized estates. Few farmers have the money to buy planting material. The innovation components include establishing rootstock nurseries, grafting, and sometimes establishing a private budwood garden to supply the budwood necessary for grafting.

Need for Improved Policies

Enhancing the diffusion of improved genetic planting materials (IGPM) for clonal rubber is currently limited by availability and quality. There are strong arguments in favor of private or government-operated nurseries, but the purity of clonal materials cannot yet be guaranteed. Future objectives should include:

- providing reliable technical information on clonal rubber production management and clonal purity
- providing nurseries with good quality certified budwood from controlled projects or budwood gardens run by the extension service
- promoting the development of private budwood gardens for nurseries

It would also be possible for farmer groups to produce their own clonal rubber planting material in village or community budwood gardens. The objectives would be the same as for private nurseries but would also include information and training on technical and management techniques.

Possible Approaches

Several different approaches are possible. The network of GAPKINDO members (the Association of Indonesian Rubber Professionals, that is, the rubber factory owners) in the region could be used to set up commercial nurseries with help from professionals recruited from government projects or retirees from estates (Bengkulu, Jambi, North Sumatra).

Planting material from all existing budwood gardens, including material from the extension service and the projects could be controlled, rehabilitated, and certified by using electrophoresis techniques for certification (a technique developed by CIRAD). Private nurseries could be supported with a reliable source of budwood from existing rehabilitated budwood gardens; and the government could support establishment of village budwood gardens.

Clonal rubber could be distributed to farmers in several ways: through the extension service and projects (after certification); through village budwood gardens and farmers groups; through private nurseries with certification; through rubber collectors or village traders; through open sale in village markets; and through a distribution channel created by projects.

The quality of IGPM, not just the size of the stumps but also its clonal purity, is essential and should be guaranteed to buyers by a certification process that should be independent from producers. Who will implement such a certification process? IGPM availability can be improved with the multiplication of budwood gardens along with proper training and information, at least for the first year, to private nurseries, operators (the extension services), or local projects. In fact, this could build a real IGPM production system to control and supply the most important component—pure clonal planting material. The actors in such a system are the private sector (private nurseries), projects, the official extension agencies (DISBUN, IDT, INPRES/BANDES), and farmer groups.

Since 1997–98, Indonesia has been enduring a serious economic and political crisis. Income analysis showed that farmers relying on rubber did not suffer significantly (Penot and Ruf 2001) with the exception of poor farmers still relying on aging jungle rubber. This finding reinforces the necessity for these farmers to move to clonal rubber to improve their situation. RAS systems are more affordable than rubber monoculture. Provided that good quality clonal rubber planting material is available at low cost and good quality, there is great scope for improved rubber agroforestry systems even in a context of diversification with oil palm.

But rubber prices are still very low, at a bottom price of 60 cents per kilogram in 2000 and 2001 on the international market.[15] Low market rubber prices and relative rupiah stabilization lead to a low producer price. [16] Rubber competitiveness suffers in particular in comparison with that of oil palm. This situation reinforces again the necessity for most rubber farmers to move to clonal rubber, either monoculture or RAS, and adopt a diversification policy mainly based on adoption of oil palm.

Conclusion

Rubber farmers have developed a series of innovations in order to adapt rubber to their extensive agroforestry practices (jungle rubber) or the estate model (SRDP) by associating rubber with perennials or annual crops. However, they have reached a stage where innovations are limited and productivity increases cannot be achieved without including rubber clones. Those clones require different management. SRAP wants to answer this demand. Rubber agroforestry systems, based on clones, are the best alternative for farmers. Technical change is driven by economic necessity, in particular since the Indonesian crisis. RAS systems are the expression of the recombination of indigenous knowledge (agroforestry practices) and external knowledge based on intensification (clones and other chemical inputs). Such technical change leads to more affordable and more adapted rubber cropping systems for diverse local situations. Meantime, positive externalities of RAS systems, such as biodiversity conservation and environmental sustainability, make them more attractive for future large scale development

Smallholders need reliable information, credit, good quality planting material, and recognition of the relevance of complex agroforestry systems by all actors, including civil servants involved in agricultural development.

Even with strategies oriented toward diversification with oil palm, rubber has still an important role to play for local farmers who do not want to rely on one export crop only.

Notes

1. *Gaharu* resin is obtained from some specific trees that develop a fungus inside their trunk. The tree is cut and the central part of the wood is collected and used as a fragrance and other uses.

2. As well as other authors such as Dove (1993) and Salafsky.

3. This same practice occurred for robusta coffee at the beginning of the 20th century (Ruf 1997) and more recently with cocoa from Malaysian estates (chapter 7).

4. SRDP is funded by the World Bank.

5. BLIG = Bah Lias Isolated Garden, London Sumatra, North Sumatra.

6. In Indonesia, there were several "partial approach" projects with a support in inputs limited to the first year, including the Assisted Replanting Project (ARP) and the Group Coagulating Center (GCC) as well as "full approach" projects with full credit and support for the first six years North and West Sumatra Smallholder Development Projects (NSSDP, WSSDP) between 1975 and 1980; the NES/PIR in transmigration areas (NES = Nucleus Estate Project, PIR in Indonesian, funded by World bank or by the Indonesian government); and eventually the Project Management Unit (PMU) projects, such as SRDP/TCSDP for local smallholders (SRDP = Smallholder Rubber Development Project, from 1980 to 1990; TCSDP = Tree Crop Smallholder Rubber Development Project, a continuation of SRDP since 1990, funded by World bank. A similar project, TCSSP, is funded by ADB). Former projects, as well as SRDP-like schemes funded directly by the Indonesian government, have been regrouped in the PRPTE project.

7. Research projects are the Smallholder Rubber Agroforestry Project (SRAP), a research program based on farm experimentation using a participatory approach with CIRAD (Centre de coopération Internationale en Recherche Agronomique pour le Developpement), ICRAF (International Centre for Research in Agroforestry), and IRRI projects (Indonesian Rubber Research Institute).

8. This principle of high-density planting to control the risk of tree mortality and cost of weeding applies not only to rubber and Indonesia but to many tree crops and regions in the world. For instance, many cocoa and coffee growers use it in the uplands of Indonesia and West Africa (Ruf 1992, 1997).

9. IRRDB (International Rubber Research and Development Board) annual meeting, Colombo, 1996.

10. All governmental rubber projects before SRDP have been regrouped in PRPTE (before 1980).

11. This credit provided to farmers explains the current smallholder oil palm boom and demand from farmers. However, many farmers would still prefer to rely on improved rubber systems, or on both crops, if credit were also available for rubber.

12. Surveys on the availability of clonal planting material by private nurseries were conducted in 1997 in West Kalimantan (Schueller and others 1997) and Jambi (Iwan and Penot 1997) showing evidence of complete anarchy in terms of quality and purity of clonal rubber production. A new planting material policy is required.

13. Personal communication from B. Chambon, CIRAD chief economist who surveyed the area as a doctoral student in 1997.

14. The selected clones are PB 260, RRIC 100, BPM 1, and RRIM 600.

15. For TSR 20 (technically specified rubber n° 20), the most widely used by the industry.

16. The rupiah stabilized at around RP 8,500 for US$1 in 2000 and Rp 11,500 for US$1 in 2001.

13

Pod Borer and Pesticides

François Ruf and Yoddang

Helopeltis is the main pest [afflicting cocoa trees]. . . . Protection is afforded by black ants whose pullulation is encouraged: ants are purchased from the natives; they sell small elongated nests . . . containing black ants . . . . A dozen of these nests are hung in each cocoa tree. In order to survive, the ants need cochineal bugs . . . which settle in the young parts of the plant—in the shoots and young fruits where the ants now pullulate; Helopeltis fears this black ant and does not dare settle on the young growth that it would otherwise prick. . . .

(Oudot, 1937, Handwritten report)

The quotation, a picture of a colonial plantation in Java in 1937, is a reminder that, in the absence of chemical inputs in 1930, colonists had to apply some basic ecological principles and that integrated pest management (IPM) techniques have been used successfully for a very long time. Does Java in 1937 bring us back to reality in 2004?

In the 1990s some smallholders in Sulawesi and Côte d'Ivoire also allowed ants to spread on their cocoa farms, where their pest control role is appreciated even though they hinder harvesting. Many other smallholders complain about the ants whose bites not only make harvest difficult but also enhance development of an epiphyte that chokes cocoa trees.

For most tree crops, IPM methods are either very experimental or very old and not yet efficient for most smallholders. More research is obviously needed to achieve better performances for IPM techniques.

In the meantime, if farmers can master spraying techniques and limit the negative impact of pesticides on human health, the use of a reasonable amount of pesticide is a key factor in combining high yields with a long tree life cycle in the uplands. In other words, a combination of tree capital and a reasonable amount of pesticides may bring high returns and good sustainability in upland agriculture.

The main objective of this chapter is to demonstrate the efficacy of this combination by using control of the cocoa pod borer (CPB) as an example. The second objective is to analyze the determinants of pesticide adoption and test the hypothesis that pesticide adoption widely depends on a high commodity price and revenue and on the dynamism of migrants who own orchards that are still relatively young. The hypothesis assumes not only a free market for the commodity but also a favorable period in the world price cycle. If the orchard is above a certain age, then difficulties are aggravated because farmers must face simultaneously the aging process and loss of forest rent. Then if farmers encounter a depressed world market for their commodity, production and revenue may enter an unavoidable recession spiral. This is probably true everywhere, but is more of a problem in uplands than in the lowlands. Is not pest control especially costly in farms planted on steep slopes? Can a pest such as the CPB destroy a tree crop farming system in the uplands? What can be learned from this borer infestation?

Most of the chapter is based on a comparison of farmer innovations and decisions at four sites in four different provinces in 1996, before the severe 1997 drought. A final section explores what can be learned from a time series and changes over time in one region, from 1996 to 2001–02.

Slash-and-Burn and CPB Control

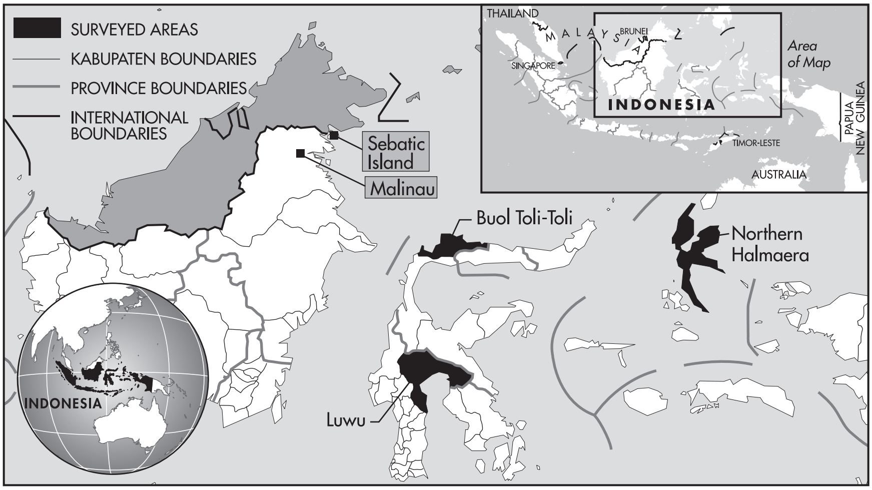
Most tree crops and especially monocrops can be approached in terms of shifting cultivation. Like annual crops, the shift in production, or shifting cultivation, is a rational response to the basic forest rent issue. Here we address the pest component of forest rent. The relative absence of insect pests and diseases in the early years of a cocoa boom did not last forever. Decade after decade, and in some cases, year after year, the incidence of insect pests and diseases increased and raised production costs by lowering yields and adding to maintenance costs.

This pest component is probably not only part of forest rent but also new crop rent. The forest may explain lower pest pressure but the time needed for a pest to adapt to a new crop also plays a role. The two rents, however, are often linked—when the forest habitat of a pest is destroyed, it may begin to spread through a monocrop. From Brazil to Ghana, this pest problem is a component of dramatic environmental change, leading to a no-less-dramatic shift in production.

Indonesia and the Cocoa Pod Borer

Indonesian smallholders have a wide range of strategies for dealing with cocoa pod borer, from doing almost nothing except shifting cultivation in Moluccas, to intensive spraying undertaken by some smallholders on Sebatic Island and Central Sulawesi. Even when the cocoa price collapsed from 1999 to 2001, some farmers continued to spray to maintain control. Despite the strength of the insect pest and the damage it causes, an intensive cultivation

Map 13.1



system appears to some smallholders as a better option than expanding the area farmed. This chapter describes this wide range of strategies.

The cocoa pod borer does not damage trees, but it does shorten their economic life by cutting yields to a threshold discouraging to owners. The borer lays its eggs on the pod; larva enter the pod, where they consume the pulp and placenta. If the infestation is complete, no beans can be separated from the placenta, and all are lost. In most cases, the infestation is only partial, and some beans can be saved from infested pods, while others may be harvested before contamination.

After a few years of infestation, farmers mention economic losses of 30 to 90 percent or even 100 percent, but they often exaggerate. Losses might reach 90 percent during the low season and occasionally during dry years; however, during the peak season, a high number of pods means fewer attacks and fewer infested pods. During the rainy season and thus during rainy years, pods are regularly washed, which makes it difficult for the moth to lay eggs and likely washes away those eggs that are deposited.[1] The real economic loss is therefore not as high as some smallholders claim.

However, in Halmaera (Moluccas) and Malinau (East-Kamilmantan), beyond a perceived 70 to 80 percent loss threshold, many smallholders stop harvesting, leading to a 100 percent loss. In Halmaera, and to a lesser extent in Central Sulawesi, some smallholders abandon the infested cocoa trees and clear forest a little bit farther away than usual, from 10 to 100 kilometers from the infested plantations. This, of course, still is the shifting cultivation principle.

It is both a very old principle that has been applied in many countries for decades and even centuries, and a local innovation. Smallholders find a way to bypass the problem at no monetary cost (except for transportation if the new plantations are remote). Their only costs are their own family labor. In the short term, it is a rational individual strategy, but it is also a forest consuming innovation with all of its externalities—it accelerates the spread of the infestation at the expense of the whole farming community.

This is why all means of controlling a pest such as CPB can be considered as a major innovation to slow deforestation and shifting cultivation. What are the various options and how effective have they been? First, integrated pest management solutions will certainly take over in the future, possibly in the near future, but so far their efficiency has not be been proved unless associated with frequent pesticide spraying.

Cutting down trees or heavy pruning? In Ghana, attempts to control swollen shoot disease by cutting out the infested trees proved useless. Although swollen shoot is caused by a virus and not an insect, the efficiency or inefficiency of cutting out trees is the same. Regardless of the insect pest or disease, cutting down trees requires total implementation. No infested trees can remain—neither the primary host or the pest's alternative hosts. Eradication of infestations with this method can sometimes be achieved on isolated estates, but it is impossible once cocoa is cropped throughout a whole region.

Intensive spraying? In Malaysia, the few estates that manage to remain in the cocoa sector rely on regular, heavy spraying. In 1996 it was the only proven way to control the CPB. However, intensive spraying over many years may lead to arrival of resistant pest strains and a drastic reduction in predators and parasites that normally keep the pest under control. Writing about capsids in Ghana, Leston (1974) mentions the inevitable increase in the dosage of the original insecticide and the switch to an inevitably more expensive one. All this reduces quality of the crop environment and increases costs. As Leston (1974, p. 101) concluded: "For governments in Ghana . . . to subsidize farmers and exhort them to spray at fixed times in the year . . . is to contribute not to increased yields but to a decline."

Even though increased by unsuitable policies and bad management, the cost of pest control is rarely passed on to the consumer, or if so, only for a short time, because there are always some other regions and countries where smallholders can clear forests at a very low cost and sell their cocoa for a lower price. The cost of maintaining established cocoa farms and thus saving part of the tropical forests is clearly externalized. It is not passed on to the market but rather to the next generations.

This is why innovations such as the apparently rational use of pesticides in Indonesia need to be watched closely. It is still early to draw conclusions for Indonesia, but some dangers mentioned by Leston are not out of range. However, if some Indonesian smallholders can manage to tackle insect pests such as pod borers at a reasonable cost while maintaining high yields per hectare, this would be a worldwide "première" to be analyzed. Is that the case?

Smallholders and extension services approach such problems differently. We examine both these approaches, but first some background information on the CPB and its invasion is required.

CPB Outbreaks in Four Provinces

Although an external introduction cannot be excluded,[2] the pod borer is often considered to have originated from the geographic and economic unit formed by Mindanao (Philippines), the east coast of Borneo (Sabah in Malaysia and East Kalimantan in Indonesia), North and Central Sulawesi, and North Moluccas (Eastern Indonesia). The insect might be a natural parasite of some fruit trees such as the *rambutan* (Lass and Wood 1985). CPB emerged in North Sulawesi in the late 19th century and seems to have been a major factor in ending a preliminary cocoa cycle of a few hundred tons a year (Topoxeus and Wessel 1983). Cocoa was almost forgotten in Indonesia until the early 20th century.

In Halmaera, the independence period of the 1950s marked the beginning of a new cocoa boom on the island. However, CPB emerged around 1968 (Durand 1995), and its spread and damage accelerated tremendously in the late 1980s.

In Central Sulawesi around Toli Toli, cocoa was adopted rather belatedly (in the mid-1980s), when the 19th century cocoa story had been totally forgotten in the region. It was, however, the first region in Sulawesi to be reinfested by CPB, officially in 1992, more probably in 1990–91. In South Sulawesi, the first cocoa trees were planted in the mid-1970s and the first CPB outbreaks were detected only in 1994–95. In East Kalimantan, CPB was officially reported in an estate in 1992 and in smallholdings in 1994. In both cases, infestations probably occurred slightly earlier.

Factors of CPB Infestation

Several factors affect the introduction and infestation of CPB.

Endogenous Environmental Factors

Entomologists usually stress the relationship between rainfall patterns and CPB population cycles. The number of insects grows along with the increasing rainy season and is lower during the normal dry season. Smallholders also stress the impact of rainfall distribution within the calendar year on the degree of CPB damage. Normal years with relatively regular rainfall distribution lower the attacks. Years with a certain number of dry months lead to increased losses. Although the population of insects may well be higher during the rainy season, its attacks are less efficient.

Accordingly, it seems reasonable to hypothesize that regions with more abundant and regular rainfall are—or will be—less infested than regions with less rain that falls in a more irregular pattern. When pods are maturing, a relatively dry month may be extremely harmful by increasing the number of "efficient" CPB eggs and larvae.

Until more information is gathers, these hypotheses seem to explain, at least in part, the different regional situations. Moluccas does not have as much rainfall as East Kalimantan, which may partially account for the extremely serious CPB attacks in Halmaera. For the time being, these hypotheses also seem in line with the accelerated spread of CPB throughout Sulawesi after the 1997 drought.

An Exogenous Factor: Hybrid Adoption

From Moluccas in 1985–86 to East Kalimantan in 1994 through central Sulawesi in 1992, almost all of the smallholders said that CPB infestation started or was tremendously accelerated by the introduction of hybrid cocoa trees. This belief is supported by our own observations. We recorded simultaneous introduction of hybrids and renewed pest levels in Moluccas in the mid-1980s and later in central Sulawesi and East Kalimantan. Durand made similar observations in western Halmaera, Moluccas (1995).

Although this finding suggests that contaminated planting material might be to blame, no facts prove it (nor do any allow us to reject the hypothesis). A second hypothesis seems more likely. The cotyledon of most recently distributed hybrids is softer than that of most cultivars, especially Amelonado, and CPB larvae can easily cut through pods of some hybrids.[3] The wrinkled surface of the hybrid cocoa pods may also form a better habitat for the insects than the smoother pods of traditional cultivars.

Aerial Spraying in Moluccas

A local exogenous factor for Moluccas should also be mentioned. Around 1974 the extension services launched an aerial spraying campaign against sexava, a coconut pest. Almost all interviewed farmers also mentioned that aerial spraying triggered the CPB revival in the late 1970s and early 1980s.[4] These statements make sense. Pod borer larvae were protected inside the pod or fruit of any host plant, but its predators were eradicated. The spraying might well have been a major mistake at a time when ecological balances were still out of fashion.

Extension Service Proposals for CPB Control

Indonesia's extension services have tried methods of eradicating the CPB. Besides experimental IPM techniques tested with a few farmers and researchers that are still under investigation, extension services have successively launched three to four techniques on a wide scale.

Pruning Eradication System

Extremely severe pruning eliminates all young branches. Trees are left with almost no leaves and no pods for 12 to 18 months. This method, similar to Leston's example of cutting out trees in Ghana to break swollen shoot infestations, aims to break the life cycle of the insect by removing its habitat and larvae. The technique was mainly promoted in Central Sulawesi in 1992 and to a lesser extent in Moluccas and East Kalimantan.

Although the principle seems to make ecological sense, it often fails due to technical, financial, and social misconceptions. Dutch planters and extension workers in North Sulawesi tried it without success in the 19th century. As soon as a plantation starts bearing pods again, trees are attacked by insects coming from a few trees that have not been pruned. Because most farmers are reluctant to lose more than one year of production—especially those farmers who totally depend on cocoa—it is impossible to convince them without strong monetary compensation. In 1992 even the coercive use of the national army proved insufficient in convincing all farmers. In Central Sulawesi, the first government attempts to oblige smallholders to adopt the severe pruning technique only discouraged most farmers and adversely affected their financial and technical capacity to control infestations.

In addition, vascular streck dieback (VSD) disease is also spreading in Indonesia. This fungus attacks branches, preferably young branches, of cocoa trees. Severely pruned trees are thus prone to this disease. The recommended pruning technique eventually caused high mortality on the plantations, including a number of relatively young plantations in Malinau. In such cases, even spraying pesticides as a complementary means of control is not really the right approach. Finally, almost all cocoa trees on the farm plot that was selected by the extension services to promote severe pruning and spraying died. It is not surprising that some farmers are convinced that the best strategy is to do nothing. Meanwhile, pest damage dampens the enthusiasm for adopting cocoa (chapter 7).

Bagging

According to recommendations made by researchers regarding this technique, all pods are supposed to be enclosed in plastic bags to prevent the moth from laying its eggs and the larvae from entering the pods. According to our surveys in Southeast Asia, this method was spontaneously adapted by a Filipino smallholder from Mindanao, himself the first cocoa innovator of the cocoa sector in Mindanao, Philippines.[5] Bagging was widely used on mangoes, and the smallholder thought to try it on cocoa pods. The idea was taken up by Mindanao extension services and a few other smallholders. This is an extremely labor-intensive but low-cost technology that is efficient for CPB control. It thus made sense to try to promote it in regions such as Moluccas where most farmers have limited income and capital.

Unexpectedly, the few producers from Moluccas who adopted the bagging method in the early 1980s were also the wealthiest. According to Durand (1995, p. 329), "the less well-off landowners tend to prefer methods considered to be less-time consuming."

In 1995–96, according to our observations in northern Halmaera and Central Sulawesi, the bagging method proved to be too labor intensive for less well-off smallholders and even too costly for the wealthiest. Even the latter eventually gave up maintenance and harvesting. Bagging proved to be technically acceptable but economically unacceptable.

Rampasan Combined with Spraying

In a technique known as *rampasan*, all pods and cherelles (intermediate stage between the flower and the immature pods) are harvested as soon as possible once the infestation is identified. Here again, the objective is to break the life cycle of the insect by preventing it from laying eggs and preventing any eggs from entering the larval stage. Extension services and local authorities help organize and coordinate the massive labor effort by mobilizing other farmers from neighboring villages, civil servants, students, and sometime the army to help with the harvest. Although smallholders do not lose in the short term (they can market the saleable beans from the harvested mature pods) and can hope for some long-term benefits (over one year), they lose in the mid-term (the next six months) because of the loss of cherelles and thus future pods. Thus the method also requires a rather coercive approach, including the army presence, as in 1995, in the village of Lewonu in Wotu in South Sulawesi.

Rampasan was implemented in Lewonu in November 1995, when farmers were also given a free donation of the pesticide Decis or Ambush. A number of farmers managed to avoid complying with the rules. Others (mostly Balinese) were just forgotten. The effectiveness of rampasan was far from perfect in the plantations where farmers followed the rule. Potential alternative hosts such as rambutan trees were still present. After one to two years, and despite heavy losses and real suffering for some families, the first results seemed uncertain. On one hand, CPB seemed to be under relative control in mid-1997. Losses seemed to remain under 20 percent on farms where rampasan occurred. Losses were more important in the Balinese section of the village, which was forgotten by the coercive approach of rampasan. At least some of them now complain about having been forgotten. On the other hand, most Bugis farmers said that the main factor behind the relative control of CBP was not rampasan, but rather pesticides, especially those smuggled from Malaysia.

Spraying

The rampasan and complementary spraying attempts undertaken in late 1995 have achieved better results than previous methods such as bagging and SPE, but the best technique seems to be spraying. The main questions seems to be, which type of spraying and which pesticide?

Farmer Innovations

Farmers have also conducted their own experiments that can be classified as four types.

IPM Methods and Preferences

In Central Sulawesi in 1994, the CPB attacks on the west coast were very different from those on the east coast. These was some evidence that the difference might be attributable to the presence or absence of ants (Desmier 1994, p. 5). In the same year in South Sulawesi before any CPB appeared in the villages, some smallholders told us that they did not fear CPB because they could use red ants (rather than the black ants promoted by most entomologists). Colonial Dutch planters used ants to control all types of insects, and the practice is still observed in various parts of Indonesia. However, farmers who already faced CPB in Central Sulawesi were skeptical about the effectiveness of ants for pod borer control. In addition, the ants turn cocoa harvesting into a torture process for the harvesters (Ruf 1993d).

In the early 1990s in north Halmaera, already widely infested by CPB, Durand (1995) observed that farmers raised certain types of red ants that ate pod borer eggs. In 1996, however, brief observations in the Tobelo district in North Halmaera indicated that the use of red ants against the borer was ineffective. Results for control by ants seem contradictory, and they are not yet a clear option. Applied research on Malaysian estates appears to confirm this conclusion. According to the researchers (Lay and Cheng 1995, p. 18), "ants contribute to a large proportion of mortality of CPB larvae. However, effective commercial use of these enemies has not yet been established."

Similarly, low-cost control techniques, such as making slow fires of coconut fibers to keep the borers away, burning grass or even old tires between the rows of trees at nightfall, or painting oil on the pods, have been observed and might have led to positive results for some individuals, but none of them look like general solutions (Durand 1995; Ruf 1993d).

Partial Shifting Cultivation Method

As long as smallholders have access to forests, the cheapest strategy is to shift the plantations. As explained above, the rationale and need for geographic shifting of production centers is reinforced by the pest. In Moluccas, this shifting happens at a village scale. Old cocoa-producing regions such as Tobelo did not completely collapse because smallholders still plant cocoa in the neighboring foothills and hills. They may benefit from two or three years without many CPB attacks. This also happens at the regional level. In northern Moluccas new migration and new planting in the southern districts (Bacan, Sanana, and more recently Gane Barat) results in a gradually increasing pace of production from new migration and planting.

Agroforestry?

When Halmaera farmers shift cocoa, they also shift coconuts.[6] In most cases, they reproduce the cocoa-coconut intercropping pattern that is the most commonly adopted mode of cultivation in the region. This is an innovation that has been known for decades and is not related to CPB revival in Halmaera. Does it play a role in CPB control? There is a consensus among agronomists that shade trees slow insect attacks. One reason is that tree biodiversity enhances a balance between insect pests and their predators such as ants. This is precisely what Oudot pointed out in 1937 and what some Dutch estates advertised at that time. This is also something that BAL estates, once the jewel of cocoa research in Southeast Asia, belatedly rediscovered in the 1990s.[7] They reintroduced coconuts in cocoa monocrops, not for shade but rather in an attempt to reestablish an ecological balance between CPB and its potential predators.

In northern Halmaera, however, cocoa-coconut intercropping does not prevent heavy borer attacks and losses, which could be explained by aerial spraying.

In Central Sulawesi in 1999, where the accelerated spread of CPB was reaching previously spared villages such as Kasimbar, smallholders seemed happy to have intercropped coconuts. Because the copra market is still relatively active, one of the basic agroforestry advantages can work. If cocoa revenues drop, these farmers can also rely on their coconuts.

Use of Pesticides in the Mid-1990s

In two regions in 1996, some farmers achieved significant control of CPB replying primarily on pesticides. The two regions were recently infested areas of Sulawesi and small Sebatic Island, along the border with Sabah, Malaysia. In a few cases (such as the previously mentioned Lewonu), farmers received a limited amount of free pesticides from the extension services. In most cases, they set up the method and even introduced the pesticides themselves. They consider that the most efficient pesticides are found in Malaysia, which makes sense since Sabah estates have been fighting CPB for more than 10 years. Most of the Indonesian farmers used a type of Ripcord, which was not yet officially authorized in Indonesia, but which was widely available in most local markets of East Kalimantan and Sulawesi. Its reputation was so good that it was even found and bought in regions still free of CPB. On Sebatic Island, Bugis smallholders have even integrated the concept of resistant pest strains and alternately use two different pesticides.

Farming Systems

The distribution and size of farms is described in chapters devoted to cocoa adoption in various districts. Except for a few merchants who own dozens of hectares, most cocoa farmers are smallholders with one to four hectares of cocoa. In Malinau and Moluccas, the average is about one hectare, and cocoa may represent only 20 percent of the family income. On Sebatic Island and most regions of Sulawesi, the average is two to three hectares almost entirely devoted to cocoa, which accounts for 70 to 100 percent of the income.

History of Pesticide Adoption

In Halmaera the CPB outbreak of the late 1960s did not prevent smallholders from renewing their interest in cocoa in the 1970s and early 1980s as prices rose and new migrants arrived.[8] Despite this renewed interest, almost nobody adopted pesticides. Some attempts made by the extension services to distribute a few pesticides had little impact. One reason may be that the first demonstration plots to combine the heavy pruning system with pesticides failed and cocoa trees died. In addition, pesticides were impossible to find on the market.

In Central Sulawesi, contrary to Halmaera, a large proportion of Bugis smallholders spontaneously adopted pesticides. In fact, they were already familiar with a number of inputs before the appearance of CPB. Their innovation was to go a step further—they decided to increase the budget devoted to pesticides and find pesticides with special efficiency against CPB. They did both using their contacts with Sabah estates, and pesticides were smuggled from Malaysia.

In Malinau, farmers took a middle course. Initally, several smallholders used some pesticides that were distributed free of charge by the extension services. There were only small quantities of these pesticides (and probably not the best suited to CPB control), so these experiments were not conclusive. Eventually, a minority of smallholders—those with enough land and capital—started buying sufficient quantities of efficient pesticides at a reasonable price from Malaysia.

In South Sulawesi in the village of Lewonu, after more than one year of pest infestation immediately counterattacked by rampasan and official pesticide distribution, most farmers undertook regular spraying (despite their significant income loss from the rampasan experience).[9] Preliminary interviews with Bugis and Balinese farmers showed a wide range but high mean of spraying frequency: 10 percent did not spray because the plantation was still young; 15 percent said they sprayed three or four times each year; and 75 percent said they sprayed at least once each month, often twice during critical periods. Even though they may have exaggerated, we think a frequency of 9 or 10 rounds of spraying during 1996 is an impressive adoption.

Innovation and Capital

Innovations that require cash raise the issue of capital. In this same Lewonu village, several cocoa farmers benefit from an extra source of income from the local development of an oil palm estate. They are part of the "plasma" of oil palm smallholdings surrounding a nucleus owned by a governmental estate (PTP).

Also in Lewonu, there is an interesting spontaneous introduction of pepper intercropped with cocoa in a few orchards close to the house, and new monocropped fields of pepper and cocoa higher up the hills.[10] Fifty percent of the farmers started new cocoa plantations farther up the mountains, where CPB is not yet a problem. These new sources of income seemed to fund the spraying activities for their cocoa:

- 15 percent from oil palm income
- 10 percent from oil palm income plus new cocoa in the hills
- 15 percent from pepper
- 15 percent from various sources (chili, banana, coconuts, cattle sales)
- 5 percent from daily wages plus cocoa
- 40 percent from only cocoa (including a majority of cocoa plantations that escaped rampasan).

It is interesting to compare the profitability of intensive cocoa farming in Sulawesi and Sebatic Island. Most farmers have neither oil palm nor pepper and rely solely on cocoa. Because they have to fund pesticide purchases from cocoa income, it is crucial to start controlling the pest at an early stage.

Cost and Returns to Spraying in 1996

Before CPB struck, the two regions with the highest yields were Sulawesi and Sebatic Island. They easily had yields of more than 2,000 kilograms per hectare on the plains and 1,500 kilograms per hectare in the hills, while the average in Moluccas was less than 400 kilograms per hectare. Sulewesi and Sebatic Island also benefited from the best cocoa-pesticide price ratio. In those two areas one liter of pesticide cost smallholders only 10–12 kilograms of cocoa. In Malinau and Halmaeara, for example, a liter of pesticide cost smallholders more than 16 kilograms of cocoa. Not surprisingly, these two regions were leading the fight against CPB in the mid-1990s.[11] Both regions include dynamic Bugis migrants who seize opportunities and innovations and exploit their recent links with Sabah cocoa estates. The relatively low price of pesticides and relatively high price for cocoa in 1995–96 (and up to mid-1998) are testimony to this dynamic migration as a cause of pesticide adoption.

Within a region at a given level of cocoa and pesticide prices, the efficiency of spraying depends upon several conditions.

First, spraying efficiency is highly dependent upon how many smallholders adopt the innovation. If an adopter is surrounded by non-adopters, his investment has almost no return. This is why some early adopters of pesticides in Moluccas and to a lesser extent in Central Sulawesi were discouraged and returned to a do-nothing strategy.

Second, good returns also depend on a coordinated spraying schedule. Although most smallholders are not really organized to spray at the same time, they must have minimal common knowledge and similar criteria for efficient spraying. It may be sufficient to concentrate spraying within a short period of time, with similar frequencies.

Third, in 1996, especially in the most advanced case on Sebatic Island, efficiency is improved by alternating the types of products sprayed on the plantations. Farmers probably learned this directly from the Sabah estates or already experienced its long-term efficiency themselves.

If all of these conditions are respected, we estimate that in 1996, before the 1997 drought, smallholders in Sebatic island achieved 70 to 90 percent yields, depending on the intensity of the borer outbreak. If the outbreak was serious, the yield might be only 70 percent. When the CPB cycle was at a low point, it might be 90 percent. These percentages also vary according to yearly rainfall and distribution.

Considering the externalities and free-rider behavior (if you spray, you help your neighbor; if you do not spray, you benefit from your neighbor's regular spraying but your decision not to spray is harmful to him), it is rather difficult to estimate returns from pesticide adoption on an individual basis.

All factors being equal, and especially if smallholders use the same amount of fertilizer, what is the spraying return before and after CPB infestation. As seen above, we estimate that the average pre-CPB yield on Sebatic Island was about 2,500 kilograms per hectare.

After the infestation, without any spraying on two or three hectares, usually in two different plots, farmers may lose only 30 percent in good years and 60 percent in CPB outbreak years (considering minimal spraying by other farmers). We assumed an average 50 percent loss. With an average pre-CPB yield of 2,500 kilograms per hectare and an average price of Rp 2,500 per kilogram in 1996, a decision not to spray might have cost about Rp 3,125,000 per hectare (about $1,335 per hectare).

If the crop is sprayed 10 times a year with theoretical half a liter of pesticide each time, on Sebatic Island it would take 10 days' work and use five liters of pesticide per hectare. In 1996, the five liters of pesticide cost Rp 130,000 per hectare, including hand sprayer maintenance. Labor is performed either by sharecroppers or by noncontract family members. By integrating the opportunity cost (relatively high due to the proximity of the labor-thirsty Sabah estates), the total cost of CPB control by spraying would be only Rp 250,000 per hectare.

A marginal investment of Rp 250,000 would help recover 2,250 kilograms per hectare (90 percent of the average pre-CPB yield) and thus achieve an additional gross product of 1,000 kilograms, equivalent to Rp 2,500,000 in the same year. This looks like a 1,000 percent return on investment!

This calculation remains theoretical and optimistic due to the absence of risk factors (cocoa prices, supply of pesticides and fertilizer, climatic and yield fluctuations, and more important a high dependency on what other farmers do). Nevertheless, the return seems high enough to demonstrate profitability during a period of favorable cocoa price and rainfall, as was the case in 1996. This explained the high rate of adoption on Sebatic Island, which was in turn a key to successful pest control.

Adoption Rate of Pesticides in 1996

Almost none of the smallholders in north Moluccas have ever tried to spray pesticides (except a few experiments launched by the extension services). In the small community of middlemen of Chinese descent plus a few Bugis who were usually the biggest cocoa adopters (25 hectare and more), some tried to spray once or twice in the late 1980s (Durand 1995). However, according to our interviews in October 1996, they eventually gave up. They not only stopped spraying, but also stopped all forms of CPB control, and even stopped maintaining and harvesting their plantations.

The situation is just the reverse on Sebatic Island and in Lewonu, where more than 75 percent of smallholders spray. The high discontinuous rates of adoption on Sebatic Island and Lewonu do not tell the whole story. The continuous rate of adoption is important and often missed in innovation surveys (Feder, Just, and Zilberman, 1982). Our survey of 20 farmers in Lewonu in December 1996 showed that the farmers bought an average of only 1.6 liters of pesticide per hectare (the equivalent of Ripcord) in 1996. As mentioned above, Lewonu smallholders tried to spray frequently, as many as nine rounds in 1996. That means only 0.17 liter of Ripcord or its equivalent was used per round per hectare.

This low volume may be explained by a learning period and by farmers' desires to keep costs low and risks at bay. Such a low rate of pesticide application seems environmentally acceptable. At the same time, this low level seems technically insufficient to maintain yields, which in fact dropped in subsequent years.

Adoption Factors

To help understand the factors affecting adoption of pesticides, we compare the regions of Sebatic Island and Moluccas. In both regions, the infestation was relatively old and had reached a high level. Why do farmers respond quite differently to the CPB damages?

The factors affecting pesticide adoption were much more favorable on Sebatic Island than in Moluccas. Beyond soil factors and the possible negative effects from aerial spraying in Moluccas, the high rate of innovation adoption on Sebatic Island comes from a combination of spontaneous migration effects and easy access to information and markets, along with a much more favorable cocoa:pesticide price ratio compared with that in the Moluccas.

These main determinants of pesticide adoption are identified by a comparison of different situations at the same time. After such a cross-section and comparative survey, what can be learned from changes and comparisons in time, especially from 1997 to 2001?

This period is marked by the severe 1997 drought, which affected the degree of infestation that generally increased after the drought, especially in Sulawesi. This period is, of course, crossed by the major financial and political crises in 1997–98 and their aftermath. It should offer splendid opportunities to explore interactions between price and ecological changes.

Table 13.1. Factors Affecting Pesticide Adoptions in Sebatic and Moluccas

Factors	*High rate of pesticide adoption on Sebatic island*	*No pesticide adoption in Moluccas/North Halmaera*
Price and revenue	High price and revenue of cocoa (high competition between Bugis middlemen and between exporters)	Lower price of cocoa (limited competition between middlemen and monopoly of one exporter)
	Relatively low price of the pesticide	High price of pesticides
Information and infrastructure	Direct access to pesticide information as plantation employees and relatives of employees in Malaysia.	Limited access to information
	Proximity and direct access to pesticides	Limited access to the input
Ecology	Rich soils	Mostly poor red podzolic soils (except a few volcanic islands where there is not much cocoa)
Institutional and technical	Spontaneous migrants with high dynamism and an objective of maximizing incomes	Indigenous or 'indigenous/migrants' with a dominant objective of securing food self-sufficiency and basic needs for the family
	Relatively young orchards	
	Efficient farming system in terms of returns per hectare and labor	Farming system giving priority to the elimination of risks
	Monoculture with a normal density around 1,100 trees/ha, with high yields and relatively high pre-CPB consumption of inputs	Intercropping with coconut and low and irregular density, < 700 trees/ha with poor yield and no monetary inputs
Agricultural policies		Possible negative exogenous factor: aerial spraying in the mid-1970s

The 1997 Turning Point

A follow-up study was undertaken from 1997 to 2001 in south Sulawesi, in the village of Noling in the plains, and the neighboring village of Tampumea in the hills. Although Noling is only some 200 kilometers southwest of Lewonu, where CPB struck in early 1995, Noling was not affected until mid 1998; the pest reached Tampumea in later 1998. In both cases, the drought conditions probably accelerated its spread. We explored farmer decisions about pest control at three levels. We looked first at a one-farm showcase; then we conducted a weekly follow-up of a 42-farm sample in the villages of Noling and Tampumea; finally, we conducted a rapid cross-section survey of some 100 farmers in the two provinces of south and southeast Sulawesi.

One Farmer's Showcase, 1993–2001

In 1998 the number of rupiahs needed to buy a U.S. dollar rose at least three-fold and in the feverish rush out of the currency that characterized the deepening crisis, up to ten-fold (Gerard and Ruf, 2000). Prices of imported goods escalated, including some fertilizers and pesticides used by farmers. However, within the agricultural sector, those oriented toward export, such as cocoa farmers, also enjoyed a price boom in rupiahs during a few months of 1998. It was soon followed by a difficult squeeze between declining gross revenues and input prices that had doubled or tripled. This situation is illustrated by the average cocoa and input prices paid by a Noling farmer named Ahmad (table 13.2). Under that changing context, what are the decisions taken by a cocoa farmer? What can be learned from this particular farmer, who has two-thirds of his land in the plains and one-third in the foothills and hills?

In 1998 Ahmad bought his Ripcord in February, when input prices had barely increased. The high price of cocoa in 1998 encouraged him to increase his pest control expenses slightly. In 1999 the situation had changed. Had price considerations been the only factor, Ahmad should have reduced his pesticide expenses because the price of cocoa had fallen and his gross revenue was cut by 40 percent. Instead Ahmad had to increase the amount of money devoted to pesticides because CPB had spread from the hills to the plains. In 2000, against a continuing background of low cocoa prices, Ahmad decided to reduce pesticide expenses.

The apparent cocoa:input squeeze Ahmad faced notwithstanding, Ahmad's actions confirmed the findings in Lewonu, that is, the amount spent on pesticides and their levels of use remained modest. Until 1998 Ahmad's fertilizer expense was 9 to 10 times higher than his pesticide expense. Since 1999 Ahmad's fertilizer expenses have been 2 to 4 times higher than his pesticide expenses, but the pesticide purchases still represent only a 1 to 1.4 percent of his gross revenues.

Table 13.2. Input and Output on Ahmad's Farm, 1993–2001

				Fertilizer expense		*Pesticide expense*			
Year	*Cocoa yield (kg/ha)*	*Avg cocoa price (Rp/kg)*	*Gross revenue ('000 Rp)*[a]	*('000 Rp)*[a]	*% of cocoa revenue*	*('000 Rp)*[a]	*% of cocoa revenue*	*Ripcord price ('000 Rp/l)*	*Ratio of pesticides expense/Ripcord price*
1993	2,018	1,484	7,484	630	8.4	50	0.7		
1994	2,418	2,140	12,938	1,199	9.3	100	0.8	36	2.8
1995	2,308	2,292	13,229	978	7.4	100	0.8	33	3.0
1996	2,749	2,600	17,875	1,200	6.7	125	0.7	31	4.0
1997	2,168	3,458	18,746	1,426	7.6	150	0.8	30	5.0
1998	1,844	12,669	58,403	3,219	5.5	250	0.4	50	5.0
1999	2,280	6,500	37,050	800	2.2	414	1.1	86	4.6
2000	2,049	5,150	26,372	1,220	4.6	341	1.3	78	4.4
2001	1,759	8,410	48,060	1,728	3.6	337	0.7	71	4.7

a. Gross revenues and input costs evaluated on the whole farm, varying from 2.50 ha to 3.25 ha according to farm pledging strategies over years. Only one third of the farm are in foothills. Two thirds are in the plain, hence good yields per hectare, despite an unavoidable decline since 1997.

With a yield maintained around 1,700-2,000 kilograms per hectare in 2000 and 2001, such low pesticide consumption may be considered a relatively good performance. It could be achieved because the CPB infestation rate seemed low on his farm in 2001 and because two-thirds of his cocoa farm is on the plains. The much stronger adoption of fertilizers may also compensate and indirectly play as a substitute to pest control (chapter 14). These conclusions also seem in line with findings obtained in Lewonu in 1996. However, as in Lewonu, Ahmad paid a price. Although his average farm yields of less than 2,000 kilograms per hectare were good, they were well below his 1996 yield of more than 2,700 kilograms per hectare. He is still fortunate. Had all his land been in the hills, his farms would have been subject to a more severe infestation and yields would have been reduced even more.

CPB Control, Plains and Hills, 1997–2001

From 1997 onward, we studied pesticide adoption among 17–20 farmers in the village of Noling on the plain and foothills, and among 23–25 farmers in the neighboring village of Tampumea in the hills. Smallholders based in Tampumea may own a farm on the plains, but most are in the hills. Smallholders based in Noling frequently own one plot in the hills, but most of their orchards are on the plain. Averages per farmer in each village give a reasonably representative picture of what happens in alluvial plains and in the hills, at least in Noling. They also confirm the somewhat surprising finding in Ahmad's case. The level of pesticide adoption is low (between 0.5 and 2.5 liters per hectare per year), which means that a only 0.5 to 3.0 percent of the revenue was devoted to pesticides.

Before the 1997 drought and the CPB spread that followed, the average per hectare yields were around 1,900 kilograms in Noling and 1,500 kilograms in Tampumea. Like most mature cocoa orchards in Sulawesi, the yields have declined since then.

With increases in cocoa price and revenue in 1998, most smallholders tried to resist CPB and buy more pesticides. Despite a price drop in 1999 and 2000, they continued buying pesticides. In 2000, and with the lowest average cocoa price in the past five previous years, farmers in Noling plain apparently did much better than those in the Tampumea hills. The number of liters of pesticides purchased in Noling doubled in 2000, the first year that the cocoa pod borer appeared on the plains. In the Tampumea hills, CPB began in 1999, the same year that cocoa prices declined sharply. They maintained pesticide adoption of about 1 liter per hectare per year. This quantity of pesticide was not enough to maintain production and yields continued to drop. In 2001, for the very first time in the history of Tampumea, the average yield per hectare dropped below 1,000 kilograms, or one ton.

Farmers in the hills were in more difficulty than those in the plains. CPB seems to strike harder in the hills, possibly because of the rainfall pattern, but also because of specific difficulties of spraying on steep slopes, particularly for older farmers. The shortage of water to mix with the pesticide also increases spraying time, cost, and human fatigue. Digging a well on each farm is nearly impossible, and rivers are far away in most cases. A simple barrel to collect rain water is an option used by some innovative farmers, but this also has a cost.

A less efficient CPB control leads to a higher number of infested pods, hence lower quality beans, which partially explains the cocoa price gap between the plains and hills, and thus between Noling and Tampumea (tables 13.3 and 13.4).

Nevertheless, in 2001, farmers on the Noling plain had at least as much difficulty maintaining pesticide applications as did farmer in the hills. Despite a recovery of the cocoa price and revenue, a drop in the continuous rate of pesticide adoption was common to both villages and slightly more visible on the Noling plains than on the hilly Tampumea farms.

Another trend could have been expected. In 2001, Noling benefited from the price and revenue recovery more substantially than Tampumea. Why

Table 13.3. Average Cocoa Yield, Revenue, and Pesticide Adoption in Noling, with two-thirds of farms on the plains and one-third in the hills, south Sulawesi, 1997–2001

Parameter	*1997*	*1998*	*1999*	*2000*	*2001*[a]
1. Pesticide (l/ha)	0.9	1.3	1.2	2.4	1.8
2. Avg cocoa yield (kg/ha)	1,534	1,350	1,431	1,403	1,350
3. Avg cocoa price (Rp/kg)	3,540	12,610	6,300	5,100	8,700
4. Avg gross revenue/ha ('000 Rp)	5,430	16,040	9,015	7,155	11,745
5. Pesticide expense/ha ('000 Rp)	31	116	106	193	140
6. Pesticide cost (% of avg revenue)	0.6	0.7	1.2	2.7	1.2

a. Provisional figures in 2001

Table 13.4. Average Cocoa Yield, Revenue, and Pesticide Adoption in Tampumea, with almost all farms in the hills, south Sulawesi, 1997–2001

Parameter	*1997*	*1998*	*1999*	*2000*	*2001*[a]
1. Pesticide (l/ha)	0.6	0.8	1.0	1.0	0.8
2. Avg cocoa yield (kg/ha)	1,334	1,236	1,219	1,089	990
3. Avg cocoa price (Rp/kg)	3,025	12,219	6,140	4,800	8,100
4. Avg gross revenue/ha ('000 Rp)	4,035	15,100	7,485	5,227	8,019
5. Pesticide expense/ha ('000 Rp)	23	70	95	99	85
6. Pesticide cost (% of avg revenue)	0.6	0.5	1.3	2.0	1.1

a. Provisional figures in 2001

did they not buy more pesticides? One reason is despite the price recovery, available savings were still low after two years of disastrous cocoa price. In addition, the year before farmers who had already decided to reduce pesticides in 2000 mentioned the negative impact from neighbors who did not spray. Finally, in the case of Noling, farmers have reduced their pesticide applications, not only because savings have shrunk after two years of very low prices, but also because they are discouraged and have no control of external factors. In other words, the Noling farmers might have been expected to use more pesticides in 2001 because they had earned more money in 2001 but chose not to because of free rider problems and reduced overall saving. This local evolution over five years is a good illustration of the interaction of price and non-price factors, but a larger sample is needed to complete the picture.

CPB Control and Indigenous/Migrant Dualism

We rapidly surveyed some 100 farmers scattered in various regions of south and southeast Sulawesi, to count the number of spraying applications, and discovered three main findings.

First, farmers continued to spray despite the drop in the cocoa price in 2000. It was confirmed. Despite revenue losses, farmers keep spraying. Farmers in southeast Sulawesi sprayed significantly more than did those in south Sulawesi, a phenomenon that seems to be explained by a more recent spread of CPB.

Second, this brief but more statistical survey showed a positive reaction to the cocoa price recovery. Unlike the Noling/Tampumea case, the degree of pest control (here measured through the declared number of spraying applications per year) seems to be increasing slightly, especially in southeast Sulawesi. Third, despite a relatively high variance within each group, the difference between indigenous and migrants seems to be confirmed. Migrants invest twice as much on pesticides (table 13.5).

Conclusion

Determinants of pesticide adoption

The main determinants of pesticide adoption are a combination of the degree of pest infestation, price and revenue factors, externalities related to neighbors' decisions to spray or not, and the time elapsed since the first CPB damage appears in a given region. The willingness to spray may well diminish over years.

These factors probably produce the strongest interactions between ecological and economic changes. In regions where CPB has just arrived and where farmers are not too deceived by neighbors' decisions not to spray, they continue to use pesticides despite the decline in cocoa prices and vigorously

Table 13.5. Number of Spray Applications per year by Sulawesi smallholders, 1999–2001

	1999	*2000*	*2001*
Indigenous	1.6 (1.6)	1.9 (2.35)	2.4 (3.3)
Migrants (mostly Bugis)	4.3 (3.9)	4.2 (4.0)	4.8 (4.3)
All smallholders	3.25 (3.5)	3.33 (3.6)	3.85 (4.1)

respond to increases in cocoa prices. (Each farmer uses more pesticides and more farmers use them). In regions where too many externalities and possibly more years of infestation make farmers feel powerless, they may reduce their investment in pesticides and more generally in CPB control.

Other important determinants of pesticide adoption include:

- The "Bugis migration effect," which shows a certain trend to innovation with a higher rate of spraying rounds than the average
- Easy access to information and markets, especially those obtained through Bugis contacts with Malaysia
- The degree of confidence farmers have in the information they receive
- The yields and revenues produced before the pest infestation, which allows farmers to determine the costs and benefits expected from any attempt of pest control
- All factors that determine production, yields, and returns, including the size of the farm and age of the cocoa trees
- The availability of labor to help with the pest control application
- All factors that determine labor availability, including the cocoa farmer's age and the number of sons ready to work on the farm. Old farmers with a low acreage in the hills are highly unlikely to spray, at least when cocoa prices are low.

Migrant dynamism

From this list of main determinants, a first issue is raised. Is the high dynamism of Bugis migrants a Bugis factor or a migrant factor?

The answer is both. Bugis culture stimulates migration of young people as an opportunity to prove their personal value. As in most countries, those who decide to migrate are usually more dynamic than those who stay. As part of the migration process, farmers also come to innovations rather than waiting for innovations to come to them. They are in a better position to compare the impact of innovations made by others. In this CPB case, Bugis migrants observed the impact of pest control measures while working on

Sabah estates, not in experiments offered by local agricultural extension services. They also benefit from risktaking by estates, learning from someone else's efforts what works and what does not.

Because they are excellent information free-riders, migrants are good innovators when they return to their own farms because they do not have to take as many as an innovator who starts from scratch or from the low-scale experiments of the local extension service.

In short, migrant smallholders seem to profit from innovations they adopt from estates. They are able to implement new technology at a lower cost than the estates for a number of reasons.

They know their cocoa farms better than estate managers know theirs. They have more incentives to work on their own farms than they do as laborers working for others. They may not pay family labor for a while. They can implement the innovation in a low-price environment, which is much more difficult for estates. They may well adapt and improve the technology.

Market liberalization and pioneer fronts

Experience in Sulawesi shows that market liberalization brings more advantages to pioneer regions with migrants and still relatively young orchards than to older cocoa regions. It would be particularly interesting to test this hypothesis in Côte d'Ivoire and Cameroon (chapter 17).

Diverse planting material vs pest outbreaks

Compared with local planting material (typically, either Amelonado or Upper Amazons), some hybrid planting material distributed by extension services had a significantly inferior resistance to CPB infestation. This type of accident is frequent and happens in all countries. However, it is a reminder of the importance of diverse planting material as the main tool to prevent outbreaks of insect pests and diseases. Although this principle is applied here to hybrid material, it is even more valid for clonal material (see chapter 12).

Technical progress vs deforestation

For long-term issues, we must return to the argument about forest protection. We hypothesize that agricultural progress and technical alternatives to slash-and-burn may lower rates of deforestation. Some Sulawesi smallholders applied the principle of tree crop shifting cultivation in the early 1990s because they did not know other efficient means to get rid of the pod borer. Better access to pesticides may help. So too might better access to fertilizers and herbicides (chapter 14). However, as discussed in a reference book on the topic (Angelsen and Kaimowitz 2001), this might not always be true in the long term. If new techniques improve the economic returns of tropical farming systems, we may thus expect these systems to spread. In other words, if pesticides improve the life cycle of plantations and thus economic returns to deforestation, more migrants are like to be attracted by these economic returns and engage in more deforestation (Ruf 1995c). This brings us back to the issue of regulating access to forests in the uplands in coordination with technical and economic solutions.

Reasonable pesticide use

Despite their doubts and hesitations, pragmatic approaches to CPB control and sustainability of cocoa farms clearly favor smallholders. Solutions such as severe pruning sometimes enforced by extension services in the early 1990s were more negative than positive. The rampasan approach undertaken in 1995–96 in Lewonu also raised doubts among cocoa communities. Its only positive but involuntary effect might have been to shock smallholders and encourage them to innovate and buy pesticides.

Bugis and Balinese smallholders clearly adopted and implemented, even if imperfectly, the solution that proved to be the most efficient and feasible—pesticides. Fortunately, extension services abandoned SPE and rampasan approaches that discouraged smallholders. Otherwise, such compulsory practices would have accelerated what we defined as tree crop shifting cultivation and led to further deforestation.

In the future, modern integrated pest managements methods may work. In the meantime, extension services should concentrate on various ways to help farmers improve spraying effectiveness. The first data provided by DGE (Directorate General of Estates) experiments in late 1997 seemed to confirm this need. The experiments did not use pesticides but instead recommended a combination of high-quality pruning and high harvest frequency. Extension services acknowledged a limited use of pesticides "in case of serious infestation" (Lainé 1997). However, a look at the preliminary results given in the tables showed that treatments with pesticides were by far the most efficient (Cocoa Pod Borer Management Project 1997). More recently, in 2001, farmer demonstration plots in Lapai, southeast Sulawesi, also seem to confirm that treatments that include pesticides are the most successful.

High harvest frequency and labor constraints

Most Bugis farmers had already been carrying out high-quality pruning and two to three harvests per month long before CPB and projects came to Sulawesi. Entomologists and extension services recommend one harvest a week. That schedule is sometimes, but not always, technically efficient for CPB control, but almost impossible for smallholders to meet because it is too labor intensive.

Weekly harvest does not allow any farm management because harvest and postharvest operations take seven to 10 days. No time would be left for pruning or weed control, let alone a minimal number of fertilizer and pesticide applications. Farmers who cannot afford to hire extra labor would be rapidly put out of the game. One harvest a week also reduces the number of pods to be collected each harvest and thus reduces labor productivity (chapter 14).

Moreover, the Sulawesi smallholder cocoa network is aging and facing labor constraints. A large proportion of Bugis farmers migrated between 1975 and 1985. Others who followed later include several farmers who were middle-age at the time of migration. In addition, the Sulawesi cocoa "machine" is encountering a phenomenon well known in other smallholder plantation economies, especially in West Africa. As more farmers adopt cocoa every year, labor demand increases while the labor supply decreases. When their own farms start producing, newly established farmers no longer work as sharecroppers or daily workers for others. Instead of farmers increasing the number of harvests in 2000 and 2001, we found a few cases of slight frequency reductions, related to farmer aging, tree aging, and labor constraints.

Knowledge and smuggling

Because effective pesticides such as Ripcord of Malaysian origin cannot be imported legally, farmers may not fully benefit from CPB-related research undertaken in Malaysia, where Ripcord seems to be widely used. In fact, Bugis traders have been smuggling pesticides from Malaysia for many years. In the mid-1990s, Ripcord smuggled from Malaysia seemed to be one of the most useful components to keep CPB-infested cocoa farms sustainable. "Indonesian" Ripcord became legally available in Sulawesi markets in the late 1990s. Other new pesticides also came to the market. Nevertheless, in 2001 some farmers were still using smuggled "Malaysian" Ripcord, convinced of its superiority. Whether farmers are right or wrong may not be the point, but what is important is that smuggling accelerated information and input delivery and played a role in farmer decisions about CPB control in the 1990s.

Farmers need to diversify their types of pesticides and sources of supply. The government should make a variety of pesticide available, so long as they are safe and of good quality.

World markets and pest control strategies

After the extraordinary rise of local cocoa prices in 1998 as a result of the Indonesian monetary crisis, the price of cocoa dropped by two-thirds in 1999, while pesticide prices doubled or even tripled. The sustainability of Indonesian cocoa farms is at stake, and obtaining the most efficient pesticides at the lowest prices is more important than ever.

Had integrated pest management techniques worked under Sulawesi conditions, the price collapse at the dawn of the new millenium would have looked like the ideal period for their adoption. However, it did not turn out that way.

Farmer doubts

In 2002 farmers still remain doubtful and confused about CPB control methods. This is no surprise. In the 1990s even dynamic Malaysian estates failed against the pest.

On one side, Indonsian smallholders do not rely entirely on pesticide spraying because it is expensive and time-consuming, especially in the hills. They still look for more efficient products. Above all, there is a lot of frustration related to externalities caused by neighbors who do not spray. On the other side, farmers seem to remain somewhat skeptical about extension service recommendations. In certain cases, farmer even complained that they were held back by being advised not to spray.

A Tentative Diagnosis

Controlling CPB infestation is an enormous problem, and it is difficult and somewhat pretentious to make recommendations on paper rather than in the fields. Nonetheless, we can try.

In the short term, extension services and nongovernmental organizations should reexamine their own experiments and encourage a reasonable use of pesticides among integrated pest management methods. The labor shortage and a search for means to reduce harvest frequency is one of the urgent issues to be discussed with Bugis farmers. Balinese farmer know-how and expertise may be also tapped. Nevertheless, the main problem seems to be frustration by farmers' inability to coordinate their investment decisions about CPB control. The main CPB-related issue thus seems to be one of farmer organization. How can farmers minimize the externalities they face? How can farmers organize themselves for CPB control, including planned spraying applications, among other things. Should answers to these questions be made a national priority? It is at least a priority in Sulawesi where cocoa is now the backbone of the regional economy.

Notes

1. Eggs are probably washed away as well, and the moth will likely have more difficulty laying eggs on pods.

2. An introduction from Sri Lanka seems possible due to exchange of planting material within the colonial British influence.

3. In Malaysia, some researchers may have lost an opportunity for early innovation due to an error of analysis. When they found more larvae in hard cotyledon pods than in soft cotyledon ones, they gave up the idea of selecting cultivars with harder cotyledon pods. They might have missed the point. A soft cotyledon also enables an easy way out of the pod. Fewer larvae did not mean less damage.

4. Farmers interviewed at different periods (from 1991 to 1996) by several members of the ASKINDO/CIRAD team. This included hundreds of farmers in different regions of Halmaera.

5. Rosalio Batal, son of migrants to Mindanao from Visayas (Ruf and Ardhy, 1994, p. 6–9).

6. Usually one smallholder who decides to clear forest in the foothills and plant cocoa and coconut does not cut down existing cocoa trees on the plains, but simply stops taking care of them. However, some of his neighbors who are discouraged about the CPB impact might decide to cut down trees on the plains. At the village level, there is a real shift in production and a shift in "plantations."

7. BAL Plantations Sendirian Berhad (situated in Tawau, Sabah, Esat Malaysia) was owned by the Commonwealth Development Corporation (CDC), London. BAL plantations started operations in 1949. Their first commercial cocoa was planted in 1956 (Lay and Cheng, 1995). Unfortunately, 40 years of cocoa research may be partially lost since the estate was for sale with new buyers intending to cut down the cocoa trees and replant oil palms. This decision is also a nice showcase of production shifts, with Malaysia being overtaken over by Indonesia in the cocoa sector.

8. Once again, migration seems to be an essential factor in cocoa booms and thus in cocoa adoption (Ruf, 1995a). In order of economic importance, three main sources must be specified. First, a combination of spontaneous and government-organized migrations from the neighboring volcanic and overpopulated island of Makian; second, transmigrations from Java; and third, a few spontaneous Bugis migrants from Sulawesi. Bugis traders, farmers, and fishermen are found everywhere along the coasts of the archipelago. Since the 1998 crisis, many of those based in Moluccas returned to Sulawesi in order to escape social and religious conflicts with indigenous people.

9. Lewonu village (and surroundings) is one of the two places where preliminary IPM experiments were carried out in 1997 onward (by ASKINDO, DGE, and ACRI). It was interesting to follow the potential 'competition' and complementarity between pesticides and pesticide-free methods. Did researchers manage to convince farmers to adopt zero-pesticide methods? Apparently not much, at least until our last observations in 2001 and probably not until research can reach convincing breakthroughs in this area. For the time being, pesticides seem to remain one of the essential tools.

10. Like cocoa, pepper seems to have also been introduced in South Sulawesi by the ex DI/TII movement, which intended to use this commodity as a source of funding.

11. In 1995/96, the "Sulawesi region" as a whole, and its cocoa belts spreading on three provinces of the island, were far from being entirely infested. In 1996, numerous villages, plains, and hills covered with cocoa still looked CPB free and even enjoyed record yields that precise year. The main regions to be visibly touched were Toli Toli in central Sulawesi and Lewonu in south Sulawesi, followed by Pinrang and some local outbreaks in part of southeast Sulawesi. In 1996, Toli Toli and Lewonu were the two small Sulawesi regions to lead the fight against CPB along with Sebatic. However, it took only three more years to spread almost every Sulawesi farm.

12. In 1995/96, the Sulawesi region as a whole, and its cocoa belts spreading on three provinces of the island, were far from being entirely infested. In 1996, numerous villages, plains, and hills covered with cocoa still looked CPB free and even enjoyed record yields that precise year. The main regions to be visibly touched were Toli Toli in central Sulawesi and Lewonu in south Sulawesi, followed by Pinrang and some local outbreaks in part of southeast Sulawesi. In 1996, Toli Toli and Lewonu were the two small Sulawesi regions to lead the fight against CPB along with Sebatic. However, it took only three more years to spread to almost every Sulawesi farm.

14

Adoption of Cocoa

François Ruf and Yoddang

Adoption of perennial crops such as cocoa is dramatically changing agriculture in the tropical uplands, as is innovation and adoption of new technologies. While this is true worldwide, the change in the Sulawesi uplands occurred more deeply and rapidly than anywhere else in the tropical world.

Although farmers have creatively seized opportunities, the adoption of cocoa and inputs is part of a process of resource and technology transfer from existing potential, which includes information, experience, and products that the Bugis profit from through their family and trading networks between Sabah, Malaysia, and nearby Sulawesi. The information system was partially established following the DI/TII (Darul Islam/Tentara Islam Indonesia) uprising that developed in the 1950s against the regime of President Sukarno. In the mid-1960s, the loss of the war triggered substantial Bugis migration from Sulawesi to Sabah. In addition, rice growing and the Green Revolution diffused innovations that have benefited perennial crops, mainly through migration from paddy fields to cocoa boom regions (Ruf, Ehret, and Yoddang 1996).

This transfer of resources and energy to “cocoa reconversion” is frequent in world cocoa stories. For example, the transfer of labor and capital from trade in oil palm to cocoa was demonstrated in West Africa (Chauveau 1993; Ingham 1981). This stresses the importance of a network to circulate information about a new crop and availability of land to trigger migration and adoption of the crop and inputs.

How have information and capital been combined by Sulawesi farmers to undertake migration and adopt cocoa? Why and how did farmers adopt a high frequency of harvests and more intense use of fertilizer and herbicides than other cocoa-growing countries, especially those in West Africa? Why so rapidly?

Cocoa Adoption in Noling and Tampumea

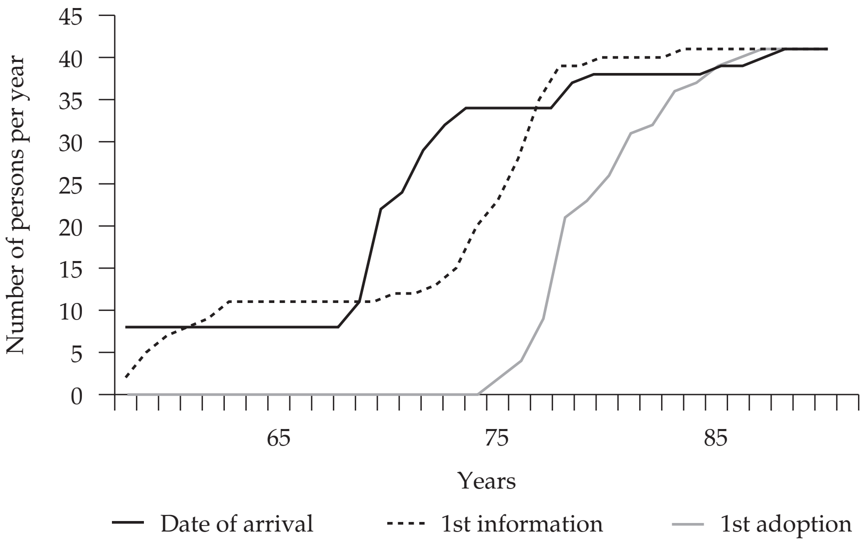
Tampumea was one of the most important base camps of the DI/TII rebellion, hidden in the hills. Noling is the neighboring village that developed in the plain and foothills when a peace agreement was signed between the national army and the rebels. In relation to that DI/TII story, this region is one of the first regions to adopt cocoa.

We collected the dates of the first adoption of cocoa, the date of arrival of the smallholder, generally a migrant, and the date on which he first gained information about cocoa. The sample was limited to 40 smallholders chosen from among the first people in the villages to adopt cocoa (figure 14.1). The group included 8 locals born in the villages or nearby and 32 migrants from other districts more than 100 kilometers away.

Two phases of information can be seen clearly in the figure. Approximately 25 percent of the first people to adopt cocoa had old knowledge about the crop dating back to the 1950s and the early 1960s. However, this previous knowledge did not lead to adoption of the crop in the 1960s. Why?

The information was gained through DI/TII, the rebel movement. To fund its activities, the movement brought plant material from Malaysian Sabah (which was British at the time); however, the movement was soon controlled by the national army. For some 15 years, and with no additional information, those who knew cocoa through this movement did not plant any. They feared that the national army would consider cocoa adoption a

Figure 14.1. Arrival Date of Immigrants, Acquisition of First Information about Cocoa, and First Adoption of Cocoa



sign of former affiliation with to the DI/TII. Migrants came to Noling in substantial numbers for the first time in 1968–69, but they tended to plant rice, tobacco, and soybean rather than cocoa (Hasanuddin 1991). Many migrants of the first wave were former rebels who had participated in the uprising. Settling them on the land was a clever way of pardoning the rebels. This migration, then, had little to do with the adoption of cocoa even though partial information about cocoa existed among these former rebel migrants.

In the early 1970s local traders operating between Sabah and Sulawesi brought new information about cocoa to Noling and a few other regions. About 1978 a farming extension agent, who was handling a coconut project in Noling and Tampumea, heard people talking about cocoa and took the initiative of multiplying cocoa plant material, with considerable help from certain smallholders. This extension agent undeniably played a role in the sudden adoption of cocoa in Noling. However, his own information and its success was based on the information smallholders already had that was related to local history and to the contacts between the Bugis and Malaysian Sabah (Ruf 1993c; Ruf, Ehret, and Yoddang 1996).

The Sulawesi boom was much stronger than that in East Kalimantan, which occurred about the same time but where the Bugis diaspora was only represented by a few individuals (see chapter 7). The reasons for the difference include the Bugis facility for local massive migration from one district to another within Sulawesi and a network of knowledge in the Bugis diaspora that made it easier to obtain information about cocoa and available land.

In short, figure 14.1 illustrates how the peak of crop adoption results from the combination of two waves of information (complementary information from different sources) and the first migratory movement. Existing knowledge and pre-cocoa migration were essential for the extension agent's information to accelerate the adoption of cocoa. Official cocoa projects had no impact or limited impact in other Indonesian provinces where preliminary information did not exist or prior migration had not taken place.

Migration, Tree Adoption, and Sources of Capital

Sulawesi cocoa adoption is inextricably linked to migration, that is, migrants came into the region specifically to plant cocoa. The region was chosen because land was available in areas of low population and labor was available in more densely populated areas nearby. Capital is needed both to fund migration and to adopt cocoa. What were the sources of this capital? To investigate this question we looked at migration and cocoa adoption in three Sulawesi villages.

The early days of the pioneer fronts and adoption of cocoa in Sulawesi were evaluated using surveys performed in the village of Lapai in 1990. In the 1980s, access to Lapai was fairly easy for migrants, with a boat trip of several hours from the province of South Sulawesi. On land, a surfaced road runs for about 15 kilometers from the coast to the beginning of the hills, facilitating settlement by farmers and crop sales. The 1990 survey described the situation of families who adopted cocoa between 1977 and 1990. In 1990, 93 percent of cocoa adopters were migrants and only 7 percent were indigenous. In 1995 the indigenous component dropped to less than 5 percent.

A second series of surveys performed in 1995 showed the situation in Sambalameto hamlet, above Lapai. It is at an elevation of 500–1,000 meters and is reached by a footpath worn by the migrants. It takes six hours to walk there from the road. Migration and adoption of cocoa took place from 1985 to 1995. All survey participants were migrants.

The third village is Pongo, in the marshy lowland plain north of the Gulf of Bone in the area south of Mangkutana. Although the village is on the plain and about 10 kilometers from the road, the position is not as good as it would seem because the plantations and access track are often flooded. The data for Pongo were collected in 1994 and described rapid migration from 1988 to 1994. Among a representative sample of 60 farmers, 7 were indigenous and 53 were considered migrants. Only these 53 cases are reported here.

In all three places, 90 percent of the land was covered by forest before migration for the specific purpose of growing cocoa. The only exception was Lapai plain where an earlier migration had resulted in clearing for a range of crops (such as coconut, cloves, rice, tobacco, and soybean).

Source of Initial Capital

The survey results for 155 farms in these three villages show the main source of capital in the first year after migration (table 14.1). Closer analysis would require examination of the structure of the initial capital. For example, the sale of gold jewelry is rarely the main source of funding for migration but is often a component. (In some cases, if two sources of capital seem of similar importance, for example, selling gold jewelry and selling buffalo, a half a mark is given to each because the migrant was allowed to choose. For example, some people among the 15–20 percent who said their initial capital was drawn from the sale of food crops were very close to being without any capital at all. That was possible during the early pioneer stage because the price of land was very low. A common feature of the three cocoa adoption situations is that 35–50 percent of the migrants were dependent on the food crop sector for income before migration.

The upland situation at Sambalameto stands out from the other two. Because access by road is more difficult, land costs 30–75 percent less there than it does on the plains. This lower price attracts poor migrants, who sometimes have just enough money for the trip and no more. Then they use the *bagi tanah* (a land-sharing contract) system in which land is obtained with no capital. These people tend to be from poor farming families or carpenters, pedicab drivers, or other low-wage jobholders in small urban areas. At Sambalemeto 34 percent of the migrants are in this no-capital category

Table 14.1. Sources of Starting Capital and Savings before Migration for Three Villages, percentage

Parameter	*Lapai*	*Pongo*	*Sambalameto*
Survey date	1990	1994	1995
Site	plain+hills	plains	hills
Indigenous people (percent)	7	0	0
Number of farms surveyed	61	53	41
Source of capital			
Sales of agricultural products			
annual crops: paddy, corn, soyabeans	19.7	12.3	14.6
tobacco	6.6	0.9	2.4
Selling of dry land or rainfed paddy land	4.9	4.7	0.0
Selling of irrigated paddy land	1.6	2.8	4.9
Pledging of rainfed paddy land	0.0	0.0	0.0
Pledging of irrigated paddy land	0.0	0.0	4.9
Selling of buffaloes and cows	8.2	6.6	14.6
Selling of motor cultivator	0.0	3.8	0.0
Selling of the house or housing land	9.8	2.8	7.3
Renting of the house	0.0	0.9	0.0
Sub-total of foodcrop revenues and related-paddy assets	**50.8**	**34.9**	**48.8**
Selling of non-cocoa tree-crop farm plots such as clove trees and coconut palms	1.6	4.7	2.4
Selling of non-cocoa tree-crop products such as cloves, cocoa nuts, oilpalm bunches	1.7	1.9	2.4
Sub-total of non-cocoa tree-crop assets and revenues	**3.3**	**6.6**	**4.9**
Selling of a cocoa farm plot in another region	0.0	9.4	0.0
Pledging of a cocoa farm plot in another region	0.0	3.8	0.0
Cocoa revenues from a former cocoa farm	0.0	13.9	0.0
Cocoa revenues as (Bagi hasil) worker		0.9	
Sub-total related to cocoa 'accumulation'	**0.0**	**28.1**	**0.0**
Selling of gold jewels	3.3	2.8	2.4
Selling of cars and/or trucks	0.0	0.9	0.0
Selling of motorcycles or bicycles	0.0	0.0	0.0
Sub-total gold and other assets	**3.3**	**3.8**	**2.4**
Family support	**3.3**	**12.3**	**7.3**
Salaries	4.9	0.0	2.4
Pensions (mostly from army)	1.6	0.9	0.0
Artisans (carpenters, pedicab drivers, horse men)	1.6	0.9	2.4
Sub-total	**8.2**	**1.8**	**4.9**

(table continues on following page)

Table 14.1. *continued*

Parameter	*Lapai*	*Pongo*	*Sambalameto*
Trade, merchant activities	**11.5**	**0.0**	**0.0**
Chain-saw worker	1.6	1.8	0.0
Non-timber forest products (rottan, etc)	1.6	0.0	0.0
Sub-total forestry	**3.3**	**1.8**	**0.0**
Private credit	0.0	0.0	2.4
Agricultural project and credit	4.9	0.0	2.4
No capital	**11.5**	**10.8**	**26.8**
Total	**100**	**100**	**100**

Source: Surveys by authors, 1990 to 1995.

(with less than $50 when they left their village). Although there is not a precise match, it is logical to assume that 34 percent of initial access to land is through *bagi tanah.* In a few cases the very first migrants avoided *bagi tanah* and obtaining land almost free of charge by exchanging a sarong for one to two hectares, something that was possible before the cocoa boom caused an exponential increase in the cost of land.

The proportion of land or rice fields that was mortgaged increased over time. This trend was also observed at Lapai. The rare planters who owned an irrigated rice field in their home village were not among the first migrants. It can be concluded that the success of the "have-nots" impressed the "haves" back home. The latter were surprised by the success of families who had previously been somewhat looked down upon in the village. This is one of the explanations behind the "copying effect" in an innovation diffusion process (Pomp and Burger 1995, p. 423),which is what happened in Sulawesi when cocoa was adopted (Ruf, Ehret, and Yoddang 1996, p. 227).

Although family support is modest, it seems to be increasing—it was the main source of funding for 3 percent of the families in 1990 and for 7 to 12 percent in 1994 and 1995. The parents' success in cocoa growing encourages children to make the same investment. Sometimes the reverse is also true. The success of a son encourages a father to follow. Parents-in-law also play a major role. When a daughter is married, her husband may receive a small plot of land or farm from the father-in-law.

The surveys may underestimate family support. In Sambalameto, two migrants in the no-capital category actually received the minimum needed for the trip and enough to live on for a few days through family support. Likewise, as we discuss later, family support has helped with herbicide adoption. Family aid to purchase herbicides for the start-up cocoa grower is smaller than the sum required for migration but is mentioned as an example of help provided by parents. In Pongo, half of the family support is generated by cocoa income since the parents already planted cocoa.

The role of perennial crops such as coconut or cloves (with occasionally a few cocoa trees) seems limited in the transfer of resources to migration. Their role possibly increased with time (5–7 percent in 1994–95 compared with 3 percent in 1990). Families who owned coconut and clove farms tended to migrate later than those who did not own any. Again, the success of the "have-nots" impressed the "haves."

In the three cases, the role of low wages, pensions, and craftsmen's income is also limited. However, in Lapai trade income was a major source of initial capital. It seems likely that migrants with substantial capital were looking for fertile, accessible land on the plain.

Finally, Pongo stands out for the remarkable proportion of cocoa sector income used to fund new cocoa migration. Income earned on other cocoa plots accounted for 28 percent of new farms, including 9.4 percent through the sale of a plantation and 13.9 percent without a sale (indicating that some migrants are capable of managing two farms on a remote basis). This phenomenon was not observed at Lapai in 1990 or Sambalameto in 1995 for simple reasons: Lapai in 1990 was one of the very first cocoa centers, so no accumulation phenomenon is observed. However, Lapai farmers made a strong contribution to the accumulation process through investment in other regions on the plain, such as Ladongi and Luwu, including Pongo, where we found the first Lapai planter. In Sambalameto, remote upland conditions are too difficult to attract cocoa farmers who want to invest savings in new cocoa farms. These "accumulators" rather look for land on the plains.

In Pongo the figure of 28 percent would jump to 30–35 percent if it included income from cocoa intercropped with coconut and cloves on previous farms and family support provided by cocoa farms.

Accumulation of Capital and Experience

This classic accumulation process was seen quite well in Ghana (Hill 1963), where farmers used the proceeds from one cocoa farm to purchase others, possibly in new pioneer regions. The same principle also worked in Brazil and Côte d'Ivoire, as well as in Sulawesi (Ruf 1995a, p. 23; 1995c, p. 255–57). Coming into a new area as a cocoa farmer rather than a newcomer means not only having capital to invest but also having experience. A farmer with 2 hectares of cocoa in one region might well feel ready to have 10 hectares in a new one. That is one reason why the Ivorian cocoa output skyrocketed in the western region in the 1980s and 1990s, and it is also one reason that similar scenarios are expected in Sulawesi in the 2000s.

In Sulawesi, however, the rapid diffusion of inputs appears to play a special role. In 1994 a power-driven cultivator was seen in Pongo as a substitute for a buffalo. This is a further sign of the transfer of resources and technological progress from rice fields to the cocoa boom. Cultivators not only represent enrichment through the Green Revolution in rice fields, but also enhance the entry of new smallholders to the cocoa sector. These machines reduce the time required to prepare rice fields and facilitate the simultaneous management of rice in the farmer's home village and establishment of a cocoa plantation in the new village (Ruf 1995c, p. 230–31).

Likewise, herbicides seem to enhance the trend for owning two cocoa plantations 50 kilometers apart or more. Like cultivators, herbicides save time for the planter, whose presence is not required as often to check weed growth, and make it easier to establish new cocoa plantations after *Imperata cylindrica.* At least on the plains, several established smallholders seem to have taken advantage of this new opportunity to establish cocoa plantations more than 50 kilometers from their first holding. It would be easier to establish a second cocoa plantation closer to the first, but land is too scarce and too expensive in well-established cocoa regions. Farmers have to move far away to find cheaper land.

Factors that Influence Migrants

Cocoa migration shows the role of "have-nots" in the adoption of cocoa. Even if substantial initial capital is often a decisive factor for rapid innovation, some farmers with limited capital risk migration that wealthier farmers do not attempt because they do not have tangible proof of the success of the operation. Three conditions—extreme poverty in the home village, one or two pieces of information that engender hope, and confidence in a leader who brings information and promises of success—may encourage "have-nots" to take these risks. Through their social and economic status, these leaders combine information about the new crop with their contact with local authorities to obtain access to land and forest (the most decisive factor) and initial capital to help fund families ready to follow. The leader may establish a clientele relationship and possibly a land-sharing contract with these families.

Cocoa Acreage and Adoption

The area under cocoa simultaneously indicates the scale of the accumulated capital and the continuous rate of adoption of cocoa. Some examples include:

- At Ladongi in a particularly fertile region in Lembah Subur in 1997, a sample of 20 farms displayed the following averages: 2.8 hectares of mature cocoa trees (variation from 1 to 8 hectares), producing 6,760 kilograms per family in 1996 or an average yield of 2,730 kilograms per hectare
- In 1990 21 smallholders in Lapai and the neighboring villages, one-third of whom were established in the hills, had an average area of 2.3 hectares, production of 4,000 kilograms per smallholder, and hence an average yield of 1,750 kilograms per hectare on the plains and hills. In 1996 in Lapai, the figures for a sample of 20 planters with cocoa on the plains and hills indicated an average of 2.0 hectares, production of

4,000 kilograms, and hence an average yield of 2,000 kilograms per hectare. (The stabilization of the land per farmer at around 2 hectares does not include farms created far away by "accumulators").

- Of 41 farms observed in 1995 at Sambalameto, an upland site, there was an average of 2.2 hectares of cocoa per holding and production had begun at only 20 farms. On average, these 20 farms produced 2,520 kilograms on 1.23 hectares, or an average yield of 2,057 kilograms per hectare.

Factoring in other surveys not reported here, in Sulawesi in general, the average area under cocoa is 2–3 hectares per family, with an intention to extend by a further hectare and perhaps more. In new pioneer regions such as Bungku (Central Sulawesi), clearing and new planting is accelerating, with some farmers able to get 30 hectares. This pattern is typical of a cocoa boom. Again, this "accumulator" process results from combining the savings from an initial farm with previous experience in cocoa. Although these accumulators help to increase the average size of farms in the future, the simultaneous installation of poor migrants on small plots and the inheritance process may keep the average around 2.5 hectare. In 2000 the average size of farms seems to tend toward 2.5 hectares, obtained through a land-sharing contract, land ceded to workers, land resold and transferred to family members, or a combination of the three.

Along the Gulf of Bone, before the outbreak of cocoa pod borer (CPB) up to 1997, the average yield of cocoa on the alluvial plain was 2,000–2,500 kilogram per hectare in monoculture and full sunlight and 1,500 kilograms per hectare intercropped with coconut. Coconut shade therefore has a negative effect on cocoa yields, but soil quality may also interfere in the yield differential (Ruf and Yoddang 1996). In relative prices, income from coconuts or copra did not compensate for shade.

The average per hectare yield in the foothills was 1,500 kilograms in monoculture and full sunlight and as much as 2,000 kilograms with favorable soil conditions; the yield was between 1,000 and 2,000 kilograms in the mountains. The sustainability of such yields was not known before 1997. Did the 1997 drought remind smallholders that lack of shade can be dangerous in the uplands, despite the use of fertilizer?

Fertilizer and Herbicide Adoption before the 1997 Drought

Fertilizer

Smallholders of the few farms that were nearly 20 years old in 1996–97 seem to have succeeded in maintaining yields through the quality of maintenance and inputs, at least until the 1997 drought. To produce 2,000–2,500 kilograms of cocoa per hectare on the plains and 1,500 kilograms per hectare in the hills, smallholders of Noling and Tampumea used some 500 kilograms of fertilizer per hectare. Beyond the ecological advantages of Sulawesi, the free cocoa market, with a high competition between middlemen, hence relatively high prices paid to producers, and relatively low price of inputs were major factors for the wide adoption of inputs.

These observations on cocoa are confirmed by the experience with other perennial and annual crops. In North Sulawesi province, for example, agricultural extension services made repeated efforts in the 1970s and 1980s to promote the use of fertilizer in coconut groves but with little success (Bourgeois 1988). Exactly the same thing occurred in Noling. Although a coconut project made fertilizer freely available to farmers there, they refused to apply it to their coconuts. Looking at the comparative prices of nuts and fertilizers, there were no obvious returns. In contrast, once cocoa was adopted and started producing, it proved to be so profitable at the time that farmers rapidly and spontaneously used large amounts of fertilizer. In short, the agricultural project may have played a role in introducing the input to farmers, but its real adoption was related to a competitive and unregulated cocoa market.

Herbicides

As in all substitution of capital for labor, herbicides are adopted when the relative cost of the input is below the alternative cost of labor. The cost of labor rises with an increase in the local price of cocoa, whereas that of herbicides remains stable or decreases.

In the 1990s a reasonable use of herbicides in young—and to a lesser extent in adult plantations—saved a little money when planters had weeding done by day-labor or on contract. The opportunity cost of family labor is also high. Frequent harvesting is a particular constraint for family labor.

In 1996 an herbicide application on one hectare took 1 day, at a cost of Rp 21,000 for the herbicide, an estimated Rp 3,000 for depreciation of the sprayer, and Rp 8,500 for the labor, for a total of Rp 32,500. In contrast, it took 10 days of manual labor to weed the same hectare, at a cost of Rp 85,000. The herbicide application thus saves Rp 52,500 a hectare. Herbicides could save double that amount if drought reduces the canopy, which then results in less shade and more weed growth, requiring a second weeding.

To complement this rapid calculation, we note the following information given us by a smallholder. It may be more accurate than the researcher's version and includes much additional information about labor productivity and the decision to choose between investment and consumption. In this case, it is estimated that labor cost Rp 7,000–7,500 ($2.70–3.00) a day in the Tampumea hills in early 1997.

The farmer used four liters of herbicide that cost Rp 90,000 and filled his sprayer 100 times. With an allowance of Rp 10,000 to purchase and maintain the sprayer, each tank of herbicide cost Rp 1,000. A worker can spray 14 tankfuls each day, so at Rp 14,000 for the sprayer and Rp 7,000 for labor, each day costs Rp 21,000. However, if the worker does the weed control manually, he would need eight days to do the same job, and it would cost

Rp 56,000 instead of Rp 21,000. The farmer happily saves Rp 35,000, "and that pays for my fish."

Herbicide is gaining ground because of the time saving and hence the gain in labor productivity. For the moment, the possible negative effects on human health and the environment are not considered by farmers. However, herbicides can be a successful substitute for fire when it comes to deciding between forest clearing (with the use of fire) and clearing of *Imperata cylindrica* fallows (with the help of herbicides).

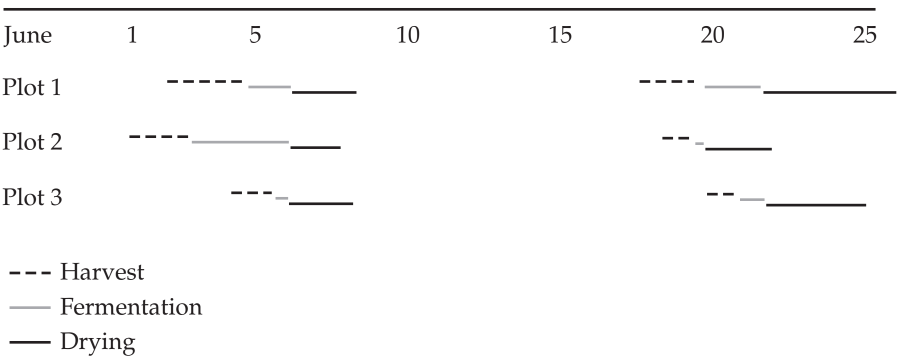
Intensification and Labor Costs on Sulawesi Cocoa Farms

On adult plantations, the climate and farmer strategies for high yields in Sulawesi result in two or three harvests per month during the peak season. This is one clear sign of an intensive farming system. In Côte d'Ivoire, smallholders usually harvest once each month, but during an entire year, cocoa farms are harvested more than 20 times in Sulawesi and 5–10 times in Côte d'Ivoire (see chapter 17).

This harvest frequency is a constraint for labor and leaves little time for plantation maintenance. Figures 14.2 and 14.3 show the farming calendar used by a planter in Noling in June and October-November.[1] In June, cocoa harvesting and postharvest operations leave only eight days of the month free for other tasks. The time is used for farm maintenance (gathering leaves and one fertilizer application) and for harvesting coconuts that are intercropped with cocoa on one of the plots.

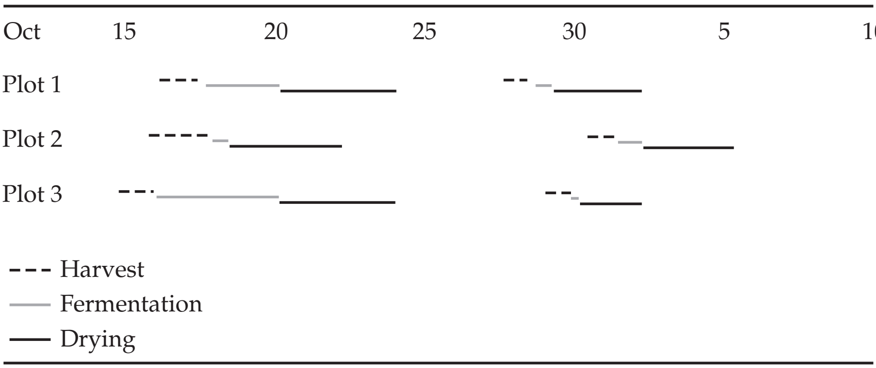
From mid-October to mid-November, the planter has only five days for jobs other than harvesting and post-harvest operations. The time is used for herbicide control of *Imperata* in young cocoa plantings. There would be far too little time for weed control without herbicides.

Figure 14.2. Farming Calendar for Three Plots on a Cocoa Farm at Noling, June



Source: Survey by Ruf, Yoddang, and Raïs, CIRAD, in Noling and Tampumea, 1993/94.

Figure 14.3. Farming Calendar for Three Plots on a Cocoa Farm at Noling, October–November



Source: Survey by Ruf, Yoddang, and Raïs, CIRAD, in Noling and Tampumea, 1993/94.

In Noling daily wages in 1997 easily attained $3 a day. This is sufficient to show that the competitiveness of cocoa from family plantations in Sulawesi does not lie in the low labor cost, but rather in great technical and economic effectiveness. However, when the constraints of harvesting and postharvest operations are involved, along with the risk of loss or theft of pods and beans, the opportunity cost of labor is even higher and can reach $10 a day. This labor constraint is certainly the key factor in the adoption of herbicides. It is also a key factor in understanding why Sulawesi farmers cannot increase their harvest frequency to reduce the impact of the pod borer, as requested by cocoa pod borer projects (see chapter 13). Well before the CPB infestation, Bugis farmers chose to have a high number of harvests per year compared with those in other cocoa-producing countries. In contrast, the increasing CPB-related difficulties, especially the additional time requested to separate the beans and prepare them for the drying process, may well reduce harvest frequency.

After the 1997 Drought and Financial Crisis

The drought in 1997 combined with Indonesia's financial crisis to bring cocoa production in Sulawesi to a turning point. To understand the situation and the prospects, we look at the ecological and economic changes that occurred.

The devaluation of the rupiah in 1986 led to a sudden increase in local cocoa prices paid to producers and a new wave of cocoa migrations. The apparent positive impact of that devaluation, combined with a continuing free market environment, led some to regard the de facto devaluation of the rupiah at the end of 1997 as promising for the future of agriculture in Sulawesi.

From July to October 1997, the monetary depreciation combined with a slight recovery of international prices to double farm prices in four months from Rp 2,500 a kilogram to Rp 5,000. Simultaneously, the abundance of paddy fields and the success of the Green Revolution in the Sulawesi lowlands made it a rice granary for the country. Cocoa growers still had easy access to staples. In October 1997, the local price of rice was still around Rp 900 per kilogram. The ratio of cocoa prices to rice prices was therefore 5:1, while a ratio of 2:1 or 3:1 would be sufficient to conserve family interests in the perennial crop.

In late January 1998 the price of cocoa rose to some Rp 15,000 per kilogram. The strong competition within the Sulawesi marketing chain obliged exporters and middlemen to adjust the producer price daily to the new exchange rate, hence the spectacular increase of the producer price in local currency. In March 1998 the cocoa-rice price ratio was 8:1.

However, the 1997 drought raised the problem of sustainability. Beyond reduced production from mature plantations related to the drought itself, an indirect effect of the drought seems to have been an accelerated spread of pest infestations, especially that of the pod borer (chapter 13). Another unavoidable effect of drought was that it triggered new migrations to forest and hilly regions in Central Sulawesi, causing further deforestation in the uplands.

The 1998 monetary crisis and its huge impact on prices favored new plantings. This spread occurred partially at the expense of some forests in Central Sulawesi (with the help of fire), but in some cases as a recolonization of degraded land (with help from an astute combination of herbicides and leguminous trees). The 1997 drought combined with the 1998 price hike also triggered replanting and, more exceptionally, the partial irrigation of cocoa farms in the hills.

Fertilizer Adoption after the Drought

Just as they had not foreseen the windfall in 1998, the farmers did not predict the scale of the price plummet in 1999 and 2000. They were equally surprised by the generalization of the pod borer infestation that followed the drought. At Noling in 2000, this ecological change caused some Balinese laborers who had *bagi hasil* sharecropping contracts to return to their transmigrant village 100 or more kilometers away. These Balinese workers were scared as much by the increased work involved in pesticide treatments for the borer in the field and postharvest as by the fall in prices and, by implication, their incomes. They were replaced by Bugis sharecroppers, but this resulted in a certain amount of tension in the labor market, and a slight rise in the share rate.

A trend can be found across the alluvial plains, going from a sixth to a fifth for the sharecropper accompanied by changes in food and lodging arrangements. In the hills, the share going to the sharecropper may vary from a third to a fifth. In early 2002 the rates of daily labor contracts rose by 40 percent in current rupiahs. Is this relative tension on the labor market going to have an additional negative impact on the maintenance of the cocoa trees, especially on the fertilizer adoption rate and hence on the sustainability of the system?

In 2000 the rapid spread of the pod borer infestation and extremely low prices led to the weakest revenues ever faced by cocoa farmers. Financial constraints caused many farmers to reduce fertilizer use but spend some money on pesticides to fight the borer infestation.

An apparently structural decline can be observed in yields from adult plantations in Sulawesi since the drought in 1997 and the onset of the borer infestation. In 1998 and 1999 farmers used pruning to counter the effects of the drought; in some cases they resorted to irrigation using hired pumps. They also used fertilizers. However, they had difficulties overcoming the successive challenges raised by the ecological and economic changes. Based on a survey of 40 farmers contacted two or three times a year, together with results from weekly visits to a sample of 20 to 40 plots, we have established a reliable data series for adult cocoa orchards in the villages of Noling and Tampumea, all situations on the plain or in the hills combined (table 14.2). How did the farmers respond to these changes?

The patterns found for Noling and Tampumea roughly hold throughout the provinces of South and Southeast Sulawesi, where the general rate of fertilizer application before the crisis was often very high, on the order of 500 kilograms per hectare, in relation with high yields of cocoa per hectare, much higher than the worldwide average. Nonetheless, the farmers opted to increase fertilizer applications in 1998. Why did they do this? The decision was prompted mainly by the fall in yields and the poor state of the trees in 1997. But obviously the price boom and increased incomes from cocoa facilitated the choice. The farmers knew that fertilizers were indispensable for the survival and the rehabilitation of their cocoa trees, and the effect was immediate. Yields and total production rose a little in 1999 (see table 14.2). Despite this rebound, the price slump in the same year cut incomes nearly in half, at least in current rupiahs. In constant currency, the drop was even greater, since the prices for all inputs, including fertilizers, doubled or tripled. The price increase forced farmers to cut their fertilizer use in 1999, but savings made in 1998 helped them keep usage comparatively high. In 2000 the farmers were obliged to give way a little more, but kept up a remarkably high level of fertilizer use. In 2001 farmers responded to rising prices and incomes from cocoa by a slight increase in fertilizer use.

In villages where the pod borer had been a problem since 1995 or 1996, the drop in fertilizer use is the main explanation for the 15 percent or more decline in production in 2000 and again in 2001. Diversification toward pepper and fruits, especially oranges, was increasing. In the villages studied here, Noling and Tampumea, where pod borer attacks started only in 1999, insufficient insecticide treatment probably played a slightly more important role in the decline in yields from adult plantations. On some 20 percent of the farms, a relative increase of fertilizer consumption in 2000 and 2001 helped to offset the increasingly negative impact of the pod borer and lack of pesticides due to poor revenues. However, the average decline of fertilizer adoption also clearly played a role in the structural erosion of yields and revenues. The current

Table 14.2. Yields, Prices, Incomes, and Fertilizer Use on the Cocoa Farms of Noling and Tampumea, South Sulawesi, 1995–2001

Category	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
Yields (kg/ha)	1,700	1,800	1,475	1,295	1,450	1,325	1,225
Average cocoa price (Rp/kg)	2,250	2,569	3,334	12,338	6,078	4,968	8,287
Average cocoa revenue (Rp/ha)	3,920,000	4,650,000	5,230,000	15,780,000	9,070,000	6,720,000	10,720,000
Average purchase of fertilizers (Kg/ha)	500*	500*	496	597	456	344	377

Source: Surveys conducted by the authors.
*Average purchase in 1995 and 1996 estimated from other samples. Records about fertilizer consumption for this sample began to be kept only in 1997.

price of cocoa and available incomes do therefore influence the degree to which fertilizer is used but only relatively because the farmers appreciate the importance of fertilizer to the health of their plantations. Farmers also keep innovating and look for cheaper fertilizers. One of the most interesting case is the increasing adoption of chicken manure when it is available.

Nonetheless, there was a real drop in fertilizer use, which, combined with damage from pod borers and increasing labor costs, maintained the process of yield erosion. Once again, economic changes (a drop in the price of cocoa, increased maintenance and harvesting costs) interacted with ecological changes (drought in 1997, flooding in 1998, spread of the pod borer between 1999 and 2001).

However, despite alarmist rumors and the sometimes dubious figures circulated in the cocoa sector, Sulawesi exported about 300,000 tons in both 2000 and 2001, about the same amount as in 1999, and nearly 340,000 tons in 2002.[2] For all that, the cocoa systems do have a problem of sustainability. Although the apparent stagnation of production in Sulawesi between 1999 and 2001 was a positive result after all the ordeals that had been faced, it was a combined result of rather contrasting trends. This apparent stabilization is attributable partly to the young plantations of new migrants on the pioneer front that had recently started to produce. The effect of the dynamic of migration and the creation of new plantations and new farms on the statistics helps to mask the declining production in the adult plantations. Despite, or because of, all the specificities of cocoa cropping in Sulawesi, and especially its heavy dependence on inputs, the principle of a partial shift of the production center (the pattern found throughout the history of cocoa) is found again.

Nevertheless, compared with this universal history of cocoa, it would seem that there is a remarkable specificity in the cocoa plantations of Sulawesi. Without fertilizer, the decline in production and the rate of mortality would have been even greater, and the harvest from the new plantations between 1999 and 2001 would probably not have been sufficient to compensate statistically for this decline. Without the capacities of most Bugis and Balinese for innovation—adopting and modifying their use of fertilizer, including varying the types of fertilizer applied and moving with the times and the market—the Sulawesi cocoa boom might well have been stifled by the hazards of climate, the pod borer, and the fall in prices.

Despite the probable drawbacks of long-term pollution, which must be further researched, fertilizer has indeed become an element that cannot be ignored in sustainable cocoa production. This conclusion is not restricted to the cocoa sector or to Indonesia. Similar conclusions have been reached for Africa and for systems based on hybrid maize. (Reardon and Barrett 2001).

Conclusion

Five conditions are needed for a large and rapid adoption of cocoa:

- *Migrants.* With few exceptions, the first feature governing the adoption of cocoa is the determinant role of migrants. They play a major role in the adoption of cocoa and of herbicides and fertilizers, including organic fertilizers such as chicken manure.

- *Minimum capital.* Although cocoa is one of the best crops to adopt with little capital (through its capacity to use forest rent and its short immature period), a certain amount of capital is essential. In Sulawesi this minimum amount is determined by the price of land, which increased rapidly once the boom started.
- *Capital-labor combinations between the "haves" and the "have-nots."* The most conventional combination is sharecropping, which is in effect a trade of labor for capital. We have also seen the combination of leaders, who have a certain amount of capital and contacts with the local administration, and followers, who possess no capital at all. The latter ensure the success of the migration by providing the critical minimum labor on a pioneer front.
- *Copying and surprise effects*. Among the various forms of copying effects that stimulate migrations and cocoa adoption, there is what economists call a "surprise effect," which occurs when richer families imitate innovations brought by poor people who pioneer land. Richer families are surprised and thus stimulated by the success of poorer people and then invest with strength. This was frequently observed in the Sulawesi cocoa story.
- *Cocoa reconversion principle.* The rapid increase in the price of land in the cocoa zone, and hence the target zone for migration, is related to the free market for cocoa and its relatively high price at certain periods. However, the price of land and rice fields in the migrants' home regions and the capital accumulated from growing rice also plays a role. This is the principle of cocoa reconversion identified in West Africa (Chauveau 1993).

High Harvest Frequency in Sulawesi

The high frequency of cocoa harvests in Sulawesi (about 20–23 times a year, at least in the 1990s) is much higher than in Côte d'Ivoire (about 5–7 times a year). This frequent harvesting is one of the factors of high yields, but it causes bottlenecks in the agricultural calendar, especially for the maintenance of young plantations; hence the advantage of a reasonable use of herbicides.

Fertilizers, Components of Sustainability

Because of the record price they received for cocoa in 1998, Sulawesi farmers were able to buy more fertilizer. This was a key decision to save and rehabilitate part of the region's orchards after the 1997 drought. In 1999 and 2000, under the combined pressure of the pod borer outbreak and sudden collapse of the commodity price, revenues shrank and Sulawesi smallholders had to reduce fertilizer application. This was clearly one of the reasons why yields of mature farms continued to decline in 2001 and seemed to slightly decline further in 2002. However, it should be stressed that without fertilizers and pesticides, Sulawesi farmers would have been unable to maintain their resistance against ecological and economic degradation. Regardless of the contribution made by the new plantings in the uplands, the supply of around 300,000 tons could not have been maintained in Sulawesi in the years 2000 and 2001. While not without drawbacks, the use of fertilizers has to be reckoned with. Most upland farming systems need this input to ensure sustainability. Especially on steep slopes and remote hills, the yield decline of mature cocoa farms clearly shows that fertilizers are not sufficient, but necessary.

Fertilizers as a Partial Substitute for Pesticides

Not the least advantage of fertilizers is their relative capacity to compensate for more costly and more polluting pesticides. By restoring trees, fertilizers help them to resist pests better. We have clear testimony of that in cocoa hills, and this is good news for those upland farmers who own remote orchards on steep slopes, where regular pesticide spraying with heavy hand sprayers is difficult and costly.

Tree Crops and Revenues

Despite dangerous price cycles and ecological changes, tree crops and export markets still offer opportunities to upland farmers. What is the role of a tree crop such as cocoa in improving the well-being of upland farmers? Here is the way one of the reference farmers from our surveys in Noling—a successful, but not exceptional, migrant who was obtaining average revenues—put it:

> Up to 1975 I was a maize farmer in my home village in the hills of Singkang, and I could hardly feed my family, let alone dress them. In 1980, after moving to Noling where I could get good land and grow tobacco, I was able to buy nice clothes for the whole family. Now, in 1995, after 12 years in cocoa, take a look at my house, my television set and satellite dish, my furniture, and see the motorbike under the ladder.

During the 1998 windfall, the number of motorbikes and even cars in the cocoa regions of Sulawesi exploded even while farmers continued to invest in inputs on mature farms and in land to create new farms. In 2002, four years after the boom year of 1998 and despite the unexpected collapse of prices and revenues in 1999 and 2000, it was still possible to say that the boom in 1998 was useful for the Sulawesi cocoa farmers and to remember that the cocoa sector was useful to Indonesia during the worst moments of 1998. The price and income cycles of the primary commodities also have their bright side.

Notes

1. These calendars also provide much information on the management of post-harvest operations and hence the quality of cocoa in Sulawesi, often criticized for being insufficiently fermented (which affects aroma and physical aspects of the beans). The duration of fermentation is managed partly according to drying constraints. For example, in the first eight days of June (see figure 14.2), the smallholder regulates the fermentation time for cocoa harvested from three fields in order to dry all cocoa batches at the same time and achieve an economy of scale in the drying work.

2. As mentioned in the main text, this increase can be partially explained by new planting coming into production in the Sulawesi, mostly in the province of Central Sulawesi, and also by some cocoa beans coming from the neighbouring Moluccas islands where cocoa was expanding in the late 1990s, especially in southern Halmaera (according to a survey made in Halmaera and Makian island by the authors in 1997).

15

Replanting after *Imperata cylindrica*

François Ruf and Yoddang

Grassland rehabilitation through government or contract reforestation has largely failed due to the difficulty of fire control and the repercussions of neglecting local community involvement. Modern reforestation strategies involve the small-scale farmer as commercial tree-producer in association with food-crops. This ensures more successful tree-husbandry, higher income, and lower external investment than plantation reforestation. The prospects are promising to ameliorate serious land degradation in major upland ecosystems by combining greater tenurial security with appropriate agroforestry solutions.

Dennis Garrity, 1993

This reflection by Dennis Garrity provides an excellent introduction to this chapter.[1] Almost all the keywords are there—tree, external investment, higher income, more secure tenure, agroforestry, reforestation, and rehabilitation. The major 1997 fires that ravaged the forests of Sumatra and Kalimantan, lit mainly on estates and not by tree-crop smallholders, also put some weight on the implicit reference to smallholders' ability in fire control. On one hand, smallholders usually control fire better than estates and government programs. On the other hand, despite all smallholders' experience, it is much more difficult to control fire as a cleaning tool in a grassland environment compared to a forest environment.

The main innovation examined in this chapter is grassland rehabilitation by investing in a tree (perennial) crop for the family farm. The aim is to show that a perennial crop can change from an agent of deforestation to an agent of reforestation. We also seek to understand why this transition seems to take place on the plains rather than in the hills.

Planting a perennial crop after grassland is an innovation in itself because it involves changes in techniques typically used after clearing the forest. Innovations are also needed to counter the disappearance of forest rent. Planting a perennial crop after grassland is a form of replanting (see chapters 7, 8, and 9).

Even if no trees are felled prior to planting a perennial crop, replanting after grassland has common features with replanting in the stricter sense. Replanting is therefore the term used for any form of planting other than that performed immediately after clearing forest. Replanting can take complex agroforestry forms such as jungle rubber systems (chapter 12) or more simple ones such as intercropping food crops and leguminous trees.

Among grassland situations, special attention is paid to *Imperata cylindrica,* the most widespread "weed" in Indonesia, known more generally by its local name *alang alang*. *Chromolaena odorata,* introduced from South America at the beginning of the century as a cover crop and soil ameliorator, is beginning to take on the status of a weed, as it has taken over certain niches previously occupied by *Imperata.* Farmers are gradually learning how to control it.

Cocoa is the perennial crop we deal with in this chapter, but this analysis could be applied at least partially to other crops such as rubber trees. Jambi, for example, is experiencing the spread of *Mikenia aliana,* which strangles young rubber trees and increases replanting difficulties.[2] We will try to show the coherence of two innovations for weed control: adoption of a limited volume of herbicides (without residual effects, such as Roundup); and the use of a biological input, the cocoa tree, combined with trees such as *Gliricidia.*

Before herbicides became available, the first solution to weed control was to increase labor for manual weeding, which could be supplied by an increasing population density and hence an increasing labor supply. However, in the case of cocoa, replanting by increasing labor time is limited in the uplands, even if fertilizer is used. Why? This form of replanting after grassland is easier and more common on alluvial plains, which are still fairly fertile after deforestation and more accessible. We compare the advantages of forest rent and plains rent and examine the components.

Our study focused on regions of Sulawesi in mid-1997—before the severe 1997 drought—that were still uninfested by cocoa pod borer (CPB). We also try to give some insights on the damage brought by CPB, the spread of which may be at least partially interpreted as a typical case of forest rent loss caused by years of cultivation and deforestation.

Appraisal of Forest Rent in the Hills

Plantation budget data under a CPB-free environment (annexes 2 to 5) can be used to appraise forest rent in different ways and hence estimate the cost of the replanting innovation for grasslands. The first method includes the investment phase, assuming that this phase is the main constraint to replanting.

Investment Phase

The difference in the number of working days needed to plant a cocoa plantation on cleared forest or grassland fallow is 203 days three years after forest and 315 days after a grassland-dominant fallow. The explanation for the extra labor needed after grassland fallow is additional weed management

Table 15.1. Estimated Forest Rent and Initial Investment in Cocoa in the Hills in 1997 (Tampumea, South Sulawesi) (US$ per hectare, unless otherwise specified)

Parameter	*After forest (a)*	*After grassland (b)*	*Forest rent (a-b)*
Labor (days)	203	315	112
Labor cost	663	1029	366
Input costs	23	56	33
Output	208	188	–19
Total (labor + input – output)	478	897	419

Note: Forest rent is defined as the difference between the investment needed to maintain an immature crop of cocoa plants after forest has been cleared and that needed for cocoa planted after grasslands in 1997 in an environment that is free of the cocoa pod borer. Assumptions as of July 1997 are that the opportunity cost of labor was Rp 8,500 per day and the exchange rate was US $1 = Rp 2,600.

Source: Survey by Ruf and Yoddang, CIRAD, June/July 1997.

every year during the first three years plus a fourth year of work. A fourth year of work for grassland is necessitated by the slow growth of cocoa trees and possibly tree mortality and replacement. After forest, the growth of the cocoa tree is much more rapid; hence a shorter period of investment is required (table 15.1).

The notion of forest rent also applies to food crops intercropped with cocoa. Without forest rent, the return on food crops decreases during the investment period, limiting the cash flow and limiting the chances to obtain inputs. This handicaps replanting cocoa (Ruf 1988; Temple and Fadani 1997).

If all labor is assessed using an average opportunity cost, the investment in replanting after forest is estimated at some $482 per hectare while that after grassland is some $897 per hectare. In relative value, this represents a near doubling of the overall investment cost. This result corresponds to smallholders' observations: "you have one hectare of cocoa after grassland and two hectares after forest." This shows one of the main "laws" of replanting—at the critical phase of the investment, replanting requires either capital or extra labor (chapter 16).

Nevertheless, in absolute value, cannot the above figures be overcome by Sulawesi smallholders? In 1997 a smallholder with 1 hectare of cocoa in monoculture producing 1,500 kilograms in the hills or 2,000–2,500 kilograms on the plains had a gross annual return between $1,700 and $3,000 per hectare, more than enough to cover the investment. Why then is the replanting rate after grassland low in the hills? It is true that the risks of plant mortality and the failure of replanting have doubtless been underestimated in the above calculation. These risks are much greater in the hills than on the rich alluvial soils of the plains. If we consider the increased risks after grassland, forest rent would perhaps double again. At the same time, although the investment phase is a constraint, it does not explain everything.

Productive Phase

The great majority of smallholders consider that a cocoa plantation in the hills after grassland, which does not benefit from forest rent, constantly requires more maintenance, especially more fertilizer applications compared with cocoa grown in the hills after forest. This is illustrated by results from farm budgets (tables 15.2 and 15.3).

In 1997 the cost of production in the hills, including depreciation, is estimated at approximately 36 cents per kilogram in plantations after forest and 46 cents per kilogram after grassland. Both figures are much lower than the producer price of $1.00–$1.15 per kilogram in 1997. The net margin would seem to be comfortable. Nevertheless, the choice between forest and grassland is clearly to the advantage of forest and will remain so as long as forest is reasonably accessible both physically and from an administrative point of view. The differential in forest rent for cocoa in the Sulawesi hills in 1997 was approximately 10 cents a kilogram. The loss of forest rent therefore increased the average production cost by nearly 30 percent. The figure would probably approach 50 percent if all the risks of failure were included.

In short, one attains +80 percent to +100 percent at investment and at least +30 percent during the production phase. To this cost is added smallholders' desire to enlarge cultivated areas with as few constraints as possible. It is not surprising that most smallholders prefer forest-covered hills to stripped hills.

It is true that some young people wish to stay near their families and attempt replanting in the hills after *Imperata cylindrica* or *Chromolaena odorata.*

Table 15.2. Estimated Forest Rent and Cocoa Production Factors in the Hills in 1997 (Tampumea, South Sulawesi)

Annual expense	*After forest*	*After grassland*	*Forest rent*
Labor (days)			
Excluding depreciation of investment phase	79	84	5
Including depreciation of investment phase	86	95	9
Operating capital*			
US$	88	160	72

Note: Forest rent is defined as the difference in the number of days of labor and in the operating capital, required to produce a metric ton of cocoa in the hills after forest compared with cocoa produced in the hills after grasslands in 1997, in an environment free of cocoa pod borer.

*Net input costs are lowered by the impact of food-crop output during the investment phase while the net labor cost is increased by taking into account the depreciation cost of labor invested during the first years.

Source: Survey by Ruf and Yoddang, CIRAD, June/July 1997.

Table 15.3. Estimated Production Cost and Forest Rent in the Hills in 1997, U.S. cents per kilogram

Inputs	*After forest*	*After grassland*	*Forest rent*
Net input costs	8	16	7
Net labor costs	28	31	3
Total	36	46	10

Note: The table shows the difference in production costs per kilogram of cocoa produced in the hills after forest compared with cocoa produced in the hills after grassland.
Source: Survey by Ruf and Yoddang, CIRAD, June/July 1997.

They do not want to go too far into the forest or take risks with the forestry administration. They are also nervous about felling trees on steep slopes or about the capital represented by a contract with a chainsaw felling team. These form a minority of cases, however, and often result in repeated failure.[3]

The drought at the end of 1997 and the resulting tree mortality in hill plantations—estimated at 10 percent at Tampumea at the end of October 1997—can only enhance smallholders' preference for the plains. This preference is implicitly understood and appears through the price of land, which is much higher on the plains. However, the value of fertility and location rents on the alluvial plains can be also be shown by the differential in production costs between producing cocoa on the plains and in the hills.

Fertility Rent and Location Rent on the Alluvial Plains

Fertility Component

In an environment free of CPB, it took only 60 days to produce 1 metric ton of cocoa in Noling in the mid-1990s (67–70 days, when allowing for depreciation of the investment phase in days) (table 15.4). The assumptions used to make these calculations are reasonable. First, we assumed a yield of 2,100 kilograms a hectare, a reasonable assumption where the average in monoculture on the plains used to be closer to 2,500 kilograms before the 1997 drought and CPB infestation. This yield level enabled a distinct improvement in labor productivity. To the best of our knowledge, 60 days of labor per metric ton on the scale of tens of thousands of hectares was the best labor productivity for cocoa in the world. In comparison, in the 1980s the more or less extensive systems in Côte d'Ivoire required some 100 days of labor to produce 1 metric ton; smallholders there used few inputs and produced 250–1,000 kilograms per hectare. Thus, until CPB infestation spread over all the Sulawesi cocoa belt, gross labor productivity seemed to be among the highest in the world—even in the hills of Sulawesi, with 70–80 days of labor per metric ton.

Table 15.4. Fertility Plains Rent and Cocoa Production in 1997

Input and expense per year	*Plains*	*Hills*	*Fertility plains rent*
Labor (days)			
Excluding depreciation of investment phase	60	79	19
Including depreciation of investment phase			
Farm life-cycle assumption : 20 years	67	87	20
Farm life-cycle assumption : 30 years	69	89	20
Operating capital (July 1997)			
US$ per year	63	90	27

Note: The fertility plains rent is defined as the difference in the number of days of labor and in the operating capital required to produce a metric ton of cocoa in the plains compared with cocoa produced in the hills in an environment free of cocoa pod borer.

Source: Survey by Ruf and Yoddang, CIRAD, June/July 1997.

The performances in Indonesia benefited from the youth of the plantations, forest rent, and new crop rent. Even before 1997 these performances were already weakening in regions attacked by pod borer. Since 1999–2000, all of Sulawesi has been harmed by the long-term effects of the 1997 drought and generalized infestation by the pod borer (chapter 13). In the hills the rate of tree mortality may have reached 10 percent, possibly 20 percent in the most deforested hills (Ruf and Yoddang 2001b, p.120).

The cocoa boom has been running for 20–25 years in Sulawesi, a period that is not yet old enough to draw conclusions about its sustainability. Between 1997 and 2002 (when this book was written), Sulawesi smallholders seemed unable to maintain their previous levels of performance. However most Sulawesi farmers produced higher yields of cocoa than might have been expected after such massive ecological changes. One of the main factors was the adoption of modern inputs: massive amounts of fertilizers, pesticides with more variability in volumes, and, more recently, herbicides.

The production figure of 60 days per metric ton confirms that the performance in the Sulawesi cocoa sector—both on the plains and in the hills—owed little to the comparatively low cost of labor and much to new farming systems and a new combination of labor, inputs, and skills. This combination also operated in a distinctly favorable ecological environment. This set of circumstances is unlikely to happen again. Since CPB exploded in all cocoa regions, more labor is needed for pruning, spraying, harvesting and, not least, postharvest operations. After the pod breaks, CPB-infested beans are difficult to split; women also devote much time to sorting out commercially usable beans from the others.

Nevertheless, some of the principles of a Green Revolution seem to have been demonstrated in the Sulawesi plains and uplands—invention and supply of capital, radical change in farming system—and possibly some of the

Table 15.5. Plains Rent and Production Costs of Cocoa in 1997, Excluding Depreciation Costs

			Location rent of plains compared to hills		
	Plains	*Hills*	*Fertility*	*Transport*	*Total*
Cost (Cents/kg)	26	35	9	6	14

Source: Survey by Ruf and Yoddang, CIRAD, June/July 1997.

limits. Is the cocoa revolution following a pattern similar to the rice and maize revolutions, which are now facing sustainability problems?

A major finding of this study is fertility rent on the plains. Under the conditions prevailing in mid-1997, the average production cost was around 35 cents per kilogram in the hills and only 26 cents on the plains—about a 25 percent difference. The fertility rent on the plains is thus 9 cents, which is equivalent to the forest rent in the hills (table 15.5).

The concept of fertility rent on the plains should be considered broadly. It includes a set of conditions on the plains that facilitate establishment and maintenance of a plantation and harvesting in comparison to conditions in the hills. Cocoa production on the plains benefits from several features:

- *Yield*—best yields and all agronomic factors that contribute to these yields.
- *Moisture*—better moisture retention capacity of the soils on the plains and all the factors that contribute to greater plantation longevity on the plains except in case of floods in lowland areas.
- *Labor and productivity*—the best labor productivity combined with the best yields. The economies of scale resulting from harvesting a tree bearing 60 pods on the plains, compared with 25 or 30 pods in the hills, were attributable partly to the forest rent or natural resource rent and partly to the plains fertility rent.

Since 1999–2000, major ecological changes such as borer infestation in all Sulawesi cocoa belts mean that the forest rent and natural resources rent have been widely "consumed" by cocoa. However, the plains fertility rent still exists. Technologies such as fertilizers and pesticides help to fight the pest outbreaks and slow down degradation of the cocoa orchards (chapters 13 and 14). According to this model of forest and plains rents, one can say that these technologies help to reduce the impact of the forest rent loss and to exploit the plains fertility rent. This seems close to the concept of a Green Revolution. In the case of cocoa, this Green Revolution is more powerful in the plains, but it is also a basic tool to save cocoa in the hills, hence to save cocoa farmers in the uplands.

On the plains, with yields of 2,000–2,500 kilograms per hectare before the 1997 drought and CPB outbreaks, field observations estimated harvesting and splitting at 50 kilograms per day during the peak season. In the mid and low seasons, the levels were still 40 and 30 kilograms, respectively. In the hills, with yields of 1,500 kilograms per hectare, the equivalent figures were estimated at 40, 30, and 20 kilograms per day (annex 2).

- *Topography*—labor is easier on the plains because of the favorable topography. Slippery slopes, especially in the rainy season, reduce labor productivity in the hills, especially labor for harvesting and spraying (chapter 13).

Location Rent Component

A location rent in the classic meaning of the term given by Von Thünen (1826) complements this fertility rent. In June 1997 it cost 6 cents (Rp 150) per kilogram to transport cocoa from Sambalameto in the hills to cocoa buyers based in Lapai on the plain. Sambalameto is a five-hour walk from the Lapai plain and accessible only by horse or on foot. At Tampumea, served by a vehicle track since the end of the 1980s, the cost was estimated at 2 cents a kilogram for holdings along the track. However, in the late 1990s pioneers were already several hours' walk from the vehicle track. Price information is slower to arrive and the cost of transporting fertilizer to a mountain plantation is higher. We therefore used the additional 6 cents per kilogram as the transportation cost estimate.

Combining the Two Rents

The combination of fertility and location rents form a plains rent of 14 cents per kilogram. On the plains, the cost of producing and selling 1 kilogram of cocoa delivered to the middleman's premises is 40 percent lower than the cost for cocoa from the hills.

Of course these are average estimates that vary according to local ecological conditions, distance, and available infrastructure. If infrastructure is developed in the hills, the rent may decrease as time passes. If the risk of tree mortality in drought years is taken into account, plains rent may also increase over the years. The opposite may apply in case of floods. The figure of 14 cents per kilogram overall, however, explains why migrants find the plains attractive.

The Impact of CPB Infestation on the Plains Rent

What impact has the CPB infestation had on the fertility component of the plains rent? At least theoretically, CPB increased the gap in labor productivity between the plains and hills. The latter are hit more severely, with deeper plunges in yields per hectare and labor productivity, more difficulty in

Table 15.6. Average Cocoa Prices in Plains and Hills in the Noling Region, South Sulawesi, 1995–2001 (Rupiahs unless othewise specified)

Average price	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
In plain	2,300	2,610	3,850	12,510	6,370	5,225	8,780
In hills	2,250	2,450	3,100	12,100	6,100	4,745	8,010
Difference = Average plain rent	50	160	750	410	270	480	770
(percent)	2	7	19	3	4	10	10

Source: Data collected and processed by authors, 1995–2002.

spraying, and more attacks, requiring that more time be devoted to bean splitting. This higher degree of infestation in the hills leads also to a quality gap, another factor in enlarging the plains rent. Insufficiently treated CPB in the hills generates more and more defective flat beans, hence a lower price per kilogram. All these factors account for an apparent increase in differential prices, at least as a percentage of the average price (table 15.6)

In 1997 and 1998, the average price differential was skewed by atypical production profiles over months and sudden price changes. In October 1997 farmers in the hills, the first victims of the 1997 drought, had little cocoa to sell and did not benefit much from the sudden price increase in late 1997. Price increases benefited the farmers in the plains much more as they still had significant production. However, in 1998 the production peak in the hills was delayed by one month compared with the plains, so hill farmers were better positioned when the cocoa price boomed in June-July 1998.

Innovations as an Adaptation to Ecological Change

On the economic side, an obvious adaptation to the CPB spread is the emergence of a new local market for bean placenta and flat beans generated by the pest. The price is only 500 rupiahs per kilogram, but it may well help farmers. The apparent use is oriented toward support of fish ponds and possibly poultry.

On the technical side, farmers are inventing specific mechanisms to make it easier and faster to split infested beans. New forms of wood tools are also being devised to shorten the pod-breaking operation. These may be small breakthroughs, but they testify to the farmers' dynamism and attempts at innovations to counter the forest loss and its impact on production costs.

Plains or Hills? The Diagnosis before the Crisis

When asked whether they preferred hills with or without forest, most smallholders chose "with forest." This does not mean that they prefer to clear forest rather than grassland. It does mean that they prefer the advantages of the forest rent for quick and efficient growth of the cocoa tree. However, the forest factor loses some of its importance when the choice is between hills and plains. If large amounts of land were still available on the plains, most migrants would choose the plains, with or without forest. In the 1980s this plains rent helped to save the hill forests. However, cocoa fever has carried the day since the end of the 1980s, and the hills are being deforested rapidly (not only for cocoa, but also for oil palm).

In the late 1990s the strength of plains rent became a factor in not replanting much in the hills. When there was a shortage of land on the plains, hill smallholders seemed willing to absorb the 9–14 cents per kilogram handicap to produce cocoa in the hills. But when the forest rent disappears, adding another 10 cents to costs, the production cost doubles in the hills. Even assuming that infrastructure improves over the years and reduces the impact of location rent on the plains, the temptation to leave the hilly regions will increase. Some migrants leave their cocoa farms to a member of their family, sell it, or simply leave somewhat more degraded hill land under *alang alang* to seek plains land 200 to 300 kilometers away at a new pioneer front.

Positive Impact of Herbicides

Our long explanation about forest and plain rents helps to demonstrate the need for external capital and technical breakthroughs to compensate for the loss of the forest rent and successfully replant tree crops after grassland, especially in the hills. As manual weed control is labor intensive and as labor remains a major limiting factor, herbicides may play a major role in making replanting successful, at least to increase labor productivity and reduce the investment required for planting after grassland. This is what is obtained from calculations made with farmers who use herbicides. The investment costs after grassland are somewhat reduced (compare table 15.7 with table 15.1). However, herbicides are not the full explanation.

Table 15.7. Estimate of Forest Rent and Initial Investment, Including Effects from Use of Herbicides, in 1997 (US$ unless otherwise specified)

Parameter	*After forest (a)*	*After grassland (b)*	*Forest rent (a-b)*
Labor (days)	203	275.5	72.5
Labor cost	664	901	237
Input costs	23	229	205
Output	208	354	147
Total (labor + input – output)	479	775	296

Source: Survey by Ruf and Yoddang, CIRAD, June/July 1997.

Interaction between Inputs and Food Demand during the Replanting Phase

A brief examination of the components of table 15.7 shows that herbicides are not the sole factor that improved the grassland situation. The output during the investment phase is also greater and is the main factor in reducing investment costs. What is this output? It is of course the contribution of the income from food crops intercropped with cocoa in the early years.

Fertilizer and herbicides change the technical data of the problem. Without inputs, food crops suffer as much as cocoa when forest rent disappears. Smallholders mention that without inputs yields of rice or maize are lower after *alang alang.* Some stress that they must wait for several months before planting annual crops. Manual control of *alang alang* means that smallholders must concentrate on land preparation to make a success of cocoa planting. The food crop may make it possible to control weeds, but it delays eradication and uses potential fertility at the expense of cocoa. In other words, without herbicides, smallholders have difficulties growing food on the *alang-alang* land because it interferes with preparing the land for cocoa planting.

Over the years the ratio of supply and demand for food crops changes. At the start of the pioneer phase in Tampumea and even on the plains at Noling in about 1980–85, the pioneers cultivated practically all food crops with cocoa. Each family met its own requirements. The local market was very limited. The site was remote, and it was a two-hour walk to the nearest vehicle road, hindering access to national food markets and especially fresh produce. Over the years cocoa plantations covered the agricultural area on the plains, and smallholders there had to buy part of their staples, even if some were fortunate enough to own a rice field. The vehicle road was built at the end of the 1980s.

In the 1990s the Sulawesi uplands that benefited from cocoa as a vector of colonization and infrastructure could make a much better contribution to the strongly growing local and national demand for food crops. Not only was demand increasing, but it was also changing and moving toward commodities with a greater value-added than rice and maize. Of course there are still beans, soybeans, and peanuts, all of which can help to reconstitute fertility. Farmers grow soybeans and peanuts primarily to get food and revenue, but they also aim at restoring soil fertility. Vegetables are grown when the fields are not too far from tracks and roads. Some growers in remote fields who had already installed irrigation pumps after the 1997 drought were beginning to grow more expensive produce such as chili. With the price of chili reaching as high as Rp 8,000 per kilogram, some growers have attained returns of $1,200 per hectare, which is close to that of cocoa.

In short, despite contradictory trends, the complementarity of inputs and food crops serves to reoccupy degraded land and investments by and for systems based on perennial crops. Shade trees also plays a role and can offer further alternatives.

Adoption of *Gamal* as a Weed Control Tool

Gamal is the most common name for *Gliricidia sepium.* The value of *Gliricidia* to farming operations has been known for decades in certain Indonesian provinces such as Bengkulu, in southern Sumatra, and Java (chapters 11 and 16). In other regions such as Sulawesi and Flores, farmers seem to have introduced it relatively recently. In 1985–86, the Kutuloncat insect devastated the *lamtoro* shade trees (*Leucaena*) that were widely used for erosion control, shade, and fodder in Java and Nusa Tenggara Timur. In Flores new shrub species, including *Gliricidia,* have been introduced on terraces in an official replanting program. This seems to be working fairly well.

Bugis farmers found the same solution by themselves in Sulawesi, especially on the west coast. They adopted *Gliricidia* even before they used *lamtoro* or ran up against insect problems. In Noling the first *Gliricidia* was adopted in the late 1970s by an innovative Bugis farmer who sought a tree to protect his young cocoa seedlings. The cocoa farmer found *gamal* trees in a Bupati pepper field where they were used as live stakes.

A large proportion of Bugis cocoa farms are shaded with *gamal* on the west coast of South Sulawesi from Pinrang in the south to Mamuju in the north of the province. In most cases, the cuttings were imported from cocoa estates in Malaysian Sabah. In Pinrang, for example, *gamal* was introduced from Malaysia by relatives of Pinrang farmers around 1975, and its use spread to all the villages in the district in about three years. However, massive adoption started in 1984 when cocoa planting started.

In the same region, in Tarailu north of Mamuju, Bugis migrants became cocoa farmers as early as the mid-1970s. They used *lamtoro* until 1988, when insect attacks in the *lamtoro* caused them to switch to *gamal*. The *gamal* cuttings were also introduced from Malaysia.

Balinese transmigrants also make intensive use of these new shade trees. Some of them told us that they tried zero-shade cocoa cultivation. In some regions of Bali, where they brought pods back to their home villages, full-sun cocoa monocropping is doing very well. But the attempts failed in Tarailu, on the west coast of Sulawesi, perhaps because the soil may have a lower capacity to retain moisture.[4]

This first use of *Gliricidia* seems to be in keeping with the traditional use of a shade tree. It is supposed to play a direct role in protecting cultivated trees such as cocoa or coffee against excessive sunlight and warmth. However, Sulawesi smallholders sometimes make jokes that *gamal* is the acronym for *ganyung mati alang alang,* which loosely translates as "elimination and death of *alang alang*." Thus, in addition to supplying nitrogen and fodder, one of the main advantages of *gamal* in Sulawesi seems to be shading out *Imperata* shoots. This new adoption is examined briefly here.

Using Gamal *to Control* Imperata

The principle of the innovation is to plant the *gamal* trees one year before planting cocoa to give them time to grow and provide enough shade to hamper *Imperata* growth after herbicides have killed the visible part of the weed. This generally successful innovation combining *Gliricidia* with herbicide is approached here only from the qualitative angle through interviews and farm visits. Although the innovation was still rarely seen in Noling and Tampumea, we saw it in other Bugis villages in South Sulawesi (Pinrang) and in southeast Sulawesi (Ladongi). Here we examine several examples of the combination used at Balinese transmigration sites in central Sulawesi.

At these sites the attempts by indigenous people at planting cocoa after *alang alang* failed when all the young cocoa trees died. Around 1990, transmigrants explained to the indigenous farmers that instead of planting cocoa as quickly as possible after burning the *alang alang* (as is the practice after forest clearing), they should first plant *gamal* and apply herbicides, postponing cocoa planting until the following year after the *alang alang* has been cleared. Otherwise, the smallholder would fight a losing battle against *alang alang*.

In these Central Sulawesi villages, farmers—both transmigrants and indigenous people—who can afford herbicides and want to plant cocoa after *alang alang* now use this technique. Of course, extra income from cocoa collection or from ownership of a small shop selling staple foodstuffs helps those owners with the purchase of herbicides and use of the whole technique. Among Balinese transmigrants, those of the previous generation of transmigration schemes who received some capital did better than the last transmigrants who were not helped.

The use of shade trees to control weeds is nothing new. Balinese coffee growers, for example, learned this principle decades ago. The innovation is combining the use of shade trees with herbicides, which enables the cocoa trees to grow faster than *alang alang*. The technique would seem expensive because it involves an extra year before any income is drawn from the cocoa. However, the investment is less risky than replanting without *gamal* or without herbicides or worse still, without either. Less risk means lower costs.

By applying that technique, some Balinese transmigrants, although late adopters of cocoa compared with Bugis, have already built very successful cocoa farms that are more than 5 hectares in size and may generate net yearly incomes of more than $10,000. The Balinese farmers recognize, however, that success partially depends on minimum soil fertility. For example, soil containing stones with *alang alang* is extremely difficult to replant with cocoa. This is probably why difficulties were encountered by a forestry project that tried to replace *alang alang* with shade trees and cocoa in the indigenous village of Bulo in Polmas district (South Sulawesi). Instead of replanting cocoa after *alang alang*, farmers in the project applied the technique to the land after *kabo kabo*—an approximately five-year fallow with tree clumps and bushes left after shifting cultivation of paddy rice. Because the cocoa planting was not always successful, the program tended to increase the *alang alang* cover more than anything else.

In the case of Bulo, why cannot an official project achieve what spontaneous innovation can? The main reasons seem to be poorer soils and poorer indigenous farmers who cannot afford herbicides, but the local absence of migrants to transfer the information may have also played a role.

In short, this *Gliricidia*-herbicide combination brings us back to the question of the relative importance of the no-weed component of forest rent in the lowlands and uplands. An almost obvious finding is that the more fertile the original virgin soil before deforestation, the greater the weed factor after deforestation, thus making the use of herbicide more important. This applies both to the rich soils on the alluvial plains and to poorer ones on the hills.

On the alluvial plains, fertilization can be delayed until cocoa trees start producing and thus exporting nutrients with the cocoa beans. In contrast, if hill soils such as those of Tampumea are already poor before deforestation, they may become critically degraded after deforestation, and inorganic and organic fertilizers are extremely important. With the help of fertilizer and herbicides, tree planting or replanting after clearing *Imperata* fallows is much easier on the plains than on the hills.

The severe 1997 drought may enhance adoption of *Gliricidia* in upland regions in which adoption was previously rare. For example, by the end of October 1997, it was verified that shaded cocoa farms in Pinrang were in a much better condition that those at Tampumea. This type of comparison could be exploited by official extension services and local agricultural projects to accelerate the adoption of *Gliricidia* in the uplands. The combination of *Gliricidia*, fertilizer, and herbicides gives trees better chances in their race against weed growth. However, according to our preliminary estimates of the 1997 drought effect, few farmers in Tampumea and in the hills around the Gulf of Bone had begun replanting, and very few used that combination of *Gliricidia* and herbicide.

Factors Explaining Slow Adoption of Replanting in the Hills

Since this combination of integrated pest management and inputs reduces the cost of replanting after *alang alang,* why was it not more widely adopted in the uplands during 1997 and 1998? As usual, ecological and institutional factors are involved.

Plains rent. Inputs make replanting more affordable in the hills, but replanting is still more attractive on the plains. After experiencing difficulties and risks of tree mortality related to the 1997 drought in the hills and foothills, some migrants are paying considerable attention to the plains again.

Poor soils. In comparison with other hilly regions, some farmers thought even before deforestation that some of the rather stony land at Tampumea was not suitable for cocoa.

Erosion. According to the farmers, a good deal of the topsoil of deforested hills has already been washed into the river. They even think that erosion in the uplands has contributed to the destruction of a few hectares of cocoa farm on the plains along the river bank. Although herbicides are increasingly seen as a way to lower erosion through a mulching effect, there is still a high risk of failure in the Tampumea uplands.

Access to water. Water is more difficult to obtain in the uplands. The 1997 drought is a clear demonstration of the issue. When farms are relatively close to a river, some smallholders manage to irrigate them by buying or renting pumps. In the higher uplands, however, a number of farms were not reached and the trees died.

Spread of Chromolaena odorata. Farmers need time to adapt to ecological changes. Some say that they prefer *Imperata* because they know how to control it with glyphosate. They are still investigating chemical methods to control *C. odorata.* Farmers can still adopt shade trees to control *C. odorata,* but they lack the proper herbicides.

Lack of capital and sharecropping. Migrants who take land under land-sharing contracts are so poor that they cannot afford to buy herbicides and even postpone cocoa planting in the hope of also postponing the day they have to share revenues from the newly established cocoa farm with the former owner. In the meantime, their strategy is to use annual crop yields only for themselves.

Patrimonial strategy of land accumulation. Despite ambiguities of land tenure, most Bugis farmers consider their grassland as relatively safe ownership. They keep that land in reserve, possibly for their children, and look for more land elsewhere. They find much larger holdings in remote plains areas of Central Sulawesi where land can be bought for $100 per hectare.[5] They can then sell their land in Tampumea at $300 to 500 per hectare. This makes sense. In a single transaction they obtain a larger acreage, plains rent, and possibly forest rent. Meanwhile, the newcomers at Tampumea need a certain amount of time to overcome replanting difficulties.

Trends since the Crisis

What has changed since 1997–98 when CPB infested most Sulawesi cocoa fields and the Asian financial crisis turned cocoa into a source of short but powerful windfall profits? A large part of the unexpected 1998 revenues was invested in land, either forest or fallow. Although social and ethnic conflicts delayed part of the planting and although the sudden fall of the cocoa price in 1999 and 2000 motivated some diversification toward pepper and oranges trees, farmers kept planting and replanting cocoa in 2000 and 2001.

Migrants still actively look for land in the plains, and in South Sulawesi province indigenous people still actively look for buyers for their forests at a price of about Rp 1,000,000, or $100, per hectare. Migrants are also ready to take fallows when forest has gone and ready to take land on hills when plains are sold out. The trend is so strong that farmers may even plant cocoa after degraded fallow in the hills.

In South Sulawesi, all degraded hilly land along the road between Pare Pare and Siwa remained empty in the 1980s and 1990s. There were no trees at all. In 2001–02, a passerby could see that part of this unused land had been converted into cocoa. This is a good testimony to the change in status of the cocoa tree. From an active agent of deforestation, cocoa may be turned into a tool of reforestation. Associated shade trees and food crops may help in that trend.

Conclusion

Green Revolution for Imperata Fallows

The main contribution of this chapter lies in its analysis of forest rent, plains rent, and a form of Green Revolution that accompanies the adoption of cocoa and inputs. Until the CPB infestation slowed it, production of a metric ton of cocoa in 60 days strongly approached the definition of a Green Revolution. This production level occurred mainly on the plains (which are, at least in part, in the uplands category as defined in chapter 1) but also sometimes in the hills. The CPB infestation is basically a normal process, illustrating the unavoidable loss of the forest rent and more generally of the natural resource rent. Farmers nonetheless attempt to resist the effects of ecological change and plant and replant, with the help both of shade trees and of herbicides, pesticides, and fertilizers.

On the alluvial plains first, and progressively in the hills, in interaction with land tenure, glyphosate and similar products without any residual effects are becoming an integral part of a technological revolution and stepping up the rate of agricultural recovery of land encroached by *Imperata,* especially in the transmigration project zones. In other countries, without the help of these inputs, replanting rates would not have emerged. Farmers instead would have looked for more forests to clear.

Agroforestry

Replanting after *Imperata* combines leguminous trees and herbicides, at least in some regions. The smallholders combine the capital of chemical inputs and the biological capital of trees, cocoa, and *Gliricidia*. This is one interpretation of agroforestry proposed in chapter 1, in which agroforestry is viewed as a strategy for reconstituting forest rent in a context of limited access to monetary capital. Some Sulawesi smallholders know how to combine an agroforestry strategy with monetary capital in the form of chemical inputs.

Although close to the characteristics of Green Revolutions, these forms of technical progress are not always well identified by the research and development communities. To a great extent that is because these strategies are spontaneous (even if the smallholders have used knowledge generated by these communities).

Tree Crop and Food Security

We have also emphasized the role that associated food crops play in innovation in the uplands. This includes their physical role in replanting as well as their economic role in generating capital. This food crop role coincides with the increase in agricultural and urban populations. The context of population increases is also a characteristic of a classic Green Revolution in wheat, maize, and rice (Griffon 1995; chapter 17).

Forest Rent Components

This chapter also aims to provide a better understanding of the influence of lost forest rent on farmers' decision making. Two of the questions raised in chapter 1 about the impact of forest rent in the uplands compared to the lowlands can be summarized: Is the no-weed component of forest rent the most difficult one to offset when forest rent is lost? Is the weed factor more important than the soil fertility factor?

After deforestation on the alluvial plain, rapid weed growth is the main constraint. Before deforestation, when farmers are just starting to clear the forest, the main advantage is the relative absence of weeds. This no-weed factor is more important than the fertility component.

The hierarchy of constraints is not as obvious in the uplands. It would seem that the fertility-erosion control constraints are at least as important. Nevertheless, as tree growth is slowed by soil with weakened fertility, the weed competition component and hence herbicides show their full importance.

In addition, the risks of drought are greater in the mountain uplands where the moisture retention capacity of the soil is lower (except for rich volcanic soils) and there is greater damage to trees, causing gaps through which sunlight passes and hence gaps in the plantation, where weeds crowd out cocoa. As a result, weed management is extremely important, as is the role of herbicides, in comparison to the plains.

Migrants' Effect on Innovations

This chapter also helps to demonstrate the migrant effect on the adoption of innovations. In addition to the role played by the Bugis, Balinese skills can also be seen in the adoption of *Gliricidia* and inputs.

Recommendations

As noted in chapter 1, spontaneous and successful recolonization of degraded land is nothing new. However, upland farmers' dynamics and technologies are not necessarily well understood by agents and institutions involved in research and development. Some of the successful examples mentioned in chapter 1, such as the recolonization of *Imperata cylindrica* fallows by cocoa after years of abandonment, deserve attention.

Further applied research seems to be required in two areas:

- A project that examines adoption rates of various technologies, for example fertilizers, as well as the factors affecting rapid adoption
- A project that examines the technical and socioecononic components of replanting using herbicides and *Gliricidia.* This seems especially important given that this replanting strategy could become a key factor in the agricultural recovery of upland areas.

Notes

1. The Garrity quote comes from the abstract of a paper contributed to a regional seminar, "Upland Agriculture in Asia," CGPRT, Bogor.

2. This species was also introduced from South America to serve as a cover plant.

3. Replanting has been attempted unsuccessfully on the same land two or three times by a few *bagi tanah* workers. Social factors are sometimes involved. It may be in the laborer's interest not to care for the trees to slow the start of production and hence delay sharing the land. They thus arrange to grow food crops. This is a classic phenomenon in smallholding plantation economics and has been seen clearly, for example, in Togo (Antheaume 1982). But as a whole, the causes of the failure to replant in the uplands seem to be above all ecological and technical/economic.

4. This seems to confirm that on the east coast of South Sulawesi and along the natural belt formed by the Gulf of Bone, cocoa farms are mainly established as monocrops (unless there were already coconut palms) because the soil and climate are usually more favorable than on the west coast. It is also possible that the west coast Bugis who have more contact with relatives who had migrated to Sabah had easier access to *Gliricidia* cuttings and were more willing to try them. On the east coast, once they had found that zero-shade cocoa is successful in normal years, there is little chance of their adopting shade trees before they face replanting problems. The consequences of the 1997 drought seem to present an opportunity to address these issues.

5. This type of land speculation is frequent in a number of pioneer front conditions around the world. The best examples are probably in Brazilian Amazon pioneer fronts where income from land speculation is a more important objective than income from agriculture. Land speculation there involves many hundreds of hectares. This is far from the case of Sulawesi smallholders who usually deal with 2–10 hectares. More comparative research on these pioneer fronts would be useful to policymakers.

16

Replanting Coffee Farms in Southern Sumatra

François Ruf, Salem Taher, and Yoddang

The chapter analyzes the conditions that make a smallholder decide to cut down an established tree crop, thus sacrificing income, and replant it rather than try to maintain it. In this context, replanting is more narrowly defined than it is in chapter 15. Here it means planting after clearing a *still productive coffee farm.*

In many ways, this investment decision is more difficult than planting after clearing forest or even after grassland—farmers who destroy a productive tree crop no longer benefit from forest rent; they sacrifice an immediate income; and because they age along with their trees, they may lack the energy and labor to attend to the replanting. Farmers often consider a coffee farm that has been abandoned for several years as a fallow or secondary forest, which is why planting after clearing either forest or grassland and long-abandoned coffee farms, or "coffee fallows," are grouped here as new planting rather than replanting. On the other side of the ledger, labor productivity and labor returns decrease as a tree crop ages, yields decrease, trees may be more prone to insect pests and diseases, and older trees may be more difficult and costly to harvest.

Coffee in Southern Sumatra perfectly matches this replanting issue. The economic life of coffee farms may be short. Coffee groves may produce a crop at two years and show significant production after three years. Yields may decline when the plantation is seven or eight years old, after only four or five years of full production. Assuming that farmers wish to keep producing coffee but have no access to additional land, only two strategies are available to address the problem of declining production—lengthen or shorten the coffee life cycle.

Lengthening the coffee life cycle includes developing shade trees and using more labor, inputs, and specific techniques such as rotating the pruning of coffee stems. These techniques can extend the economic life cycle of coffee groves to 20, 30, or even 40 years, while maintaining acceptable yields. Several techniques allow some continuous regeneration of the coffee tree and avoid the total loss of coffee income for one or two years, but at the price of increased harvesting and pruning costs.

Shortening the coffee life cycle uses the natural short cycle of coffee. When yield is on the decline, smallholders cut down the coffee trees and replant. They benefit from the most productive years of young coffee groves, but they also must invest in the labor in this replanting stage and lose two years of coffee returns. When do farmers choose this second option? With cocoa replanting, additional capital is needed because of the new importance of fertilizers, herbicides, and pesticides, along with issues of forest land tenure and the various "rents," but what criteria are involved with coffee?

History of Tree-Crop Shifting Cultivation

Tropical agriculture has changed gradually in the provinces of Bengkulu and South Sumatra over the past 50 years, and the two provinces are a fairly good illustration of the concept of tree-crop shifting cultivation. In the 1920s Bengkulu farmers started planting robusta coffee after obtaining the seeds from neighboring Dutch estates. The whole region was still covered with forest, and coffee farms were developed by clearing forest. The farms spread after independence.

In the late 1950s planting after forest clearing continued, but there is also clear evidence of the tree-crop shifting cultivation concept. Farmers seemed to abandon their coffee farms, but it was mostly to establish a fallow period of forest regeneration before cutting and planting again.

According to one researcher (Cramer 1957, p. 38):

> It [the coffee plantation] is kept only for 5 to 7 years and then abandoned. Every year a new field is opened but if the new fields have been planted to coffee, the soil needs to be rested for seven to ten years, and for an even longer period for poor soils. From an economic point of view, the system of maintaining the coffee planting only a few years and opening new land every year has proved to be a defensible system. In Southern Sumatra with its very wet climate, Robusta gives the heaviest yields in the first cropping years.

This quotation explains the importance of giving up (or now cutting down) seven-year-old coffee trees. Beyond the issue of forest rent, the early maturity of trees may justify the choice of not trying to extend the life cycle of plantation capital. Agronomic factors, especially Sumatra's very wet climate,[1] shorten the time the tree needs to produce and strengthen the classic climbing yield curve of the first five years of a producing coffee plantation.

This shifting cultivation could still be economically viable as long as the farmers have plenty of land and forest. The limiting factor nowadays is labor. For each hectare of coffee, farmers try to minimize the amount of work and inputs. Combining low labor input and high returns per hectare through forest rent gives a high return per man-day.

Of course, as Cramer (1957, p. 38) also notes, "the drawback is that [shifting cultivation] leads to a serious destruction of virgin forests and their replacement by grass plains that may affect the ground water supply." This drawback became more and more apparent in the 1990s. Because of almost complete deforestation, this system of shifting cultivation has almost disappeared (although it has not completely died out in Bengkulu, where there are still recent pioneer areas). In most cases, it has been replaced by a high-frequency rotation system. Instead of leaving the plantations fallow for 10 to 15 years before clearing them again, more and more plantations are cleared and replanted as soon as the yield decreases, especially in Bengkulu. It is a sort of regular replanting of coffee trees, in rotation with annual crops, mainly market gardening, tobacco, ginger, and chili.

The parallel between shifting cultivation of annual crops and perennial crops and their change from a pioneer and expansive phase to a replanting and more stabilized phase seems obvious.

Social Background

In Bengkulu, households own as little as a quarter of a hectare to 10 hectares, with an average of 3.4 hectares, including 2 hectares of coffee. The migrant effect is important. Indigenous people own an average of 2.9 hectares, while migrants own 4 hectares.

In more populated regions of Lahat in the neighboring province of South Sumatra, the average may drop to 1 hectare of coffee, and there are landless families. Even in Bengkulu, we estimate that 10 percent of coffee smallholders are sharecroppers. Among the 10 percent, probably half own a very small coffee farm and the other half do not own any coffee.

In 1991–92, the average price of 1 hectare of land was Rp 2 million–3 million ($1,000–1,500) if close to the road, and Rp 1 million ($500) if far from it. Coffee farms close to the road were bought and sold at around Rp 4 million–6 million per hectare; those far from the road sold for Rp 2 million. The value of the coffee capital was thus low compared with cocoa farms in Sulawesi, but coffee prices were at their lowest during this time period.

This structure of 1–2 hectare coffee farms is attributable to an increasing population density (often more than 200 people per square kilogram), the result of the migration process, inheritance, and generation changes. Families split up bigger farms to enable children to have land. However, rebuilding and enlarging coffee farms can be achieved through land markets and partially funded by savings from agricultural wages, sharecropping, and various institutional arrangements.

Sharecropping

In 1997 the going rate of crop sharing for coffees farms in Southern Sumatra was two-fifths for the sharecropper and three-fifths for the owner, with pesticide and fertilizer inputs covered by the two parties at 50 percent each. Any additional costs such as herbicides or day workers are paid by the sharecropper. Sharecroppers had improved their bargaining power since 1991, when the share rate was only one-third for the worker and two-thirds for the owner.

Land Access and Social Innovation

Since the late 1970s or early 1980s, a new type of institutional arrangement for land access was introduced called *sorongan.* Under this type of contract, the worker asks a landowner if the worker can plant or replant coffee on fallow or old coffee land in return for a cash payment. Depending on the landholding pressure and the expected price of coffee, the amount varies from Rp 200,000 to Rp 400,000 per hectare ($70–150). These contracts also stipulate that:

- During the two-year immature period, all food crops belong to the worker.
- The coffee harvests are shared 50-50 between the owner and the worker during the three major harvesting cycles (years 3, 4, and 5).
- The duration of the contract is five to seven years.
- All input costs are covered by the worker.
- When the contract expires, the coffee farm must be returned to the owner, theoretically with good maintenance that includes the presence of shade trees above coffee.

This social innovation is an indication of the shortening of the coffee life cycle in relation to increasing population and land pressure. In earlier years, farmers managed all coffee farms for 20–30 years. They still know how to achieve this, but they cannot afford to do it. They have to increase per-hectare income, and their strategy is to shorten the coffee farm cycle in order to maximize the "young age" effect of the tree capital on yields, even if they have to devote more labor to replanting.[2] The need for labor is also demonstrated by the invention of this social arrangement between those who own land and those who have family labor as their main asset.

After the land contract expires, the worker may continue to work the land by using another type of contract such as renting. For instance:

- Irwan obtained an old coffee farm planted in 1983 under a *sorongan* contract. He replanted it. After the contract expired, he kept managing the farm under a three-year rental contract of Rp 2.5 million per hectare for all three years.
- Herman received a coffee farm plot planted in 1986 by *sorongan* contract. Then he continued by contract at around Rp 1.5 million per hectare for two years.

According to one village chief, this successive double contract system did not exist in 1990. This dynamic social arrangement displays not only the mounting pressure on land, but also the impact of land pressure on replanting decisions. From the worker's point of view, difficult and costly access to land is one of the determinants of replanting. From the landowner's point of view, his own lack of labor is a determinant of not replanting himself. However, because land is scarce, he may benefit from an increasing land rent that is exchanged for cash and labor invested in replanting.

Ecological Background and Technical Innovations

Impact of Forest Rent on Coffee Yields

Our first surveys in 1989 in Lahat, South Sumatra, covered coffee planted on average soils, with three or four weedings a year, no fertilizer, and a rather high density of around 3,000 trees per hectare. Our survey showed that per-hectare robusta coffee yields after replanting were between 1,500 and 2,000 kilograms in the peak (year 5 or 6), while the yield for trees planted after forest clearing were 2,000 to 4,000 kilograms per hectare.

According to Lahat farmers, when coffee seedlings are planted after forest clearing, they are twice as tall, at least during the peak years, as are coffee bushes replanted after coffee. These statements might be slightly exaggerated, but everywhere in the world coffee yields strongly respond to the forest rent effect. Under the heavy rainfall of Southern Sumatra, the forest rent effect on yields may well be amplified during the first years. This seems confirmed by recent surveys in Kepahiang, in Bengkulu province, which found that per hectare yields of cik ari coffee planted after forest clearing were often nearly double the yields of the same coffee after replanting.

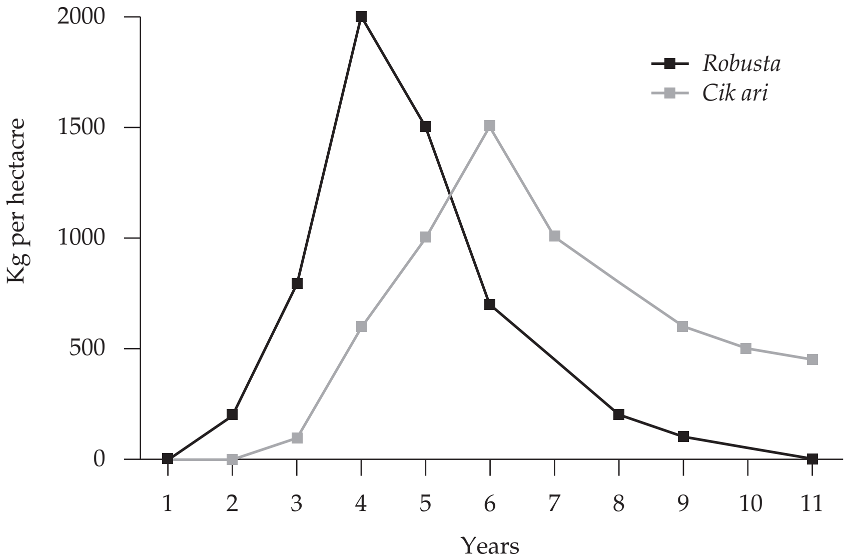
It is clearly understandable that farmers and especially migrants who often have a strategy of quick returns prefer to consume forest rent as long as it is physically and politically feasible. They start replanting if the forest rent has already been consumed or is made inaccessible by policies protecting forest, and sometimes if a location rent proves to be greater than the forest rent (chapter 15). This location rent and its interference in farmers' choices may apply to annual crops intercropped with young coffee seedlings.

Invention and Adoption of a New Planting Material: Cik Ari

The Lahat district in South Sumatra is about four hours by road from Kepahiang district but is more densely populated. Density should favor innovation, which is what happened with planting material. Godoy and Bennett (1989) found that farmers in Lahat had developed a technique for coffee planting with limited shade and had locally selected a variety with a very early maturity, *Marzuki,* which produces a crop as early as the second year after planting, with a peak yield in the fourth year.

In the same region of Lahat, several smallholders also told us in 1989 that they had selected a new planting material, characterized by early maturity,

Figure 16.1. Yield of *Robusta* and *Cik Ari*



high yields, and soft branches that did not break. They called it *Lembut bakir*.[3] In Kepahiang, we also found great enthusiasm for a new planting material with early maturity and high yields that was said to have come from Lahat district. In Kepahiang, they called it *cik ari.* Although it remains unclear whether this is all the same coffee plant material, farmers are clearly showing an interest in planting coffee with early maturity and quick returns (figure 16.1).

Family agriculture has always been able to select and develop varieties adapted to the ecological environment and its strategies. Here the main strategy is to get a quick return, but early maturity has a drawback. The trees are much less sustainable and die after 8 or 10 years, creating the need to replant. *Cik ari* increases yields and returns, but it does so at a price—its life cycle cannot be extended even for one coffee season to take advantage, say, of a sudden price increase. In other words, the life of the coffee farm is predetermined by this planting material.

Cost and Returns to Replanting

In Lahat and Pagar Alam coffee trees whose production has dropped to 400 kilograms per hectare are cut down at the end of the rainy season and cabbage is sown. In 1989, with a price of Rp 150 per kilogram of cabbage, producers earned a net income of at least Rp 300,000 per cycle (after input purchases) and thus Rp 700,000–1,000,000 annually with three cycles of cabbage.

Coffee income, at a price of Rp 1,250 per kilogram, was only around Rp 500,000 per year (Ruf 1989).

Even though the vegetable crop is much more labor-intensive than coffee, a high proportion of families in Lahat choose this option, at least on half of the available coffee acreage. Land becomes the limiting factor. Farmer decisions start to rely more on income per hectare than returns to labor.

By truck, Lahat is a six-hour drive from Palembang, a city of 1 million inhabitants. Even at that distance, this urban demand for vegetables offers an extremely useful complement to the international coffee market. One again finds a relationship between population growth in producing and consuming regions of the same country. Transportation costs and the oil rent of Indonesia also interact. With fuel at around Rp 230 a liter in 1989, local transportation costs were around Rp 100 a metric ton and Rp 100 a kilogram (less than 5.5 cents in 1989).

In Kepahiang in 1991, a 3-hour drive from Bengkulu and a 10-hour drive from Palembang, export-oriented ginger was still more spectacular. Ginger income was three to four times higher than coffee when coffee yields fell to some 300 kilograms per hectare.

Factors Influencing Replanting

The best way to approach the determinants of replanting is to understand how a farmer makes decisions. A few cases studied between 1989 and 1992 are presented here.

Land Shortage, Declining Coffee Yields, and Food Crops

One young farmer we interviewed in Lahat had inherited two coffee farms. Both were created by his father who had cleared secondary forest. One was nine years old in 1989, and the young farmer intended to keep it for 20 years until the coffee groves were too high and too difficult to harvest. The other one was 18 years old, and he had cut down the coffee six months earlier because the trees were so tall it made pruning difficult and because yields were declining to 600 kilograms per hectare. The farmer had already replanted the farm with new coffee seedlings and intercropped with cabbage. He anticipated a yield of 1,500 kilograms per hectare of coffee.

In Lahat a coffee yield of 500 kilograms per hectare is often the minimum threshold. Yields below that level may not earn sufficient income for a family, especially if the farm is only 1 or 2 hectares in size. Another key point is the high demand from Palembang for food crops. With available land in short supply, and the opportunity to earn twice as much from the sale of cabbage or any other vegetable as from relatively low-yielding coffee, it is understandable that farmers would occasionally clear their coffee farms. However, they kept replanting coffee for two reasons—the international market for coffee is seen as safer than the local market for vegetables, and although coffee replanting requires labor, several years of vegetable crops would be extremely demanding for labor and inputs.

In short, land saturation is clearly one of the most important factors leading to the replanting decision. In addition, strong urban and domestic markets for food crops clearly enhances the decision. As shown in the above cost-and-return approach, in the worst case food crops partially fund replanting. In the best cases they double or triple the annual income.

Location Rent, Annual Crops, Capital, and Anticipated Prices

One farmer of Kepahiang owns two coffee farms, a 0.5 hectare plot less than 500 meters from his house and the other a 1.5 hectare plot 3 kilometers away. The first plot was replanted in coffee after he had grubbed up an 11-year-old coffee farm planted by his father that was still producing around 600 kilograms a hectare. Why did he cut coffee trees at that yield? The farmer's answer in 1990 was as follows:

- He preferred to use his own labor to replant coffee near the house rather than walk to the farther plot.
- It is easy to carry and sell annual crops that are intercropped with young coffee plantings (groundnuts and especially potatoes and ginger, which may both yield between 15 and 20 metric tons per hectare).
- In 1982 the local price of coffee dropped to a very low Rp 600 per kilogram, down from the peak price of Rp 2,000 in 1976. The new price drop in 1989 and 1990 let him anticipate an aggravated downtrend in the early 1990s. He thus decided that it was the right time to cut down trees and replant, as prices were likely to remain low. It turned out that he was right. Prices remained at their lowest from 1989 to 1993.
- The price of ginger, which had been introduced in the village in the early 1960s, had been rising rapidly since 1978. Many farmers started planting ginger and needed more places to grow it. Cutting down coffee trees and replanting them was a valuable option. Many of them even sold gold jewels in order to buy ginger seeds (chapter 6).
- He wanted to try a coffee planting material seen in the neighboring farms.

These spontaneous answers showed some major determinants of the decision to replant:

- A "short distance" factor, or location rent
- Market opportunities for food crops that can be intercropped with young coffee and fund the replanting investment
- A strategy to improve the planting material
- Low prices for coffee compared with those of (possibly newly introduced) annual crops
- Capital—selling gold jewelry to buy ginger seeds is part of the replanting process. In 1991 and 1992 other farmers mentioned that

credit from banks was necessary for replanting. Credit was not used for direct funding of replanting, but for surviving and to offset the sacrificed coffee incomes.

- Anticipated prices—with the price of coffee so low at the time of cutting, the farmer was asked why he replanted coffee and did not concentrate on annual crops. The answer was also quite clear. The farmer knew that the price of coffee would increase later, so it was right to cut and replant when prices were low.

Management of Replanting

Another farmer in Kepahiang owned three farm plots in 1992. Two were coffee farms and the third was an irrigated paddy field. The first plot of about 1.5 hectares was close to the house, and this is where he undertook progressive, active replanting after cutting down coffee trees only seven or eight years old. The plot was divided into three parts. The first had been replanted in 1989 and was already producing some 300 kilograms of coffee in 1992. The second had been replanted in 1991 and intercropped with ginger in 1992. The third one had just been cut down and replanted in 1992. Intercropped groundnuts had already been sown at the time of observation in 1992. This organization with replanting spread over three or four years enabled the farmer to have both an *agung* coffee harvest and food crop revenue every year. (An *agung* harvest is the peak harvest year, usually the fifth or sixth year after planting.) The second coffee plot is about half a hectare and is located farther in the foothills. The coffee groves are 10 years old and produce some 800 kilograms. Major determinants are also clear in this description of replanting management:

- Short distance
- Flat areas instead of slopes
- Opportunity in the ginger market
- Adaptation of the replanting rate to available labor force
- A strategy of income security.

Beyond the opportunity for active markets of annual crops and a strategy of progressive replanting, the farmer benefits from another coffee farm in the hills and from a paddy field that brings some food security.

All these factors make the risk of replanting affordable. The impact of these factors, especially topography and labor availability, can be illustrated with charts of cropping system alternatives (figure 16.2). In most cases, the life cycle is extended in the hills to take into account distance from home and additional labor needed for replanting in sloped areas. Risk of erosion is also part of the explanation. That is why the longer coffee cycles in the hills are compatible with a higher density of shade trees compared with the flat areas. All this can be considered as part of a "flat area" or "plateau" rent, which is close to the concept of the plains rent for cocoa grown in Sulawesi.

Figure 16.2. Alternative Cropping Systems

a. Intensive Replanting Cycles in Relatively Flat Areas

Years *0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
-----------------				------		------			------	
Coffee planting + annual crops				*agung* period		cutting trees clearing and replanting + annual crops				New *agung* period

b. Intensive Replanting Cycles in Hilly and Sloped Areas

Years *0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
-----------------				------		------		------		
Coffee planting + annual crops				*agung* period		stem bending for triggering new choopons + annual crops			New *agung* period	
							----------- Cutting of old stems			

c. Less-Intensive Replanting Cycles

Years *0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11–18*
-----------------				------	....				------		
Coffee planting + annual crops				*agung* period		declining yields			Selective/partial stem bending and triggering		

Whatever the topography, more extensive cycles (summarized in figure 16.2b) also can be explained by distance and labor shortages. The selective and partial stem bending for triggering new *choopons* may be decided at 9 or 10 years or even later. Replanting may occur later depending on the land available to the household. As a general rule, the greater the acreage available to the household, the longer the coffee cycle before replanting.

Large Acreage and Farmer Age

In 1992 Mr. Ayub was 55 years old and owned one 3-hectare monocrop coffee plot that had been planted in several stages between 1970 and 1985. The life cycle of the coffee groves varied between 7 and 23 years. The plot was 500 meters from the house. He also owned one 0.75 hectare agroforestry coffee plot next to his house. This plot was mixed with rambutan, clove, coconut, banana, and pepper vines.

He delayed coffee replanting because he generally worked alone and lacked family labor, especially for weed control. However, in 1992, he intended to introduce candlenut trees on one-third of the 3-hectare plot. That would require less work than replanting coffee, and he was attracted by their increasing price and by television broadcasts about farmers' success with the trees in Aceh.

This small example is a reminder that farms larger than average and farmers older than average usually postpone replanting decisions. They have no obligation to increase returns per hectare, and they often lack labor. Sons have been sent to school. More extensive farming systems optimize returns per unit of labor. This confirms that replanting is triggered by land shortages and optimizes land returns, possibly at the expense of labor returns, although the high demand for annual crops from urban markets may modify this principle.

This case also confirms the principle of tree-crop diversification of larger coffee farms. Labor-demanding replanting is suited to small farms with a relative surplus of labor. They have to concentrate on coffee and intercropped food crops. In contrast, the larger farms with a relative lack of labor seek more diversified capital.

Income, Family Life Cycle, and Inheritance

Mr. Baman is 75 years old and has two coffee plots. One has never been replanted and is 30 years old. Despite the absence of a labor force, the other plot has just been replanted and the farmer says that he will keep it for only seven years. This mixing of strategies—one plot without replanting and another with frequent replanting illustrates one of the difficulties of demonstrating a relationship between age, future inheritance, and life cycle of the coffee farms. However, Mr. Baman strongly states two reasons behind the decision to replant one farm at the age of 75—one is to upgrade his income in order to guarantee the current family needs, and the other is to transfer the land to his child in good state.

Drought and the Low Price of Coffee

The years 1991 and 1992 years were full of lessons. The first year was an El Niño year, and drought led to dwindling yields and some damage to the coffee groves. Both years were among the worst in terms of international coffee prices. How did the farmers react?

According to our qualitative observations, 1991 and 1992 were effectively characterized by massive felling and replanting. The low yield and low prices made "alternative" annual crops necessary. With a land shortage, this meant massive felling of coffee trees, but in most cases it also meant replanting because farmers anticipated price increases and still relied on coffee as a low-risk crop in terms of both price and weather. If they had had only food crops in 1991 instead of coffee, they would have suffered much more from the 1991 drought.

Through its impact on yield and income, a drought (perhaps any harmful climatic event) may have a positive impact in the medium term. If land is scarce, a drought enhances replanting decisions in the two following years.[4] This is exactly what seemed to be under way in Sulawesi with nurseries prepared in late 1997 by cocoa farmers facing their dying cocoa farms in the hills (chapter 15).

In 1992 all the farmers we interviewed said that they were anticipating a much higher price for coffee in 1994–95. That is exactly what happened. In January 1994 producer prices jumped to Rp 5,600 per kilogram from Rp 1,800. From July to September 1994, these 15 or 20 farmers sold most of their production for more than Rp 6,000 per kilogram. For the numerous farmers who decided to cut down and replant in 1992 or better in 1991, it was the perfect decision. Price and supply cycles coincided at the peak. Some of the largest smallholders were even able to buy a car in 1994–95. Of course, farmers could not forecast such a price hike, but they were right to anticipate a price recovery.

Determinants of Replanting

The examples above show most of the determinants of replanting and suggest strong interactions. These factors are organized and ranked here through a survey of 121 farmers and their 225 coffee farm plots. It is not yet a model of replanting, but rather an analysis that could form the basis to build a model. In addition to the sample of 225 coffee plots, we also used a subsample of 81 coffee farms clearly established as replanted after clearing still-productive coffee groves. For these farms, we examine the determinants of the life cycle of the cleared coffee plot.

Land Shortage, Tree-Crop Life Cycle, and Expected Better Income

One way to explore the determinants of the replanting decision is to ask farmers their reasons for felling a coffee farm and replanting it. The main factors cited were low yield (56 percent), zero yield (21 percent), wanting to introduce *cik ari* (8 percent), and needing the land to plant ginger (7 percent). Eight percent listed other reasons.

More than half of these farmers did not hesitate to fell coffee bushes that were still producing. According to the size of their farm and family requirements, there is a wide range of yields considered as "too small." Some wait until the yield drops to around 200 kilograms per hectare. Others may cut trees when they fall below 600 kilograms per hectare. This high threshold is frequent in Lahat where the population density is among the highest in Southern Sumatra. Families who have only 1 hectare cannot afford a drop in income. Either they try to earn nonfarm income (by hiring out their services to larger farmers or by looking for a nonagricultural job), or they have to take some risks with part of their coffee. In most cases, they cannot afford to let it get too old.

The determination to introduce new planting material such as *cik ari* or take the opportunity to intercrop ginger is also related to the need to maintain or increase income against a background of land shortage.

In short, 92 percent of these spontaneous answers referred to the need to maintain or increase family income. Were land still available, they would have maintained or increased their income by clearing forest and planting coffee. Because they lacked land, they replanted old abandoned coffee farms and possibly grubbed up still productive farms.

Smallholders maintain or increase income by shortening the coffee life cycle rather than lengthening it. As is seen in the cases described, they optimize the young age of the tree on yield. Land shortages and expected better income are definitely the starting points of the replanting decision. Then all factors that influence income have an impact on the replanting decision.

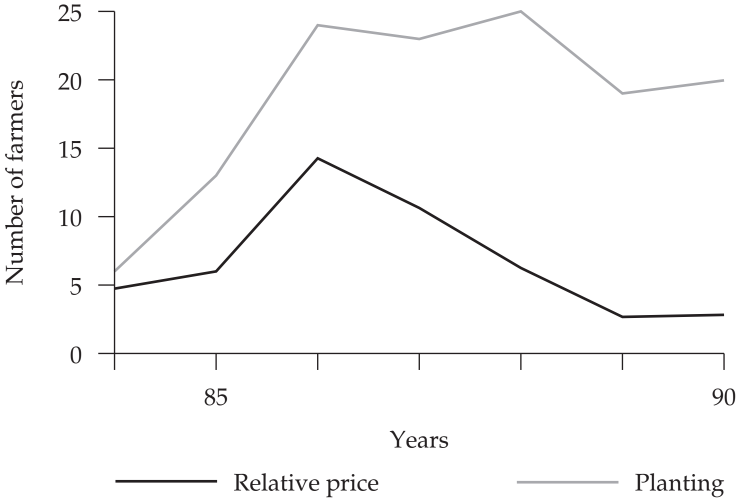
Price Effect on Replanting

No spontaneous answer directly mentioned price movements as a determinant in replanting or not replanting. However, the question was asked in 1991 when the price of coffee was dropping and the price of ginger was rapidly increasing. A coffee price of only Rp 1,000 kilogram may tip the scale toward considering a yield of 600 kilograms per hectare as too low. A price of Rp 3,000 may encourage the farmer to move the critical threshold upward.

The two-part hypothesis is thus that an increasing price encourages new planting but may discourage replanting in the short term, and that a falling price may encourage replanting under two conditions: the farmer anticipates better coffee prices (and thus expected better income) in the years to come, and immediate good prices for annual crops that can be intercropped with the coffee seedlings.

To test this hypothesis, we analyzed the date of planting and replanting with current coffee prices (figure 16.3) and comparative prices of coffee to ginger (figure 16.4). We measured the annual rate of planting by recording the number of farmers in that year who decided to plant or replant (rather than the acreage planted or replanted every year). The dates of planting that are used here are those of coffee farms still existing in 1990. Because some of

Figure 16.3. Total Planting and Coffee/Ginger Price Ratio



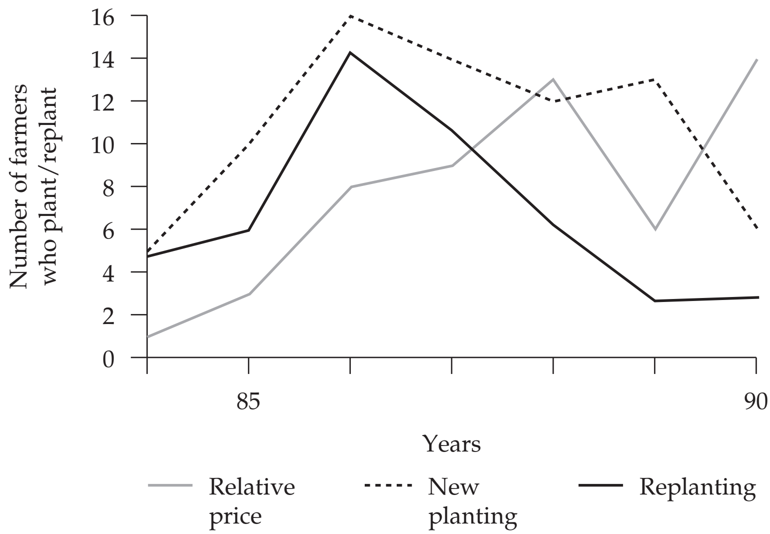
the plantations created in the 1970s had already been cleared in 1990, they are not recorded here. Although the data series may seem imperfect, the impact of the 1977–78 price hike on decisions to plant and replant is still visible. More important, the 1980s data show that planting and replanting decisions closely track coffee prices. In 1983 a first devaluation of the rupiah increased the local coffee price; the number of farmers planting and replanting started increasing in 1984 and 1985. In September 1986 a more substantial devaluation gave an event greater boost to the industry.

These data confirm the common hypothesis of a positive linear correlation between the price in local currency and the spread of planting ($r^2 = 0.58$). This correlation is improved by excluding replanting and taking into account only new planting after forest clearing ($r^2 = 0.60$ on the 1975–90 interval and $r^2 = 0.78$ in the 1984–90 period). The number of farmers undertaking new clearing and planting clearly follows the price increase. It doubles or triples when the price doubles. Then, when the current price slumps, planting seems to drop as well.[5]

The replanting rate pattern was similar to that of planting when the price increased (from 1983 to 1986), but it was quite different when the price fell. Except in 1989, the replanting rate kept rising when the price fell. This finding matches our hypothesis, but how can it be analyzed? Does it mean that the replanting decision is not influenced by the price ($r^2 = 0.33$)? The influence of coffee prices on replanting is certainly not linear and simple.

A further differentiation must be made concerning replanting. We have defined replanting as planting after clearing a productive coffee farm plot. However, the cleared plot could have been seven years old or 40 years old.

Figure 16.4. New Planting, Replanting, and Coffee/Ginger Price Ratio



When the coffee price increases, replanting may be of more concern to old farms and poor yields. When the price decreases, the rate of young coffee farms being cut down and replanted may increase.

To explore this hypothesis, we selected two years with clearly opposite price trends—the most spectacular price increase occurred in 1986, while one of the worse price declines occurred in 1990. In 1986, when coffee prices increased, more than three-fifths of the total plantings were new plantings. In 1990, when the price of coffee had been decreasing for three years, replanting accounted for 70 percent of the plantings. In addition, although the small size of the samples makes it impossible to draw a final conclusion, it seems that the percentage of young farms being replanted increased slightly.

This makes sense. The lower the coffee price, the less difficult the decision to sacrifice income to renew capital. Thus to a certain extent, when prices decline, logically there is a positive price elasticity for new planting and a negative price elasticity for replanting. However, replanting cannot be undertaken without minimum income security. Replanting is an option mainly because cabbage, ginger, or chili bring opportunities for high income during the first year of replanting.

Of course, these comparative prices interact with other factors. First, low coffee prices also mean that farmers anticipate that coffee prices will rise sometime in the future. The coffee tree remains the basis of the farming system, and farmers have always experimented and integrated the principle of coffee price cycles in their decisions, whatever the opportunities offered by annual crops.

Second, beyond problems related to the small size of the sample, it seems that the price effect did not work well in 1989 because of a shortage of available ginger seeds and lack of capital to buy seeds. Whatever the level of farmer income and savings from the previous years, there is a need for credit. A third interacting factor is land shortage. It can be assumed that forest land was less accessible in 1990 than in 1986. Some farmers seem to have been expelled from protected forest. Thus, again price elasticities of planting and replanting incorporate nonprice factors.

Nonprice Factors

In 1991 in Kepahiang, 90 percent of the coffee farms still had a life cycle of more than 10 years. Ten percent were cleared before they were 10 years old. We asked farmers why they decided to replant. The few farmers who replanted before their trees were 10 years old said they did so because the trees had been broken by wind and because they wanted to switch to the new *cik ari* planting material. These reasons concern the objective of maintaining or increasing yield and income. In the case of the first answer, the replanting decision was eased because the damaged trees produced no income, thus no income was being immediately sacrificed.

Four main factors influenced those farmers who waited for more than 10 years to replant: lack of capital (28 percent); lack of labor (27 percent); the opportunity to acquire new land, either through inheritance (14 percent) or purchase (12 percent); and lack of quality planting material (18 percent).

These four nonprice factors seem to be of similar importance, interact, and possibly overlap. Most farmers who complained of lack of capital used to hire workers. It means that they do not have enough family labor to carry out replanting. A farmer may also lack capital because he has just bought

Table 16.1. Distribution of New Planting and Replanting of Coffee during One Year of Price Increase and One Year of Price Decline (Kepahiang, Bengkulu), percent

		Replanting after clearing a productive coffee farm	
Year	*New planting after clearing forest or fallow*	*More than 15 years old*	*Less than 15 years*
1986 (24 plantings) price increase	62.5	25	12.5
1990 (20 plantings) price decrease	30	35	35

Source: Survey by authors, Bengkulu, Kapahiang, 1991.

land. While he is planting coffee on this land, he has neither savings nor labor to devote to replanting. However, each factor and its interaction with the other factors deserves to be looked at separately. One way to do that is to analyze data by ethnic group. The hypothesis is that each migrant ethnic group has a specific history of migration that reflects social and economic characteristics, especially access to land.

Migration Patterns

The first variables to test the impact of land availability on the replanting rate are the life cycle of the former coffee plots cut down while they were still productive (subsample of 81 farm plots) and the coffee area per household undertaking replanting on one of these plots.

The relationship between the replanting decision and the average size of land and coffee per household is subject to opposing influences. A family with only 1 hectare of coffee must renew the tree capital in order to maintain income, but the low level of capital available also puts the family at risk. A family with a 4-hectare plot may not find it as necessary to replant but presumably has more savings and thus is more able to afford it. However, as shown by their answers, smallholders may well decide to use any savings to increase their area by buying land and old coffee farms, which in turn leads to postponing replanting productive trees. With these interactions and opposing effects, there is no clear linear relationship between the area owned by households and their replanting rate, but there is a trend. Half of the households who own less than 1 hectare of coffee cut down part of their coffee groves before the age of 15 years. The percentage drops to 15 percent of the households who own more than 2 hectares of coffee (table 16.2).

The ethnic criteria help to confirm the impact of land shortage on replanting decisions (table 16.3). Pasemah and Serawai migrants own the largest land areas and coffee farms in Kepahiang. They also cleared the oldest coffee farms for replanting. Migrants from Java and Bali had smaller farms, on average, and cut down younger trees. They shorten the life cycle of their coffee trees.

Table 16.2. Influence of the Size of Households on the Coffee Life Cycle

	Distribution of coffee plots according to their life cycle (percent)		
Area of coffee per household (ha)	*7–15 years*	*16–20 years*	*21–40 years*
< 1	50	21	29
1–2	42	24	34
> 2	15	27	58

Source: Survey by authors, 1991.

Table 16.3. Migration History and Coffee Life Cycle

	Acreage per household (ha)	*Distribution of coffee plots according to their life cycle (percent)*		
		7–15 years	*16–20 years*	*21–40 years*
Pasemah	4.9	15	15	70
Serawai	4.6			
Javanese	3.6	64	29	7
Balinese	3.3			

Source: Survey by the authors, 1991.

These figures partially result from the history of migrations. The Pasemah were among the last migrants to come when they arrived in about 1970, but they settled close to forest reserves and rapidly became the largest coffee smallholders. They came from Lahat, where they had experience in coffee farming, and they maximized the forest rent through high-density planting (an average of 3,320 trees per hectare, rather than the 1,800 trees per hectare planted by the other ethnic groups). They made the most of this easy, cheap access to land, forest rent, and the price hikes in the 1970s. In return, they had time before they had to think of replanting.

Serawai migrants, from Southern Bengkulu, have a different history, but one that led to a similar effect. They were among the first migrants to Kepahiang in the late 1940s and set themselves up as coffee farmers by taking over pieces of the local Dutch estate. They were thus farther from protected forest and were not as able to extend their coffee farms as easily as the Pasemah did. The Serawai strategy was to extend their capital by buying land from indigenous people. Half of the Serawai mention opportunities to purchase land as the main reason for postponing a replanting decision.

The Javanese came in the late 1950s and had some opportunities to clear forest at that time. However, they no longer benefit from forest rent. They are close to roads and have a strategy of market-oriented food crops. They need to replant coffee in order to free land.

The Balinese came in the late 1960s, not directly from Bali, but from transmigration schemes in northern Bengkulu. They did not dare to take forest land, but rather sharecropped old coffee farms or coffee fallows from indigenous people. They also had a strategy of rapid replanting and marketing food crops.

Coffee Trees, Topography, and Distance

In an analysis of the diversification of coffee systems of South Sumatra, Godoy and Bennett (1989) observed that producers who stayed in the heart of the coffee belt at an altitude between 700 and 1,200 meters did not clear much new land, but rather preferred to replant. In contrast, farmers who stayed above 1,200 meters cleared much more forest.

Replanting by long-established smallholders is explained by the lack of available forest at the most suitable altitude, the distance from their houses to the nearest accessible forests (two to four hours), the disadvantage of slight slopes, and the land ownership risk. However, new migrants, usually poor, put up their houses close to the forests and were willing to face risks related to ecology and illegal deforestation (Godoy and Bennett 1989).

Similar conclusions are drawn from the Kepahiang case. The slow rate of replanting by the Pasemah and Serawai is partly related to their proximity and better access to forests. Among farmers in four villages close to forests, only 25 percent replanted before 15 years, while 50 percent waited for 20 years. In contrast 50 percent of the farmers living in the three villages along the main road cut down and replanted their coffee farms before 15 years, while only 25 percent did so after 20 years. In both cases, the remaining 25 percent cut down part of their coffee farms at the intermediate age of 16 to 20 years.

Market for Intercropped Annual Crops

If there is a strong urban demand for food crops or a well-established export channel for a crop such as ginger, these markets encourage coffee replanting. This has been well illustrated by individual cases and the cost-and-return approach. Replanting is the way farmers free land in order to plant one or two years of annual crops. Also, the sacrifice of the coffee income may be compensated by revenue from the annual crop. Two to three cycles of cabbage may provide twice the income per hectare that the sacrificed coffee would have. While studying transmigration in Lampung, Levang (1989) also described coffee replanting funded by food crops such as potatoes, chilies, and onions.

This role of annual crops and increasing demand for food crops is extremely important for triggering a tree-crop replanting phase. As with cocoa in Sulawesi, it fits with the migration process and urban population increase.

Enhancing Location Rent with Annual Crops

When markets and prices are relatively free, the distance between the field and the road generates a location rent, which is enhanced in mountainous countries. As in Sulawesi, the distance factor is accentuated by slopes that make walking, working in the fields, and carrying inputs and produce more difficult.

Location rent applies to coffee, but is even more important for annual crops such as cabbage or ginger. A hectare that yields 2,000 kilograms of coffee may also produce 20,000 kilograms of ginger. If these annual crops are intercropped with the young coffee seedlings at the replanting stage, the distance between the field and the road acquires increased importance (chapter 6). The most rapidly replanted coffee farms are clearly those closest to the roads.

Location factors of course interact with price factors. The surge in ginger prices and the coffee price collapse in 1990 accelerated replanting. Location rent was also enhanced by local access to capital.

Capital and Credit

In the late 1980s, and especially in 1990 and 1991, middlemen involved in ginger developed a system of credit by supplying seed and fertilizer to be repaid by sharing the ginger output. To minimize costs, especially those of transportation from the field to their shops, they sought fields close to the roads. Generally, farmers making the replanting decision need savings and capital to cope with a sacrifice of coffee income, labor costs for coffee replanting, or input costs such as seed and herbicides. Intercropping a valuable annual crop such as chili, ginger, or cabbage may fully cover replanting costs; however, capital to buy seed is still a prerequisite.

Early Maturing Trees—*Cik Ari*

Eight percent of farmers who replanted said a change of planting material was their main motivation for replanting, and 18 percent of those who postponed replanting mentioned the lack of good planting material. Early maturing planting material is accelerating replanting rates in two ways: when first adopted, farmers are looking for quick returns, but then they must replant at the end of the *cik ari* life cycle in seven to 10 years.

Life Cycle of Trees as Capital

Whatever their prices, crops such as cabbage, ginger, or chili are not really alternatives to coffee. They are complementary, but coffee remains the basis of the system. The ginger disease outbreak in 1992 illustrates this point very well. Against a background of few alternatives and land shortages, the life cycle of the tree remains a strong variable in the replanting decision. With some planting material, there is a longer life cycle, hence flexibility, and farmers can play on the life cycle. With others, such as *cik ari* and its shorter life cycle, they lose this flexibility.

Value of the Tree Capital

The value of the tree capital at the end of its productive agricultural life also plays a role. In a deforested region, the value of coffee stems (and intercropped shade trees) as firewood may be high. This can be a stimulant for replanting.

This is also congruent with the principle of intensification after several years of pioneer fronts. At a certain threshold of deforestation and migration, the demand for firewood increases while the resource disappears. This situation brings new opportunities for the tree crop and makes replanting more attractive. Selling a tree for firewood (or much better, timber) can at least partially pay for replanting. That is also true for timber produced by rubber trees and more importantly for associated timber trees in jungle rubber.

Family Life Cycle

Age is a factor in the decision to replant, with older heads of families more reluctant to replant than young ones (table 16.4). This relationship is partially combined with the local history of migrants who set up their villages close to the forest 20–40 years ago, and thus have time before replanting. Among farmers interviewed about their reasons to postpone replanting, 12 percent mentioned a land purchase. The average age of this 12 percent was 58, while the average age of heads of families was around 45.

Among the younger farmers more eager to replant are indigenous people who inherited coffee farms and Balinese who bought fallow land. Both are also motivated by the annual crop market. Taking into account the additional labor required by food crops, it also makes sense to be attracted by their market potential when one is young. In contrast, if their sons have been sent to school, 60-year-old farmers lack labor at the moment they need it. Thus replanting is postponed.

Labor and Institutional Factors

Twenty-seven percent of farmers who postpone replanting beyond 10 years refer to a labor shortage, which is one of the main constraints. There is a need for extra labor to replant tree crop seedlings and intercrop annual crops. Families that lack labor miss out on replanting.

In Kepahiang, a detailed appraisal of labor availability would require further surveys. Daily labor costs seem to have increased to Rp 5,000 in 1997 plus two meals and cigarettes, which put the cost of a man-day at about Rp 8,000 ($3) in July 1997. By Sumatran standards, this seems to be a relatively tight labor market.

Table 16.4. Influence of Farmer's Age on the Coffee Farm Life Cycle

	Distribution of coffee plots according to their life cycle (percent)		
Age of head of household	*7–15 years*	*16–20 years*	*21–40 years*
20 to 39	44.5	37	18.5
40 to 54	37.5	18.7	18.7
55 and above	18.2	18.2	63.6

Source: Survey by authors, 1991.

However, because the younger generation lacks alternatives, inheritance and the increasing difficulty of acquiring forest land in Kepahiang tend to increase the average amount of labor available per hectare of coffee. Young farmers who do not have enough land are obliged to look for labor contracts with larger smallholders. In the neighboring province of Lampung, Levang (1989) observed that some Javanese migrants rented old and almost unproductive coffee farms to grow three or four cycles of cabbage. Then after a year, the owner of the former coffee farm receives a clean plot with fertilized soil, ready to receive coffee cuttings at no cost.

Even more sophisticated versions of the same institutional arrangements, with seven-year contracts modeled on the seven-year life cycle of *cik ari,* are developing rapidly in Kepahiang. This is one more sign that labor availability is increasing and favoring replanting decisions. This additional labor is supplied by new migrants and by sons of already established farmers. This is general rule extends far beyond Kepahiang, Indonesia, and coffee, and is valid in most family tree-crop economies in the world.

Conclusion

Main Determinants of Replanting

The case of Kepahiang and coffee is a convincing framework to build a model and theory for tree crop replanting decisions. The starting point is land shortages. Smallholders renew their capital to maintain or increase income with a degree of security. Determinants of replanting are those that influence that objective, either by posing a threat to it—a land shortage, for example, or coffee price slump—or by favoring it—availability of capital, innovations in planting material, or increasing prices of intercropped annual crops.

Although rarely the case, policies should play a major role in stimulating factors favorable to replanting; particularly needed are forest protection measures, supplies of adapted planting materials, and guarantees of easy access to inputs, especially herbicides. Governments also have an important and more simple role in avoiding untenable immigration and migration policies. Migrants remain useful in a replanting phase, but there is a need to achieve a delicate balance between the interests and rights of indigenous people and migrants.

Replanting as an Intensification Process

The case of Kepahiang confirms and completes the Boserup model. By cutting down coffee groves, replanting, and introducing cabbage or tobacco, an innovation increased labor per unit of land. This innovation was generated by increasing population and land shortages. Additional innovations included new planting materials that enabled further intensification, and labor and capital introduced from a region of higher population density. Ginger seeds and fertilizer also meant introduction of monetary capital in the farming system. All these innovations under the partial pressure of increasing population enabled families to increase income per unit of land, and thereby maintain and possibly increase income per unit of labor and family.

A Strategy to Achieve Sustainability

By progressively adapting their coffee shifting cultivation, smallholders based in Kepahiang invented and adapted quite efficient replanting systems. Shorter coffee cycles increased the economic risks, but farmers managed by combining short- and long-cycle coffee plots and diversifying their income with annual crops and sometimes nonfarm income. This innovative scheme achieved sustainability through a short life cycle of a perennial crop and may well apply to other tree crop economies and in other countries.

For example, research has shortened the maturing and unproductive phase of oil palms to 3 years, from 5 to 6 years. Under these new conditions, smallholders may well implement a strategy of harvesting as many bunches as possible for 10 or 11 years and then cut down the trees after 14 years before they grow too tall to make harvesting difficult or suffer from diseases. In some countries, this replanting decision may also be favored by the high incomes available from cutting down the trees. For oil palm in West Africa, for example, it is not the timber value, but rather the palm wine business that can generate cash for replanting.

In short, a sustainable income per hectare and per day of labor can be achieved by shortening the life cycle of trees rather than by lengthening it. This deserves to be explored with participating smallholders.

Notes

1. Annual average rainfall in several areas in south Sumatra from 1977 to 1985 was 2,500 millimeters, with the dry season between May-June and October.

2. It seems to be a clear illustration of the Boserup theory (chapter 1).

3. Some Lahat farmers even complained that some extension workers had borrowed their invention and introduced it in other places as their own product. This is rather positive in terms of innovation spread. The only complaint is the loss of author's recognition and rights.

4. Where land and forest are abundant, a drought does not trigger replanting but rather abandonment of farms and migration to neighboring forest regions to start new clearing and new cycles, as has frequently occurred in cocoa in Africa and South America.

5. These survey data are shored up by official statistics. In Kepahiang district, the recorded coffee area increased by 50 percent within one year. It jumped to 19,000 hectares in 1986–87 from 12,400 hectares in 1985.

17

Price and Nonprice Factors in a Green Revolution

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Despite difficulties encountered by upland farmers, a Green Revolution, perhaps even a "double Green Revolution," is occurring in the Indonesian uplands. It remains largely unknown because it originates with the true entrepreneurs—farmers.

Are relatively high yields sufficient to justify using the term Green Revolution to describe certain Indonesian upland areas such as those of Sulawesi? How do market and land policies interact? What might be the lessons for other upland regions? These are the complementary questions raised and tentatively answered through a short comparison of Sulawesi and Côte d'Ivoire farming systems. We test the hypothesis of a broad application of the Green Revolution concept to the uplands through various combinations of trees and inputs.

We also enlarge the geographical framework and suggest that Green Revolutions of any sort may be on the way in the uplands of many countries. This looks like an irreversible trend under the influence of population increases, land saturation, ecological changes, and free markets.

To better understand the continuous interaction between price and nonprice factors, we examine the reasons for intensive farming in Sulawesi compared with the more extensive farming and limited use of inputs in Côte d'Ivoire, at least until the mid-1990s. Pesticide use seems to have rapidly increased in some parts of Côte d'Ivoire beginning in the mid-1990s. The same can be said of fungicides in southwest Cameroon. In Côte d'Ivoire again, fertilizer consumption, for which statistics were largely unavailable until the mid-1990s, was burgeoning in 2001–02. A clear understanding of the reasons behind the surge of input consumption in Côte d'Ivoire may help to test the hypothesis of an ongoing Green Revolution in the uplands of many countries.

In addition, we also explore the preliminary impacts of monetary depreciation on cocoa and input prices and thus on cocoa and input adoption.

Cocoa Yields in Sulawesi and Côte d'Ivoire

Before the cocoa pod borer (CPB) infested all of the cocoa-growing regions of Sulawesi, the average yield on the alluvial plains was 2,000–2,500 kilograms per hectare in monoculture and full sunlight, and 1,500 per hectare where cocoa was intercropped with coconut. The average cocoa yield was also 1,500 kilograms per hectare in the foothills in monoculture and full sunlight. Since CPB and climatic events such as El Niño struck in the late 1990s, per-hectare yields are around 1,400 kilograms in the plains and 1,000 kilograms in the hills.

Despite uncertainties about sustainability, these figures compare favorably with yields in Côte d'Ivoire. There, 8–15-year-old plantations in the 1980s growing cocoa in monoculture with moderate use of inputs (principally one or two insecticide spraying operations) produced per-hectare yields of 400–1,000 kilograms. In the early 1990s, when cocoa prices plunged, the per hectare yields on a number of established farms fell to some 200–400 kilograms with no more applications of inputs.

However, abnormal aging of orchards, slumps in yields, land saturation related to increasing population pressure, and a serious lack of economic alternatives (and possibly the 1994 devaluation and liberalization of internal marketing in 1992) triggered innovations in several regions of Côte d'Ivoire. Since the mid-1990s, pesticides have been in high demand, and access to them has been eased thanks to initiatives by farmers and traders. Some traders reinvented credit contracts while some farmers took the initiative to look for fertilizer, and this combination launched a new business in buying and selling fertilizer. All these innovations helped to build new solutions to forest rent exhaustion (chapter 1). Since 1994–95, cocoa yields seem to be recovering, even doubling; some farms owned by foreigners in southwest Côte d'Ivoire may achieve close to 1,500 kilograms per hectare when fertilizer is used. The life expectancy of the cocoa farms is also prolonged.

Similarly, in some parts of southwest Cameroon, good pruning and systematic use of fungicides in young cocoa monoculture have helped to obtain per-hectare yields of 600–1,000 kilograms. That represents a substantial improvement over the 200 kilograms produced on old cocoa farms under heavy shade in the central southern part of the country (Temple 1996; Varlet and Berry 1997).

Côte d'Ivoire seems on the way to recovering its past yields and even increasing them, while Indonesian cocoa farms suffered a structural decline in yields from 1996 to 2001. So a comparison between Indonesia and Côte d'Ivoire is not just a simple comparison between high yields in one country and poor or middle yields in the other, but a more dynamic, evolving comparison. The recent progress in some regions of Africa seems to confirm the existence of potential Green Revolutions worldwide in the uplands with the same key combination—one major tree crop, fertilizer, pesticides, and possibly some intercropped trees to maintain an ecological balance.

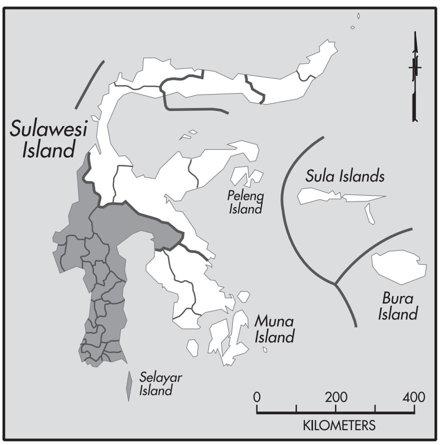
Cocoa Price Effect in 1997–98

Cocoa smallholders in Indonesia and Côte d'Ivoire experienced major changes from mid-1997 through 1998. In Côte d'Ivoire, the producer price, which was still fixed by the state, soared in 1997 to CFAF 450 per kilogram, from CFAF 315, and then in late 1998 to CFAF 550. In Sulawesi, because of the dire money depreciation, the producer price jumped from Rp 2,500 in June 1997 to Rp 5,000 three months later and skyrocketed to Rp 10,000–15,000 within seven months. The comparative prices of cocoa and inputs should be examined before and during these price changes, first with 1997 data (table 17.1) and then with 2001–02 data (table 17.2). (In Sulawesi, prices in June 1997 are a better reference than those of November, which were unstable.)

There is a strong relationship between the relatively high cocoa prices in current rupiahs in Sulawesi in the 1980s (and even in the early 1990s), the relatively low prices of fertilizers and herbicides, and the impressive adoption of these inputs and thus the high yields. From 1989 to June 1997, Sulawesi smallholders needed to sell only 7–10 kilograms of cocoa to cover the purchase of one 50-kilogram bag of fertilizer bag, a combination of urea, potassium chloride (Kcl) and TSP. In late 1997 and 1998, the Asian crisis and the increase of international and producer cocoa prices in rupiahs stimulated further purchases of inputs and helped smallholders to reduce the negative impact of the 1997 drought on their trees.

Similarly, one can easily understand why the majority of Côte d'Ivoire smallholders hardly adopted herbicides and fertilizers before 1997. From

Map 17.1



Map 17.2

Table 17.1. Comparative Cost of Inputs and Other Goods in 1997 before and after Increases in the Price of Cocoa, 1997

	Sulawesi		*Côte d'Ivoire*	
Parameter	*June 1997*	*Nov. 1997*	*June 1997*	*Nov. 1997*
Cocoa price	*2 800 Rp/kg*	*4 800 Rp/kg*	*315 Cfaf/kg*	*450 Cfaf/kg*
Fallow land in upland	360	272	320	220
Forest land in upland	250	217	380	270
Fallow land in alluvial plains	830		No alluvial plains	
Labor cost per day (cash)	2.0	1.1	2.4	1.7
Labor cost per day (total)	2.9	1.7	3.2	2.2
Gramoxon (1 liter)	4	2.9	17	12
Roundup	6.8	4.0	Almost never used	
Urea (50 kg bag)	7	4.4	35	24
NPK fertilizer (50 kg bag)	16	10	35	24
Blower	Almost never used		1016	711
Handsprayer	33	32	206	144
Rice	0.3	0.2	0.8	0.7

Note: Costs are expressed in kilograms of cocoa, that is, the number of kilograms needed to pay for the input or other good.

Table 17.2. Comparative Cost of Inputs and Other Goods, 2001–02

	Sulawesi		*Côte d'Ivoire*	
Parameter	*June 2001*	*April 2002*	*June 2001*	*April 2002*
Cocoa price	*8 250 Rp/kg*	*10 980 Rp/kg (1)*	*300 Cfaf/kg*	*675 Cfaf*
Fallow land in upland	333	296	367	222
Forest land in upland	303	228	400	296
Fallow land in alluvial plains	848	683	No alluvial plains	
Labor cost per day (cash)	1.4	1.4	3.3	1.5
Labor cost per day (total)	2.1	1.9	5.0	2.2
Gramoxon (1 liter)	4.5	3.4	18	8
Roundup	5.2	3.9	25	11
Urea (50 kg bag)	7.1	5.6		
NPK fertilizer (50 kg bag)	19.4	14.6	40	17
Blower	Almost never used		1167	519
Handsprayer	34	26	258	115
Rice	0.25	0.22	0.9	0.4

Note (1): In 2002, the price in nominal rupiahs did not increase much due to the relative recovery of the Indonesian currency.

1990 to June 1997, Côte d'Ivoire smallholders needed to sell at least 30 kilograms of cocoa to cover the purchase of one 50-kilogram fertilizer bag. The number of kilograms of cocoa needed to buy one liter of herbicide was also four times that recorded in Sulawesi. Food prices also play a role here. If a Côte d'Ivoire farmer needs to sell threefold more cocoa to buy rice and feed the family, less income is available for farm inputs.

In October 1997 the terms of trade started to improve in Côte d'Ivoire. The increase of the producer price in Côte d'Ivoire in late 1997 was accompanied by a strong positive price-elasticity of input adoption. After late 1997 in the regions of Soubré and Gagnoa, we observed a spectacular increase in smallholder demand for and use of inputs, which seems to have had an immediate effect on yields. For example, the owner of a 15-year-old cocoa farm, which had not been sprayed for a few years, applied two rounds of pesticides; six months later his per hectare yield had increased 30 percent. A few innovative farmers were able to crop 1,500 kilograms per hectare by spraying pesticides only four times a year and applying fertilizer at a rate of 350 kilograms per hectare. This was still a small percentage of smallholders in Côte d'Ivoire, but it announced a tremendous change.

Overall Côte d'Ivoire was able to increase its production and match its record yields in 1994–95, producing 1.1 million metric tons of cocoa in both 1997–98 and 1998–99. Moreover, to the surprise of virtually all international experts, Côte d'Ivoire kept its production level around the 1.2-metric-ton threshold in 2001–02 and even 2002–03, despite the grave political crisis and civil war. What happened?

Cocoa Price Effect in 1999–2002

In mid-1999 international cocoa prices started to collapse, as did producer prices in Indonesia and Côte d'Ivoire. Producer prices in Cote d'Ivoire were lower than in Sulawesi because of government taxes and lack of competition between middlemen at certain periods of the year, especially in May-June when cocoa bean quality is supposed to decrease due to seasonal climatic factors. This is well illustrated by the price of June 2001 (see table 17.2).

However, the situation improved rapidly after October 2001. Ivorian farmers were less affected by the high tax burden than expected, owing to the rapid increase in the world price. In late 2001 and early 2002, the cocoa-fertilizer price ratio was approaching that faced by Sulawesi smallholders. One fertilizer bag required the sale of 17 kilograms of cocoa in Côte d'Ivoire compared with 14 kilograms in Sulawesi. The relative price decline in fertilizer compared with the price of cocoa helps explains the increase in fertilizer adoption in Côte d'Ivoire.

As in 1997–98, the price increase in 2001–02 triggered typical short-term price elasticity of input consumption. New infusions of pesticides and fertilizers after the 1997–98 price increase and then again after the 2001–02 price increase helped to maintain production (figures 17.1 and 17.2). Despite an aging national orchard and a price fall in 1999 and 2000, Côte d'Ivoire produced nearly 1.4 million metric tons in 1999–2000 and around 1.2 million metric tons in each of the next three years.

However, this so-called price elasticity also involves major nonprice factors. The recent increase in input adoption would not have been so strong if these nonprice determinants had not been so favorable.

Nonprice Factors: Survival of Tree Capital through Fertilizer Adoption

The Soubré/Buyo region in southwest Côte d'Ivoire was entirely covered by primary forest until the early 1970s, when massive cocoa migration began. The migration involved many smallholders from the eastern region of Côte d'Ivoire, at some 400 kilometers from Soubré, where cocoa farms were already old and abandoned, sometimes destroyed by fires. While the eastern region was on the decline, Soubré became the new center of the Ivorian cocoa belt in the early 1980s. By the mid-1990s, although the region was still covered by very young cocoa farms, large parts of the Soubré orchards were already 20 years old and beginning to decline. The pioneer front started moving farther to the south and southwest. This pattern looks like a typical cocoa shift of production, or tree crop shifting cultivation, and close to a boom-to-bust model (chapter 1).

An external factor, however, limited the local bust for the moment—a new and unexpected adoption of fertilizer enabled an increasing number of farmers to delay the mortality of trees and an accompanying slump in yields.

Figure 17.1. Pesticide Adoption by Foreign Migrants and Cocoa Price (East-Soubré, Côte d'Ivoire)

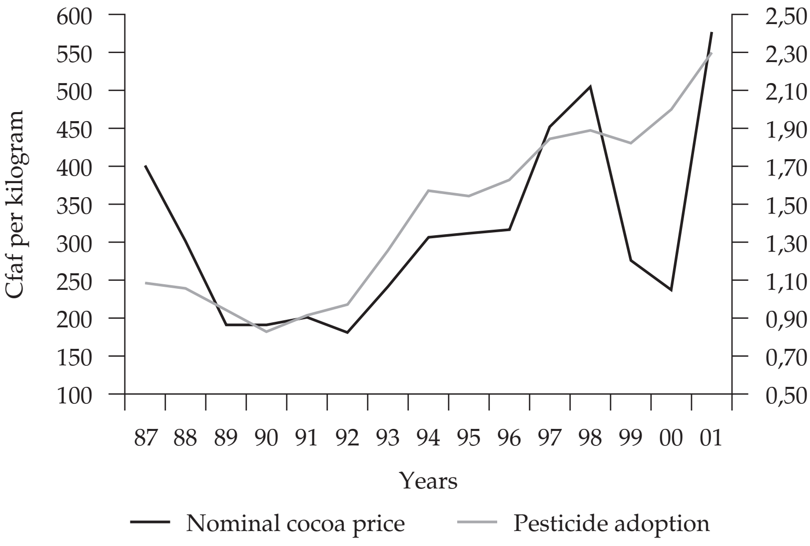
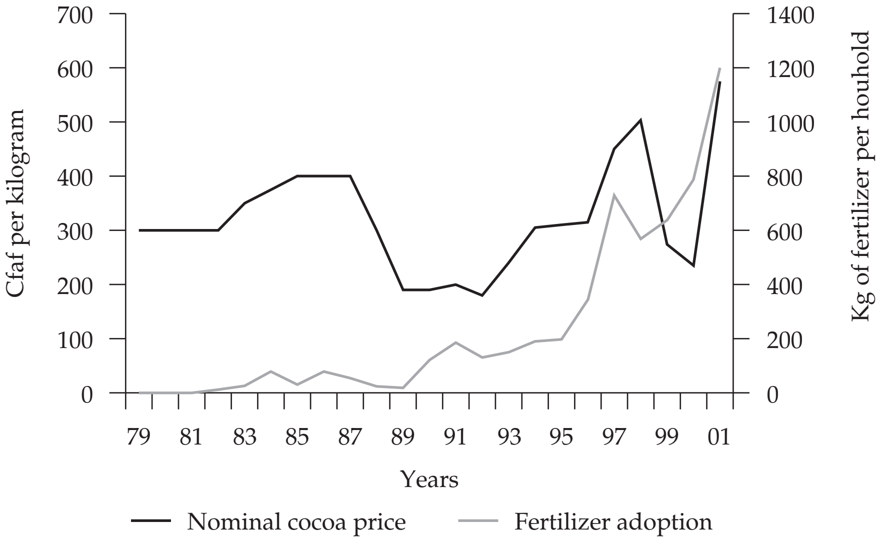


Figure 17.2. Fertilizer Adoption and Cocoa Price



Why did it happen in this region of Soubré in the 1990s and not earlier in other Ivorian cocoa belts on the decline?

The main factor was the constraint caused by the local ecology. When migrants caught cocoa fever in the 1970s, they did not pay enough attention to the stony and gritty soils of the Soubré region. The standard system of forest clearing and direct seeding of cocoa beans did not work as well as it had in previous cocoa belts. Intercropped banana trees produced for only one year instead of for the 10–20 years common in other regions. Cocoa trees grew relatively well, with nice green leaves, but did not bear pods for five years—two years later than cocoa grown in the central western region. Worse, cocoa trees started dying. A 10-year-old cocoa farm in Soubré looks like a 20-year-old farm in Abengourou in the eastern region or Gagnoa in the center west of Côte d'Ivoire. On a 15-year-old cocoa farm in Soubré, most of the cocoa trees have died and been replaced by *Chromolaena odorata* weeds.

In short, the principle of tree-crop shifting cultivation was tremendously accelerated by unsuitable soils. Migrants had no choice. They had to react to their dying cocoa trees. They had to find a way to prolong the life cycle of their cocoa trees, turn to some other crop, or leave and try to find a new plot of primary forest in another region. By the late 1980s finding a new forest plot began to become very difficult. Unprotected forests became extremely scarce. Forestry services increased their repression made of such factors as imprisonment, informal taxation, and the loss of houses to fire, at the expense of migrants at the edges of protected forests. More important, having to leave a farm after only three to five years of production was a poor return on migration and planting investment.

With their backs to the wall, some migrants had to innovate. They started looking for fertilizers. How did they get the idea and implement it? It was all but obvious in forest regions that had hardly any experience with fertilizer. A showcase is the Brahimakro village, some 35 kilometers from Soubré. This is a village of Burkinabé people from the neighboring country of Burkina Faso. The Burkinabé had worked as laborers and sharecroppers on cocoa farms in Ghana and then Côte d'Ivoire for almost a century. However, since the 1970s they increasingly gained access to land in Côte d'Ivoire and became planters themselves.

The village chief at the time of our study was one of the first two migrants who arrived in this part of the forest and founded the village of Brahimakro in 1979. At the time, he was still a cocoa farmer in the eastern region in Bongouanou, some 300 kilometers from Soubré, where he owned a 10-hectare cocoa plantation. The farm was old, however, and already considerably damaged by drought. He gave up this farm in the eastern region, moved to Soubré, where he cleared 10 hectares and planted cocoa — a showcase for the tree-crop shifting cultivation principle. The only problem was that five years later, the farm looked green and nice but did not produce anything. Some trees had even died before producing.

He remembered that in the mid-1970s when the eastern region was still the major cocoa belt of the country and at the top of its regional cycle, some of the biggest village planters who owned more than 50 hectares of cocoa sometimes used a little fertilizer. In 1983 he decided to try to buy one bag. The use of fertilizer was unknown in the town of Soubré, but the head of the local extension services in Soubré confirmed the value of fertilizers. No fertilizer was available in Soubré, but some Burkinabé farmers had already organized a small trade of pesticides from Abidjan and resold them at the farm gate, so he asked one of these people to bring him a 50-kilogram bag of fertilizer, which he bought and applied on a quarter-hectare plot. Within a year, he verified the positive impact on production compared with trees that had not received fertilizer. The next year, he bought 30 bags.

The other village cofounder did the same. Both experienced a failure on lowland areas or valley land where soils were too sandy; fertilizer could not prevent cocoa trees from dying after a few years when the roots reached the white sand horizon. However, both had success in the uplands. Not only did trees survive and produce, but yields increased enormously by local standards. They reached 1 metric ton per hectare on average in the late 1980s.

Soon other Burkinabé in the village followed their example and started to buy fertilizer; they were followed by farmers in many other villages, including Baoulé migrants. In turn, this demand caught the attention of small traders in the town of Soubré. They took the opportunity offered by the collapse of the extension services to set up their own shops and also gained some experience in inputs by smuggling pesticides and sprayers from Ghana. They added fertilizer to their stock, and the fertilizer business was launched.

A few other villages might have slightly preceded Brahimakro in adopting fertilizer. The very first innovator seems to have been a *diula* (a migrant from the northern savanna of Côte d'Ivoire) who made the first trials in 1979, possibly from experience gained in cotton fields. Followers increased between 1983 and 1988. In the village of Koffi Kouadiokro, Baoulé migrants (from the central part of the country) also arranged to send one cocoa farmer to Abidjan to buy fertilizer for them. This envoy became a well-known trader nicknamed "Mr. Fertilizer Kouakou."

A Temporary Setback

Fertilizer adoption suffered a setback in 1989 and in the early 1990s due to the slump in cocoa prices. Only the biggest farmers and those most anxious to conserve their dying cocoa farms kept buying some fertilizer. Some even extended the acreage of paddy and maize to sell food and then buy fertilizer for cocoa farms. This is another example of the complementary roles of annual and perennial crops in sustaining upland farming systems (chapter 15).

Some reluctance and caution also came from a number of smallholders who strongly believed that the short-term effect of fertilizer on yields would be followed by sudden death of the trees. That is one of the reasons why it took 12 years for fertilizer adoption to become widespread.

New Surges in Fertilizer and Pesticide Adoption

The purchase of pesticides took off again in Soubré in 1993–1994 and then in 1997. One reason was that farms planted by a second wave of migrants in the late 1980s started to produce, hence a revenue effect enabled new migrants to buy pesticides. The other reason was the relaunch of the whole marketing chain of cocoa in 1994 and the apparent increase of the cocoa price after devaluation of the Côte d'Ivoire currency. Prices rose from CFAF 200–240 per kilogram in January 1994 to CFAF 310 per kilogram in November 1994. The increase of pesticide use in 1994 happened despite a near doubling of input prices and an increase in the price of cocoa of only 50 percent (see figure 17.1).

In the Soubré region planters maintained their use of fertilizer in the early 1990s when cocoa prices were still low and even in 1994–95 when the prices of fertilizer doubled. The sudden price jump for cocoa to CFAF 455 in 1997 followed by another increase in 1998 immediately triggered a jump in fertilizer demand. That scenario repeated itself at the turn of the century. Although the price of cocoa fell again in 1999 and 2000, farmers barely reduced their fertilizer purchases. Then with the sudden price increase, the demand in fertilizers jumped to new records in 2001–02 (see figure 17.2). In other words, the price elasticity of fertilizer consumption is low when prices decrease and high when prices increase. This is explained by the farmers' awareness that their trees need fertilizers to survive and produce.

Further Interaction of Price and Nonprice Factors

Despite the strong increase in fertilizer prices in 1994 and two pronounced cocoa price collapses in 1989–93 and 1999–2000, fertilizer adoption kept increasing at an exponential rate from 1983 to 2002 and probably in 2003. This can be interpreted as a strategy by a few farmers to maintain and even increase input consumption during the crisis—a classic entrepreneur's decision to invest and increase production when price falls in order to try to maintain income.

Price and revenue effects are overestimated, however. The entire adoption process had been built up in the previous 10 years and was triggered primarily by nonprice factors—vital problems of tree survival, problems with soils, slump in yields, a beginning of forest shortage, and preexisting information conveyed by experienced family planters. A clear technical breakthrough achieved by the dominant fertilizer company also played a role. The best formula adapted to cocoa (0-19-23-5, which means 0 units of nitrogen, 19 units of phosphorus, 23 units of potassium and 5 units of magnesium) started to be known by more and more farmers every year.

Evolution of Farmers' Motivations

The starting motivation for adopting fertilizer in Soubré was to save the trees, not to maximize returns. However, at least since the early 2000s, migrant farmers were also increasingly motivated by the objective of maximizing returns. From our field surveys, we estimate that a farm producing 500–600 kilograms of cocoa per hectare that applies 250 kilograms of fertilizer per hectare can reach an average yield of at least 1000 kilograms of cocoa per hectare for two to three years. This enables and justifies farmers' practice of applying fertilizer according to a rotation principle, from one farm plot to another. For instance, every year, 2 hectares of a 6-hectare farm receive 500 kilograms of fertilizers. A farmer will need three years to apply fertilizers to the whole farm. Taking into account our estimate of 40,000 metric tons of fertilizers sold to cocoa farmers in Côte d'Ivoire in 2002, this means that approximately 160,000–200,000 tons of cocoa beans resulted directly from the fertilizer innovation. In other words, some 15 percent of the Ivorian cocoa supply is no longer attributable to the forest rent but to the fertilizer adoption. This is the beginning of a technical revolution. Paradoxically, this may also be an unexpected consequence of social and political troubles in Côte d'Ivoire. As fertilizer significantly increases returns in a single year, the positive impact of price and revenues outweighed the negative impact of fears and risks of expulsion from the country and even threats to life.

Lessons from the Cocoa-Fertilizer Stories

The Ivorian experience proves once again the incredible strength of family agriculture and smallholders' capacity to maintain their investments and take risks during crisis periods, at least over one year.

Two or three more simple lessons can also be drawn from this case. The initiative came from farmers. In Schumpeter's sense, they are fully entrepreneurs, making decisions to innovate and use all means to implement their input trading business. This innovation came about through a combination of previous smallholder experience (in cocoa and possibly in cotton regions where some cocoa farmers came from) and the availability of inputs in the capital of the country. Extension services also brought information in response to farmers' questions. This information had an economic impact a few years later after the extension services had already collapsed. The Côte d'Ivoire case confirms two rules for innovations identified in Indonesia. One is that an innovation cannot result from only one item of information, but requires a combination of at least two items. The other is that the assessment of the efficiency of extension services must be applied to a long period of time. In many cases information is used years after it is received, when the farmers' environment make it worth using.

More importantly, farmers in southern Côte d'Ivoire and South Sulawesi have been motivated by similar nonprice factors. Following the 1997 drought Sulawesi farmers increased their fertilizer consumption in 1998, not to improve their income, but to help damaged trees. As in Côte d'Ivoire, the strategy was to save the trees and hence the farmers' capital.

Otherwise, can the cocoa-fertilizer story in Côte d'Ivoire teach something about the impact of the monetary depreciation and strong fertilizer price increases in Sulawesi? Conversely, can Côte d'Ivoire learn from the earlier and more important adoption of fertilizers in Sulawesi?

In Côte d'Ivoire, despite a very slow increase in the price of cocoa after the devaluation in 1994 and an immediate doubling of input prices, the consumption of inputs was maintained and even resumed immediately. This seems to be explained partly by the high returns of the innovation and partly by the relatively low fertilizer expenses compared with total labor, which still represented more than 80 percent of production costs. Is it the same encouraging scenario for Sulawesi? From 1997 through mid-1998, despite the negative impact of the 1997 drought on yields, Sulawesi farmers had to reduce the fertilizer consumption. In most cases, the drop from some 500 to 600 kg per hectare per year to something between 300 to 350 kg seems sufficient to maintain the trees but not the yields under a background of CPB infestation.

Finally, in 2002, we estimate that some 50 percent of Côte d'Ivoire cocoa farmers and 95 percent of Sulawesi cocoa farmers share the same conviction about the absolute necessity of fertilizers in cocoa farming. Compared with the historical situation in the cocoa world, which used no fertilizer at all until the 1980s, this is a technical revolution, possibly a green one.

In addition, the financial and ecological crisis was an opportunity for some Sulawesi farmers to look for substitutes to manufactured fertilizer such as chicken manure. This may announce also a spontaneous evolution in cocoa farming toward a diversification of fertilization methods, including organic ones.

High Yields in Sulawesi: Price and Nonprice Factors

High yields in Sulawesi, before the outbreak of the CPB and to a certain extent since, are undoubtedly the result of price and nonprice factors combined. Some of these determinants are purely ecological, related to the forest and plains rents (chapter 15). Others are market and price factors such as a free marketing channel. Historical, cultural, and institutional factors, especially the rules of land tenure influenced by forest land policies, also play a role. They are listed and assessed here. The important question from the cocoa smallholder's point of view is how many kilograms of cocoa he must sell to buy 1 hectare of land, 1 liter of herbicide, or 1 kilogram of rice. The comparison between Sulawesi and Côte d'Ivoire is quite illustrative (see table 17.1).

Ecological Determinants

FAVORABLE SOIL AND RAINFALL CONDITIONS. Intensive systems with high yields are enhanced by more favorable soil and rainfall conditions in Sulawesi than in Côte d'Ivoire. The absence of a true dry season enables a better distribution of harvests within the year, hence higher yields. In Sulawesi, even if the upland soils are less favorable than the lowland alluvial land and even if production is more concentrated than on the plains, the soil and climate combination seems more suited to high cocoa yields than it does in Côte d'Ivoire.

FOREST AND NEW CROP RENTS. Forest rent and new crop rent and the youth of the plantations played a highly favorable role in Sulawesi until the late 1990s. Then the region began to be affected by drought and pests. The effects of the drought and pests strengthened every year from 1997 to 2002. Average yields on the island declined. In other words, cocoa farmers started to lose the benefits of the forest rent at a regional level. Until 1997, however, the combination of these forest-new crop and soil-climate rents contributed to high yields and hence an income effect that enhanced the purchase of inputs.

Harvest Frequency

A pace of 18 to 24 harvests per year in Sulawesi instead of the 5 to 8 common in Côte d'Ivoire is partially a consequence of a more favorable climate pattern, with a less pronounced dry season in the cocoa areas of Sulawesi. More frequent harvests are also the consequence of quite different smallholder practices and strategies. In Côte d'Ivoire, even during the peak season, the most frequent strategy is to harvest only once a month. The main idea is to collect as many pods as possible in any one harvest and thus maximize labor productivity. However, this optimization of labor is achieved at a price. Delaying harvests results in a high rate of overripe and rotten pods on the trees. At least some years, Côte d'Ivoire farmers may lose up to 20 percent of their yields.[1]

In contrast, during the two peak seasons in Sulawesi, the usual strategy is to harvest as frequently and as early as possible, at least twice a week; very rarely do pods get overripe. By harvesting frequently, farmers certainly maximize their yields and returns per hectare, but Sulawesi farmers also think that they optimize their labor returns (see Chapter 14, pages 185–86). How do two contrasting sets of practices achieve the same objective?

In addition to its direct impact on production profile within a year, rainfall also influences farmer decisions through risk at the drying stage. In Sulawesi the risk of unexpected rain that may damage the cocoa is high; the practice of drying smaller amounts of beans at any one time thus reduces the risk of losing a harvest to dampness. In addition, Sulawesi farmers complain more than their Ivorian colleagues about rat infestation and attacks. Smaller harvests also minimize those risks.

Another reason for these opposite strategies may lie in the institutional background of cocoa supply in the two countries. In Sulawesi the average farm size is still below 3 hectares of cocoa with a per-hectare yield of 1,000–2,500 kilograms before 1997 and of 700–2,000 kilograms in 2001. Most Sulawesi cocoa farms rely on family labor complemented by daily contracts. In Côte d'Ivoire, although the statistical average is 4–5 hectares, the median is close to 6–7 hectares. A high number of migrants do own 6 or 7 hectares or more, with a per-hectare yield of 400–1,000 kilograms and greater reliance on sharecroppers compared with Sulawesi.

This comparison of large farms with middle yields and smaller farms with younger trees and higher yields certainly accounts for a different strategy of optimizing labor productivity. The larger farms in Côte d'Ivoire have fewer pods per tree, trees that are not in line (hence a higher risk of overlooking mature pods on trees), aging trees that have grown tall with pods that are difficult to harvest, and eventually a higher dependency on nonfamily labor. It thus makes sense for farmers to reduce the frequency of harvesting. In Sulawesi, with smaller farms, more productive trees that are easier to harvest, and family labor, it makes sense to keep the pace of harvests as high as 18 to 24 a year. However, along with the farm aging process and relative decline in yields, one may expect a less intensive pace of harvests in the mid-2000s.

Market and Price Factors

FACTORS OF HIGH INCOME. In Sulawesi smallholders' quest for high yields is enhanced by a market in which competition is almost perfect and by the Indonesian government's hands-off policy toward cocoa. This generates relatively high cocoa prices paid to growers, hence an income effect and high purchasing power, especially for inputs. A high cocoa price means that a high yield per hectare maximizes labor returns.

High land prices. Despite the high purchasing power of cocoa, the high price of land in Sulawesi limits the capacity of migrants to invest in land and thus encourages the concentration of family labor on a small farms. In 1988, only a few years after the beginning of the Sulawesi cocoa boom, migrants already needed to sell a minimum of 300 kilograms of cocoa to buy 1 hectare of land in the hills and 600 kilograms to buy 1 hectare on the plains.

In Côte d'Ivoire, land had long been extremely cheap. In the 1970s a hectare of forest could be acquired for approximately 20 kilograms of cocoa. From 1985 to 1988 in the region of Grand Bereby at the edge of the last protected large forest in the country, a hectare could be bought for some 60 kilograms of cocoa. For 80 years inexpensive land encouraged large landholdings and medium yields.

By 1997, as forest was disappearing in Côte d'Ivoire, the price of land expressed in kilograms of cocoa was beginning to resemble that in the Sulawesi uplands. However, despite the higher price of cocoa in Indonesia, the purchase of alluvial land in Sulawesi still requires 2.5 to 3 times more cocoa than any land in Côte d'Ivoire.

Low input prices. At least until the 1998 monetary crisis in Indonesia, the price of inputs in Sulawesi, compared with the price of such goods in Africa, was exceptionally low and a major factor in the rapid adoption of inputs. Table 17.1 even plays down the advantage of Sulawesi producers, who rarely use NPK. Farmers mainly buy nitrogen, KCL, and TSP, which means that the average amount of cocoa needed to buy a 50-kilogram bag of fertilizer is only 6 kilograms. In Côte d'Ivoire, at best, the relative price of fertilizer is still four times as high.

Oil rent accounts for the low price of urea made in Southern Sumatra. Among other explanatory factors, Sulawesi smallholders have benefited for 20 years from subsidies for paddy inputs, especially fertilizer. Part of these subsidies were diverted to cocoa by Sulawesi farmers. This was an indirect, unexpected effect of the food security policy and of the Green Revolution in rice.

In 1997 the herbicide Gramoxon was three or four times more expensive in Côte d'Ivoire than in Sulawesi. In 2002 it was still two to three times more expensive. Another example is the removal of royalties on the active substance in Roundup, which had a much more rapid effect on the price of herbicides in Sulawesi than in Côte d'Ivoire. The price effect appeared faster in Sulawesi than in Cote d'Ivoire probably because of more competition among the distribution network. No wonder Roundup is hardly used by cocoa smallholders in Côte d'Ivoire.

Low price of tools in Sulawesi. Sulawesi smallholders also did not need to pay as much as Ivorians did for tools. First, a Sulawesi farmer needs to sell only 33 kilograms of cocoa to buy a hand sprayer, compared with 200 kilograms of cocoa in Côte d'Ivoire. More important, Sulawesi smallholders hardly ever use the extremely costly sprayers that are in high demand in Côte d'Ivoire. Why? The prevalence of mirids in West Africa may account for the need for a powerful machine to control these insects.[2] However, Côte d'Ivoire farmers also need these powerful sprayers because they have a relatively large area per family, prune their trees much less, and have fewer pods on the trees. In Sulawesi, smaller areas and much better maintenance of the trees enables farmers to control pests fairly well with a simple hand sprayer.

Modernization and motorization do not necessarily support intensification. They may accompany relatively low yields and extensive farming systems.

Lower labor costs. In chapter 15 we said that labor costs expressed in U.S. dollars were relatively high in Sulawesi and offered no real advantage over Côte d'Ivoire, at least until the financial crisis of late 1997. In chapter 14 we mentioned a 40 percent increase in daily labor cost and at least a 40 percent increase of the cash component of the daily salary in early 2002. However, because of the relatively high producer price of cocoa in Sulawesi, labor costs expressed in kilograms of cocoa are slightly lower there than in Côte d'Ivoire. In April 2002 the increase in daily labor salary turned out to be a simple adjustment to the recent rise of the cocoa price. This relatively low labor cost expressed in kilograms of cocoa encourages higher maintenance and higher yields, at least up to the threshold that maximizes labor returns.

Devaluation. Devaluation favors industries that have dollar incomes, but a large part of their costs (especially labor) are paid in the local currency. A free market and strong competition within the marketing channels guarantee that devaluation will have a large positive effect on the current price paid to producers, at least in the short term. The September 1986 devaluation in Indonesia had positive price and income effects that enabled input adoption and fueled the Sulawesi cocoa boom. Hence the devaluation of 1998 raises the high probability of a new cocoa boom in Central Sulawesi in the 2000s.

In Côte d'Ivoire, most inputs are imported and their prices nearly doubled after the devaluation of January 1994. Yet the apparent increase in the nominal price of cocoa until 1998–99 also played a role in the recent surge of pesticide and fertilizer adoption. This is further evidence that, up to a certain threshold, producers are more influenced by nominal prices and income and less by the constant prices often used by economists.

Technology Transfers

Bugis smallholders in the uplands of Sulawesi benefited from technical and financial impacts of their contacts with Malaysian estates and from the Green Revolution in the Sulawesi lowlands. Uplands farmers benefited from technology transfer (including the adoption of herbicide) from Malaysian estates and from saved income transferred from the lowlands (rice income increased by the Green Revolution).

Nevertheless, the example of herbicides suggests that Bugis families participated spontaneously in the establishment of the Green Revolution in the rice fields by contributing their share of technology transfer. A more in-depth survey might well bring some surprises about the local development of the Green Revolution in paddy fields.

Last but not least, the initial capital or savings of Sulawesi migrants—derived from the Green Revolution in the lowlands, clove and tobacco farms, and possibly from salaries at Malaysian estates—provided greater input purchasing power than most migrants in Côte d'Ivoire enjoyed.

Land and Forest Policies

Opposite policies led to different relative prices of forest and nonforest land. In Sulawesi uncertainties about forest land tenure lower the price of forests, but also account for the high price of cleared land. In addition, forest policies have an indirect impact on the way farmers can optimize forest rent. In Sulawesi, uncertainties about forest ownership encourage some well-connected farmers and civil servants to clear the forest and then sell it to new migrants. The latter do not dare to buy forest and prefer to buy cleared land. Thus, the time that elapses between clearing a forest and planting cocoa enhances weed growth. The situation is different in Côte d'Ivoire, where ease of access to forests for migrants favors planting immediately after felling or burning, or both. This makes a substantial contribution to the economic effectiveness of the relatively extensive cocoa model in Côte d'Ivoire. In Sulawesi the extensive model is less possible, less attractive, and less frequent.

Purchasing Power of Cocoa

The terms of exchange between a kilogram of cocoa and a kilogram of rice in Sulawesi and Côte d'Ivoire are more favorable to the Sulawesi cocoa producer. This is partially explained by the abundance of rice in a region known for its Green Revolution success. However, this higher purchasing power of cocoa in Sulawesi applies to almost all goods and services, including trips to Mecca, one of the requirements of the Islamic faith. Compared with Côte d'Ivoire, a Sulawesi farmer needs half as much cocoa to take this trip.

Other Combined Factors

The combination of basic ecological factors (favorable soil and rainfall), biological and ecological factors related to the pioneer phase (forest and new crop rents and the youth of the plantations), social and human factors related to the pioneer phase (the youth of the migrants and hence of the labor force), and price and market factors make an ideal environment for large consumption of inputs and high yields.

The Sulawesi experience suggests a hypothesis that deserves to be tested in West Africa—the liberalization of a market is more effective in a pioneer situation than with aging plantations and populations.

Determining Input Prices

The basic explanation for high yields in Sulawesi is the structure of comparative prices of land, labor, and inputs, and its dynamics over the years and decades. Sulawesi is marked by high land prices and low input prices. This comparative price structure, however, is affected by many factors other than land and input prices. It is the result of a complex interaction of market, ecological, and social environment factors. The best example is the formation of land prices.

Why Are Land Prices High?

Except for two or three years at the very beginning of the cocoa boom, the average price of land in Sulawesi has been much higher than in Côte d'Ivoire. At least before the monetary crisis, the per-hectare price of land was about $400 in the hills and $1,000 on the plains, in comparison with less than $200 in Côte d'Ivoire. This is the result of:

- *Markets.* A free market and strong demand ensures high prices for marketed products. Whatever the agricultural product, from kiwi in New Zealand to wine in southern France, low prices tend to deflate the cost of land while high prices inflate it. In addition, high producer incomes in Indonesia encourage traders to invest in cocoa farms, thus increasing the demand for land.
- *Anticipation of return.* Despite the costly investment, farmers' anticipation of high yields and high incomes makes new migrants willing to invest in land.
- *Policies.* Ambiguous forest land policies play a role. One consequence is an increase in the value of fallows.
- *Marketing.* Cultural and historical factors enable Bugis to control internal marketing and thus ease the investment of trade incomes in cocoa farms. The demand for established cocoa farms by traders clearly increases the price of land.
- *Demand for land.* A high price for land in one area may increase the price for land in another. The high price of land in the lowlands clearly increased prices per hectare in the uplands. Demand for land also increases its price. A story about tourism illustrates this point. When an international hotel was built in their home village of Bali, some Balinese transmigrants in the village of Lewonu received compensation of about Rp 200 million for each migrant in 1996 (around $80,000). They immediately reinvested the money in land in Lewonu.

> The sudden demand for cocoa farms increased the price per hectare to Rp 25 million, at least Rp 5 million above the local market price. A few Bugis farmers sold their cocoa farms to benefit from the windfall.

From High Land Prices to High Yields

Most factors accounting for high land prices also explain high yields. As mentioned above, this is not by chance. The high price of land stimulates high yields to gain a return on the investment as rapidly as possible.

More important, high land prices prevent migrants from buying large areas. They need time to recover after an investment of $400–1,000 per hectare. Once they have rebuilt a capacity in cash and investments, many other migrants have arrived, land has become scarce, and prices have risen. This is the main reason why most farmers own less than 3 hectares of cocoa, at least in the same region.

The situation observed in Bungku, Central Sulawesi, in 1997 illustrates this point. This region had been almost uninhabited two decades earlier. The few residents were rare indigenous and some migrants who had come in the 1950s and 1960s. In the 1980s transmigration schemes developed rapidly, and in the 1990s oil palm estates took over a large piece of land near the new roads. "Unlimited" forest land was still available, however, in the hills and mountains. The consequence of this environmental and historical background is that indigenous people are unable to control land. In 1996 and 1997 new migrants could still get land for less than $100 a hectare. Under these conditions, a number of migrants could afford to buy much more than 2 or 3 hectares. In Central Sulawesi, migrants with some capital buy a 50-hectare forest and either keep it in reserve and sell it later at a substantial profit, or put it under a *bagi tanah* contract and thus get 25 hectares of cocoa almost free.

This situation contrasts with that in the 1980s in South Sulawesi. The acceleration observed in Bungku partially results from the accumulator effect. Migrants there who had already experienced the profit of a small cocoa farm a few years earlier in another region had everything they needed to multiply their investment—information, planting materials, and capital. Migrants to South Sulawesi in the 1980s did not have these things. In addition, prices were much lower in this pioneer region compared with the inflated prices in the established cocoa region. This is typically the situation in most cocoa histories—that of Côte d'Ivoire in particular. In short, at least for a few years, the Bungku region of the late 1990s and early 2000s should look very much like southwest Côte d'Ivoire in the 1970s—cheap land for enthusiastic migrants who already have experience in cocoa and some savings from their cocoa incomes. It will favor larger farms at least for a few years, and then the price of land should increase with the high price of cocoa in 1997 and 1998.

Green Revolution in the Sulawesi Uplands?

Despite the high uncertainty over the precise sustainability of the cocoa system under intensive monoculture with substantial use of inputs, might it be possible to conclude that a Green Revolution occurs in the uplands when tree crops and chemicals are perfectly combined? Does this apply to cocoa in Sulawesi?

Criteria for a Green Revolution

In discussing the definition and criteria for a Green Revolution, Griffon (1995/97, p. 7-9) said there had to be four main changes:

- *The entire transformation of a farming system*, including adoption of new varieties and planting material, increased sowing density, and mechanization.
- *Voluntary policies on infrastructure,* including increase of irrigated blocks, development of electricity networks that lower water pumping costs, and development of roads and transportation that ease access to inputs and marketing.
- *Voluntary policies about the overall environment of farming systems,* including the state marketing network, which is not monopolistic but is used to regulate marketing and prices, both for farmers and consumers; special facilities for extension services; and price policies, stocks, credit, and subsidies to inputs to reduce risks.
- *A context of sustained population growth,* guaranteeing a market for staple food producers.

In our context, we propose that a Green Revolution involves:

- an invention (new variety, new planting material)
- introduction of capital in the farming system
- voluntary policies and heavy funding to encourage these changes and innovations, both in agriculture and its environment
- a recognition that innovations may come from farmers themselves

This combination should lead to higher producer income and much higher productivity per unit of land, and perhaps more important, per unit of labor. The Green Revolution in paddy pushed millions of Asians out of the paddy fields and sometimes out of agriculture. At the same time, industry and services that could absorb that labor were developing rapidly in Asia. Thus the Green Revolution in Asia was more beneficial than limiting. However, Green Revolutions have their limitations.

Limits of a Green Revolution

According to Griffon, the main limits encountered by the Green Revolution, especially in paddy and maize, are:

- *New ceiling on yields for several reasons,* including salinization, increase in fertilizer prices, and increase in water pumping costs.
- *Externalities such as pollution of groundwater and rivers by input residues.* In Indonesia, an additional externality is the deforestation agent, especially through transmigration schemes. Thousands of hectares of forest have been turned into irrigated or semi-irrigated paddy fields.

In short, in the 1990s there was increasing evidence of lack of sustainability in these Green Revolutions. These doubts were leading to new lines of research on a double Green Revolution that would combine high yields *and* sustainability (Griffon and Weber 1998). Especially from the angle of the 1997–98 crisis, one can also stress the potential constraints on job and wealth distribution as a component of lack of sustainability. How do these criteria and limits apply to tree crops in uplands?

Adoption of Cocoa: A Stage in the Green Revolution in the Sulawesi Uplands?

Transformation of a farming system. Even if the fertile valleys of Ladongi and their pre-CPB yields of nearly 3,000 kilograms per hectare are classified as lowland, the figures for Sambalameto and other villages make cocoa farming close to a Green Revolution in the uplands of Sulawesi. In 1997 a family with a 2–2.5 hectare farm in the hills produced a total of 4,000 kilograms of cocoa, for a gross return of Rp 10 million–12 million. Even if Rp 2 million is deducted to allow for 500 kilograms per hectare of fertilizer and the use of various pesticides and herbicides, together with a little day labor, the figure was still Rp 8 million–10 million, a net income of $3,500–$4,500.

Before they migrated and adopted cocoa, many of these families of five or six people had hardly 1 hectare of maize in their home region and earned less than $300 a year from poor yields. One can understand why so many of these families opted first for "all cocoa" and second for "full sunlight" and intensive monoculture.

To a certain extent, there was a dramatic change in planting material since these farmers switched from annual crops to tree crops. In terms of cocoa varieties, there has been no recent decisive progress in plant material, although early innovators in Sulawesi used a mixture of Amelonado and Upper Amazons and possibly hybrids. This planting material was brought back from Malaysia through an uprising network in the late 1950s. Later on, by using that planting material, farmers eventually produced hybrids somewhat unintentionally. This plant material proved to be quite sufficient to achieve spectacular yields.

In addition, there has been invention or reinvention of an almost full-sun monoculture system (which was generally not recommended by extension services).

Fertilizer, pesticides, and herbicides have been broadly adopted in Sulawesi to maintain plantations. In 1998 fertilizer and pesticides helped to save trees from the drought and maintain relatively high yields. Herbicides still help to reduce the number of days of labor per metric ton of cocoa produced. They increase land productivity, and above all labor productivity. Herbicides are becoming essential in the grassland clearing phase and during investment in immature plantations. This input is significant as a stage in the Green Revolution and part of the extension of farm areas and hence accumulation.

Sulawesi farmers have rapidly learned how to prune trees, keeping them at a reasonable height, which makes harvesting easier. More important, the choice of an almost zero-shade system slows the growth of the tree. In contrast, a heavy shade system triggers rapid growth of the cocoa tree as it competes with shade trees for light. This makes harvesting and pruning more time consuming. Harvesting is more expensive because a cocoa tree that has grown rapidly seems to bear more pods in the crown and fewer on the trunk. In Sulawesi tree trunks of zero-shade cocoa farms are covered by pods during the peak seasons. This brings economies of scale during harvest.

We clearly see the stimulating effect of a crop with a substantial return to labor that uses inputs that make it possible to maximize the net profit over a full year in a free market with strong competition. But there are also limits. The 1997 drought and its differential impact on various farming systems, with shade and without shade, seemed to remind farmers that they should be a little bit more cautious with zero-shade systems when soils are stony. This drought, however, was also an opportunity to trigger and enhance upland farmer initiatives in water pumping and temporary irrigation. This experience will serve in the future and bring more capital into the system. In short, some doubts remain about the sustainability of the system, but the same doubts apply just as much to the classic Green Revolution in rice or maize.

VOLUNTARY POLICIES ON INFRASTRUCTURE AND SUBSIDIZED FERTILIZER. In terms of infrastructure, even if roads were planned more for mining and transmigration (and thus for the paddy self-sufficiency objective), Sulawesi cocoa benefited in the late 1990s from state-funded infrastructure.

Although the help was unintentional, Sulawesi cocoa farmers greatly benefited from fertilizer subsidies for rice that lasted until the mid- to late 1990s. Farmers simply diverted the subsidies by using the fertilizer for cocoa.

VOLUNTARY POLICIES ABOUT THE OVERALL ENVIRONMENT OF FARMING SYSTEMS. The only major criterion that possibly does not fit the concept of the Green Revolution seems to be marketing, price, and extension service policies.

There are no government institutions involved in cocoa marketing and price regulation, but in most cases this is the best situation for an export-oriented crop. A free market guarantees better access to the world's chocolate eaters, whose numbers continued to grow in the 1990s. The 1997–98 crisis and the sudden devaluation of the rupiah also proved that a free market, with almost perfect competition in the marketing chain, offers good price sustainability and is probably much safer than any regulated price system. Extension services involved in tree crops have played only a limited role in the Sulawesi cocoa boom, but farmers benefited from transfer of know-how from Malaysian estates and to a lesser degree from the Green Revolution in paddy rice.

Conclusion

At this stage, despite ecological changes (such as CPB outbreaks) and yield declines, it can be concluded that a cocoa-generated Green Revolution took place in the uplands of Sulawesi. Before the CPB outbreak, that is to say, before the loss of large components of the forest rent, one observed an extraordinary increase in returns per hectare and returns to labor, as well as a substantial increase in the amount of capital in the system in the form of inputs in a free market context. Since the CPB explosion, farmers have shown that they are ready to invest and save their patrimony. They of course have hesitations and doubts, but they are resisting the dire ecological change threatened by the CPB outbreak, particularly in comparison with previous situations in world cocoa history. This is widely due to the possibility of using fertilizers plus a few pesticides and herbicides.

This kind of Green Revolution in the uplands might be little known or little recognized because it does not come from government policies and declared objectives. Innovations are rather the result of spontaneous actions by smallholders able to combine endogenous and exogenous know-how and inputs with little state interference.

To a considerable extent, this principle may apply to a number of other tree-crop farming systems, including jungle rubber systems and other highly complex agroforestry systems such as the Damar forests developed over decades by smallholder families (chapters 1 and 12; Gouyon, De Forest, and Levang 1993; Michon, De Forest, and Levang 1995). In their typical form, the sustainability of these agroforestry systems through a long life cycle and relatively easy replanting is guaranteed by the diversity of tree capital. However, these systems still lack the high yields that are dependent on monetary capital in the form of chemicals and improved planting materials. This is precisely what the rubber agroforestry system experiments are trying to do (chapter 12). How can a combination of biological and monetary capital be optimized and a double Green Revolution be achieved?

The same ideas apply to coffee farming systems. Cases of diverting fertilizer subsidies from paddy to coffee groves have also been observed (Hefner 1990). Southern Sumatra is full of innovative coffee replanting schemes invented by smallholders (chapter 16). More generally several countries such as Colombia and Costa Rica, some parts of Brazil, and more recently Vietnam have developed intensive models with high yields and significant gains in labor productivity. These gains helped to resist price slumps in the early 1990s. For example, in Costa Rica, modernization of the farming system relies on adoption of miniature varieties of coffee trees, increased density of trees per hectare, high quality pruning, and fertilizer (Daviron and Fousse, 1993; Daviron and Losch, 1997). This description is quite similar to what Bugis farmers have done with cocoa in Sulawesi and sounds very much like a Green Revolution.

The examples of coffee in Costa Rica and Vietnam, and the more detailed comparison of cocoa in Indonesia and Côte d'Ivoire, show that a basic tree crop, possibly intercropped with another tree or trees and combined with fertilizer, pesticides, and herbicides, remains the key option toward a rather spontaneous Green Revolutions in the uplands. The trend seems universal.

Innovation Process

As mentioned in chapter 9, the experiences in Sulawesi and Côte d'Ivoire confirm that annual crops may also add sustainability to a tree-based farming system, especially through their role in replanting and funding inputs to be devoted to tree crops.

The Ivorian reference also reminds us that innovations in terms of intensification are encouraged by price increases but often triggered by nonprice constraints to be solved—a shortage of land, forest, or rich soils, and the need to keep the tree capital alive. Under these constraints, a price slump may also shore up an innovation. Farmers have to be creative. However, a very low price must not last for too long; otherwise farmers stop anticipating higher prices and lose faith in the crop.

Another conclusion also brings us back to Schumpeter. The driving force of innovation remains the producer (Dulcire 1993/95). This has been demonstrated with the first cocoa adopters in Sulawesi and Kalimantan. They verified the information by traveling to Malaysia, smuggling the plant material back to their country, planting it, and even becoming middlemen in order to bring cocoa to ports before more professional traders were attracted by profits and took over the business (chapter 7; Ruf 1994). The same principle applies to fertilizer adoption in Côte d'Ivoire. The very first fertilizer adopters made their own trials and organized themselves as fertilizer buyers before more professional traders took over.

One finds a certain positive impact of smuggling once again. Smuggling proved to be useful—for cocoa flows between Kalimantan and Sabah, and herbicide and pesticide flows from Sabah to Sulawesi and Kalimantan. Smuggling brought knowledge about products and business to both farmers and traders. To a certain extent, the same applied to smuggling pesticides and sprayers from Ghana to Côte d'Ivoire.

Fertilizers versus Tree-Crop Shifting Cultivation

The great example in the Ivorian experience—rather limited to the Soubré region until 2000–01, but rapidly taking over the whole cocoa area of the country since 2002—is the key role that fertilizers can play in tree-crop sustainability and to a certain extent in forest protection. Although this aspect should not be overidealized, the Soubré case shows an original process. Migrant farmers who were used to switching from one forest region to another and to implementing tree-crop shifting cultivation suddenly changed their view owing to a simple input: fertilizers. Of course, they did not adopt fertilizers to save forests. They did so to save cocoa farms in danger of dying. However, the unexpected consequence was a growing awareness that forest is not necessarily an unavoidable production factor. Fertilizers and other inputs may help to build new upland systems that are much less forest-consuming.

Whatever the prices, one of the common findings in both the uplands of Sulawesi and Côte d'Ivoire is that fertilizer is often adopted to save tree capital, not only to optimize short-term yields and returns. Under certain conditions, if much forest has already gone, fertilizers and other inputs can help to save what remains of the forest locally.

Notes

1. They also lose in bean quality. The seemingly increasing rate of free fat acidity (FFA) in Côte d'Ivoire is certainly related to the high rate of overripe and rotten pods that are not entirely excluded from postharvest operations.

2. Mirids are insects that sting the cocoa leaves, leading to a drying process and mortality of entire branches, and even the entire tree if the attacks are severe and repeated.

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Conclusion: Technical Breakthroughs and Upland Farmers' Self-Help Action

François Ruf and Frederic Lançon

This study covered about 40 locations that represent a wide range of Indonesia's upland economies and agriculture. These detailed case studies produced several important lessons, many with significant implications for public policy.

Perhaps the most important finding is that real innovations and proven development advances often owe more to smallholders and traders than to official projects. This finding is not a surprise, but it confirms the hypothesis that the extent of upland development may be underestimated and overlooked because it is often generated from the grassroots.

Another conclusion is that proved cases of innovations often arise from unpredictable circumstances that are thus difficult to anticipate in terms of policies. Policies and projects may well have a positive impact, but in many cases the innovations derive from a combination of farmers' initiatives, unexpected events, and the results of transformed policy objectives

For example, smallholders in South Sulawesi may have adopted hybrid coconuts promoted by official projects in the 1970s more for land rights reasons than for the coconuts themselves. Nevertheless, a few years later, when cocoa prices made it an attractive crop, these coconut farms eased cocoa adoption by providing cleared and free land ready for cocoa interplanting. A state effort to promote fertilizers on coconut farms failed. But once cocoa arrived, farmers spontaneously adopted fertilizers on the newly formed cocoa-coconut farms and enjoyed the subsidies that were conceived at the state level to promote fertilizers for use in paddy, not tree crops. Although they did not initiate this simple and modern form of agroforestry led by cocoa revenues and consolidated by fertilizers, extension services and policymakers involuntarily helped to build it and eventually supported it by changing their policy objectives.

This coconut-cocoa story is a perfect showcase of the positive effect of an unexpected development since pure hybrid coconut monocropping would have been a failure in South Sulawesi. This tree-crop story also illustrates an important conclusion about these innovations arising out of unexpected developments. The interaction of trees and a reasonable amount of modern inputs such as fertilizers and herbicides represents the main hope for the modernization and immediate future of upland agriculture.

Main Innovations in the Indonesian Islands

From a technical point of view, the range of agricultural innovations the study teams found in the Indonesian uplands can be divided into three categories:

- Innovations that improve natural resource management
- Innovations that intensify agricultural production
- Innovations that introduce or develop a crop

As in all attempts at classification, clear distinctions are elusive. A number of innovations cover two or even all three categories. Moreover, farmers are very good at changing the initial objective of exogenous innovations. These categories simply facilitate our analysis.

Natural Resource Management

Terraces and related technologies such as hedgerows are the main technologies in this category of innovations. They control soil erosion, one of the most negative effects attributed to upland farming practices under land pressure. This innovation is generally combined with fodder trees such as *Leucaena leucocephala* (locally named *lamtoro*) or *Gliricidia sepium* (usually called *gamal*) and fodder grasses. Large areas of hilly and mountainous landscape have been converted into terraces in many locations in Nusa Tenggara Timur, Java Timur, Java Tengah, and Yogyakarta provinces (chapter 4).

Some of these innovations are far from new. Some, such as terracing itself, and stone terrace walls, were launched decades ago, often on a self-generated basis, before the agricultural extension services became active (Nibbering 1997, 175). Some, such as *Gliricidia* hedges, may be more recent, but most are a combination of long-standing and new ideas and reflect a long process of attempts, successes, and failures. The maintenance level and labor intensity of these terracing technologies vary from place to place according to the history and dynamism of the farming system. Neglected terraces, for example, are very often rehabilitated when new opportunities arise.

On-farm reservoirs have been recently developed at several project sites in Yogyakarta province, as well as through a provincial government program in Java Tengah. The aim is to provide sufficient water in upland farming systems that must cope with a dry season. The adoption rate varies according to the location; in both provinces, however, several individual farmers or farmer groups had already dug their own reservoirs before the official projects were started (chapters 3 and 5).

Intensifying Agricultural Production

Multipurpose trees and grasses help to limit erosion and regenerate soil fertility; hence they play a potential role in intensifying agricultural production. Trees and grass hedges are often, but not always, combined with land management techniques. Even though they are a component of soil erosion control, it is important to underline their links to agricultural production per se. They represent a significant source of fuel wood, particularly in remote areas of Flores and Lombok where forest wood resources are scarce (chapters 2 and 8). These trees also contribute to soil fertility when their leaves are incorporated into the soil, and protect against excess heat as well as strong rains and wind (chapter 16). They are also increasingly used as one of the tools to slow weed growth and thus to facilitate planting tree crops on grassland (chapter 15). Another major objective in planting these fast-growing trees and grasses may be to increase fodder production within the farm to support livestock production (chapters 2 and 4).

Adoption and planting of these fodder trees and grasses is partially related to the dynamism of the livestock component in the farming systems. Farmers often point out that labor availability for collecting grasses and leaves is a greater constraint than fodder resources. The rapid development of local markets for grass and other crop residues used for feed is also interesting.

At the country level, however, one of the main factors in adoption of *lamtoro*—and more importantly *gamal*—is farmer awareness of needing these trees to control weeds, especially *alang alang,* and sometimes to reduce erosion. Farmers use these fodder trees as shade trees to control *alang alang* and regenerate soils when starting to replant coffee or cocoa, which is an important strategy for improving the sustainability of a number of farming systems. In several regions such as Southern Sumatra and Sulawesi, farmers spontaneously switched from *lamtoro* to *gamal* when the former was attacked by pests, clear evidence of their understanding of the benefits these trees provide.

Artificial insemination has been introduced in several upland areas. Farmers seem to use this technique frequently to regulate the calving rate (chapter 2).

Changes in technical inputs can also increase agricultural production. The team noted several examples of the adoption of new planting materials by upland farmers. These new planting material, either hybrids or clones, usually increase the yields per hectare without significant increase in labor. Examples include the wide dissemination of rubber clones in Sumatra and Kalimantan and improved local maize varieties in Java Timur, the use of hybrid cocoa in Sulawesi, the more limited adoption of arabusta coffee trees, and adoption of new varieties of potato in upper slope areas in Java. Considering the high variability of agriculture and economies in the uplands, dissemination of new varieties will not play the same role as it did for lowland rice farming systems.

Upland farmers are also keen to invest in fertilizer and other chemicals provided that crop sales offer a sufficient return. This is particularly true for some crops such as vegetables, for which farmers can invest several million rupiah per hectare, but the use of inputs is also increasing for other crops (chapter 5). In Sulawesi, for example, fertilizer use for cocoa proves to be spectacular, with an average 500 kilograms per hectare and yields above 1,500 kilograms of cocoa beans per hectare, at least before the pod borer outbreak (chapters 13 and 14). The extensive use of cheap and abundant chicken manure from poultry industries in Java Timur and the outer islands such as Sulawesi is another illustration of the willingness of upland farmers to improve their cultural practices as long as it is economically viable.

Herbicides appear to have been adopted later than fertilizers and pesticides. Once farmers learn how to select and apply herbicides properly, with no residual effects, herbicides will be among the major tools of agricultural change in the uplands. Herbicides, possibly in combination with *Gliricidia* and other shade trees, have shown potential promise as a major factor in tree-crop replanting and recolonization of the *Imperata* uplands (chapters 11 and 15). A spontaneous Green Revolution may well have occurred in a number of Indonesian upland regions, even though the effects are still widely underestimated.

The combination of chicken manure with chemical fertilizers, along with the combination of herbicides and *Gliricidia* trees to control *alang alang,* may even be signs of a spontaneous "double Green Revolution" toward more sustainability (Griffon 1995; chapter 17). The proven sustainability and relatively good productivity of *damar* agroforests reminds us that farmers invented commercial agroforestry several decades ago (chapter 1 and annex 1).[1] This type of agroforestry without modern inputs proved its sustainability over a century or so but not its capacity to adapt to a continuous decrease of land per family. There is need to modernize of this type of agroforestry strategy. The seemingly successful experiments with new rubber farming systems that combine valuable farmer know-how in agroforestry with modern clonal material is another example of how to intensify agricultural production without undermining sustainability.

Changes in Cropping Systems

Introducing new plants in farming systems is the most common type of innovation. This is not surprising, because upland farmers reduce risks either by diversifying their sources of income for a given period or by shifting from one crop to another according to changes in the agroeconomic environment. Various patterns can be identified in the introduction of new crops.

One pattern is gradual and limited introduction, where new plants remain a component of more complex systems. The introduction of vegetable production or various tree species, such as avocado, candlenut, and cashew, in dry upland areas close to main urban centers, illustrates this process (chapters 8 and 11). The new crop or tree is often grown by many farms but on a limited area.

Another pattern is rapid and massive introduction of one tree crop. Examples are the introduction of cocoa trees in most regions of Sulawesi (chapter 14) and to a lesser extent in Kalimantan (chapter 7), and the impressive development of orange orchards in the southern districts of Java Timur (chapter 11). New crops may rapidly become the core of the farming systems. This process is generally associated with the existence of "natural" rents or comparative advantages, such as secondary or primary forests available for clearing in the case of cocoa, or the high elevation sites on Javanese volcano slopes that lend themselves to apple production.

These types of innovations are not mutually exclusive and are often deliberately combined. One common combination, for example, is land management techniques, multipurpose trees, and livestock production; another is on-farm reservoirs for vegetable production during the dry season. Again, innovations sponsored by a governmental agency or a project are often adopted by smallholders in combination with other information or other objectives. The forestry department, for example, helped to promote cocoa and coffee in Sulawesi and cashew in Flores as soil protection crops. Farmers adopted the crops because of favorable markets.

Innovators in Uplands

One factor in adoption of innovations is how the innovation is actually transferred. The number of innovators involved in technology transfer to upland farmers is probably higher than in irrigated lowland settings, where projects and official channels are more established.

Traders

The team confirmed the prominent role played by traders, particularly Bugis traders and traders of Chinese descent, in the development of new crops in various locations. Middlemen have had a long-standing role in promoting rubber adoption throughout Sumatra. More recently, on a smaller scale in a few subdistricts, ginger was also relaunched by middlemen-exporters who benefited from information on Asian and Middle Eastern markets (chapter 6). There is also the striking example of a woman trader in Timor Tengah Selatan district in Nusa Tenggara Timur who established an orange tree nursery and adapted the planting material to local conditions (chapter 11). Traders are involved not only in marketing farm output, but also in supplying input and developing planting material.

Box 18.1. Making the Decision to Replant Tree Crops

The **farmer's objective** is to maintain or increase income and food security despite a land shortage. Farmers make replanting decisions when they need and anticipate higher income. Replanting should enable farmers to face a number of constraints.

Land shortage is the most important factor triggering a replanting decision.

Forest shortages (the dissolution of forest rent—lower fertility, more weeds, more pests, and so forth). When forest is no longer available, farmers must consider replanting as an option, including replanting after degraded fallows. Replanting may include changing tree crops (such as oil palm replacing rubber or cocoa) to ward off pests, diseases or weeds. This diversified replanting may be an ecologically determined process (see below).

Aging orchards with lower yields and increased maintenance and harvest costs, combined with land shortages, push farmers to try replanting.

Droughts and plantation fires or any climatic incident that destroys the tree-crop farm make it easier and more necessary to decide to replant since no immediate income is lost.

Food shortages may be overcome because replanting tree crops enables the farmer to liberate land for food crops.

A number of structural factors and opportunities may also hamper or accelerate replanting decisions and make the difference between failure and success.

Favorable ecology. Ecological constraints that do not look insurmountable at the pioneer stage may become critical at the replanting phase. For example, in Sulawesi until recent years, cocoa replanting did not appear as a problem on fertile alluvial plains, while much less favorable conditions in the hills clearly hampered replanting.

Market opportunity for intercropped food. Replanting liberates land for annual crops for at least one or two years, which may trigger the replanting decision. In addition, an appealing market opportunity, either domestic or export-oriented, as in the coffee-growing regions in southern Sumatra (cabbage, ginger, chile pepper), may accelerate the rate of replanting.

Opportunity to use new planting materials. Maintaining income can be greatly helped by using appropriate planting material-more productive and vigorous, able to adapt to exhausted soils, or resistant to new pests and diseases. Access to new planting materials helps make the decision to replant.

Diversification opportunity. A market for a new crop may be an opportunity to suppress an insect pest or disease problem at the replanting stage. In Brazil, for example, replacing cocoa with coffee may be a way to solve the Witches' broom disease at the replanting stage. In Côte d'Ivoire, replacing cocoa with rubber or oil palm lowers the cost of weed control because it is less costly to control weeds around 140 young oil palm trees than around 1,500 cocoa seedlings. A market for a new crop may be a way to overcome the disappearance of forest rent.

Box 18.1. ***continued***

Capital constraints. Replanting may be hampered by lack of capital, but access to capital may entirely solve the problem. Farmers who replant do not benefit either from forest rent or from cheap access to land. They need capital to replant. Local projects are a reasonable way to provide capital, which is probably one of the main reasons behind a number of successful of clonal rubber replanting schemes in Sumatra (Chapter 12).

Technical progress. Beyond introduction of new planting materials or a new crop, herbicides and fertilizer are essential for successful replanting and thus makes the decision easier.

Labor. After two or three decades of migration, land scarcity may reduce the migration rate. People are not as interested in migrating if it is difficult to obtain land. There may also be a labor shortage because children have been sent to school.

Family and tree life cycles. In the intersection between family life cycles and tree life cycles, older farmers may lack the labor to replant, while young men may not always have access to land. Replanting, therefore, may rely on the land market. Those who have enough labor and capital to replant also have the capital to buy old plantations. This is a frequent pattern in plantation economies.

Preservation strategies. The tree crop is the basis of the farming system and must be protected for the next generation. As long as forest land is available, this inheritance objective favors new planting. When forest and land become scarce, replanting one's own old farm or after buying an old tree farm is the only way to preserve an intended inheritance.

Cash value for trees. Cut trees may have a cash value, which is a means to convert tree capital and labor to cash, and a way to fund replanting. If forest becomes scarce, and if the farm is not too far from a road, the high quality firewood of coffee is a valuable asset that can be sold to neighboring farms and cities. Rubber and coconut may be used more and more as timber. One of the best showcases is oil palm in West Africa where palm wine is highly appreciated and marketed. Farmers can easily exploit palm wine during a couple of weeks and get enough cash to replant and buy something for the family. This is a model to explore and adapt to other tree crops, possibly through agroforestry systems (with a high potential in timber opportunities). Whatever the trees and countries, the strategy of generating cash by cutting down a tree crop is one of the key points for sustainable farming of tree crops in the future.

Location rent. Selling rubber logs, coffee firewood, or palm wine is easier if the farmer is close to a road. If a farmer wants to replant a coffee farm along with a ginger or cabbage intercrop, he must select a farm close to a point that can be reached by a truck.

box continued on next page

Box 18.1. *continued*

Price factors may directly trigger a replanting decision:

- **Comparative prices.** Farmers compare prices of the commodity produced by their tree crop to those of other tree crops and annual crops that can be intercropped. Unless they strongly anticipate higher prices for their commodity, they may make a replanting decision that is also a diversification decision.
- **Anticipated revenue.** When a price collapses, farmers anticipate more revenue for their commodity in the years to come and rightly consider that the time to replant has come. The lower the price, the less revenue they lose when they cut down part of their tree capital.

Price factors may indirectly trigger a replanting decision:

- A decline in a commodity's price usually pushes farmers to reduce the cost of maintenance and inputs devoted to the established trees, which in time leads to a decline in yield and income. This approach could even increase tree mortality, which would make the replanting decision easier because the owner would not need to give up short-term income. This would be similar to a drought or plantation fire.
- A decline in a commodity's price puts small farmers in difficulty but also reduces the price of land. An owner in urgent need of cash could sell an old farm to a richer farmer or to a new migrant who will have the labor and capital needed to cut down the trees and replant, thus benefiting from the price decline.

Property rights. Institutional factors, including property rights, affect replanting more than planting during a pioneer phase. When replanting time comes, smallholders have more to save and more to protect.

The success of cocoa in Sulawesi and East Kalimantan illustrates not only the role of Bugis traders, but also the evolution of some dynamic farmers who become collectors working for middlemen, and then middlemen themselves. Many commodity traders and suppliers live in the villages close to the farmers, and each successful promotion of a new product is a source of personal profit—it is no wonder that they are much more effective than extension workers.

Smugglers

In some cases, an innovation comes from smugglers who are basically defined as free-traders. They bring information and planting material and further inputs across borders (chapter 13).

Migrants

Traders, smugglers, and families moving from one place to another usually bring information and inputs to the newly colonized place. The case studies cite numerous examples, from vanilla to cocoa.

Estates

Estates are good innovators, especially if they are unwilling to transfer their technology. Prohibiting access to information is an excellent way to have it disseminated. In Southern Sumatra, Colonial coffee estates tried to stop their employees from taking seed out, but surrounding villages quickly adopted coffee from this source. Cocoa technology is another example. There is potential for estates and smallholders to complement each other (chapter 7), but credit and land policies devoted to estates might be put to better and more productive use by smallholders.

Official Projects

In recent decades many public and nonprofit projects and programs have been implemented, especially in the most critical upland areas of Java. These projects have been quite successful in promoting and enhancing land management techniques. Despite the great dedication of staff, however, there seems to be considerable difficulty in disseminating information about intensive cultural practices and promoting new cropping patterns. These limits may be caused by a variety of factors. Many of the projects focused on improved production techniques for food crops, but considering the high variability and degree of risk in upland food-crop farming, this objective may have been misplaced. In addition, innovation processes often require more time for implementation than projects can allot to them, and the institutionalization of project activities within agricultural research and extension services is not simple (chapters 4 and 9).

Although projects work simultaneously on many components of upland farming systems, they may miss some important elements. For example, projects tend to emphasize the links between each component within the farming systems while neglecting connections between farmers and their socioeconomic environment. In particular, projects and extension programs are not very efficient at dealing with the marketing of promoted crops. Apart from the milk-producing area in Java, public cooperatives generally do not provide adequate marketing services to upland farmers.

However, agricultural public services can play a significant role in providing planting material to farmers, especially for tree crops. Local authorities are sometimes the key in transferring and disseminating innovations to farmers. The development of *Leucaena leucocephala* forests in the Amarasi subdistrict of Nusa Tenggara Timur seems to have been initiated by traditional authorities (chapter 2).

Economists and policymakers lack data about most projects. Final appraisals may be done rapidly or not at all. Projects should be seriously evaluated five years after they are completed, which leaves time for a more sustainable appraisal and time for a copying effect and other tools of innovation adoption to occur. Among good examples is the showcase of rubber clones. In the late 1980s and early 1990s, projects applied to rubber schemes were usually praised for the quality of their work and highly criticized for their cost and limited influence. The projects worked with a very small proportion of rubber farmers (chapter 12). However, in the late 1990s, to the surprise of most rubber experts, clonal planting materials are in very high demand. It is difficult not to conclude that experts strongly underestimated the potential copying effect. If regional projects are based on a major innovation, such an innovation may spread widely from farmer to farmer.

Influential Individuals

Sometimes influential individuals enjoy farmers' confidence and play a crucial role in innovation dissemination. Such individuals may belong to the farming community or have considerable knowledge of the socioeconomic environment. One of the best examples from our surveys is Father Boland, a priest in Flores who was the key person to promote and develop *lamtoro* hedgerows and cocoa in Sikka district.

Many innovative farmers remain obscure or unknown because they are not in a position to claim their discoveries, for example, the building of high-yield and short-cycle varieties of robusta coffee in southern Sumatra (chapter 16). The farmer in Rembang district (Java Tengah) who established a group to rehabilitate a large on-farm reservoir could also be included in this category (chapter 3). Extension officers who provide useful information about coffee in Sulawesi are another example (chapter 9).

Military

Although conflicts inflict great suffering, they sometimes also bring know-how and inputs, such as ginger brought to Bengkulu farmers by some Japanese army staff (chapter 6). Local uprisings may also have positive effects. For example, the Sulawesi and East Kalimantan cocoa stories were accelerated by the knowledge acquired by former DI/TII members about cocoa and available land in the country. Former members hidden in remote base camps in the forest could later remember there was forest available ready to be overtaken by spontaneous migrants. They also learned about cocoa through the rebel network because the head of the uprising, Kahar Muzakkar, had launched an experimental cocoa plantation in 1958 with the intention to fund his movement—and, he hoped, a new state—by this type of agricultural commodity. Kahar Muzzakar's plan and its early implementation was a key determinant of the successful cocoa boom that finally started in the late 1970s (Ruf 1995). This story is a perfect example of the impact of migration and population moves and of informal networks on the spread of innovations (chapter 7).

Factors Affecting the Adoption of Technical Innovations

Innovation adoption or rejection depends upon numerous factors. In this section we review several factors observed in different situations in order to list some general rules about the dissemination and adoption process. In each case, however, it is clear that even though the adoption process relies on the efficiency of channels through which technical information is conveyed, farmers will not fully adopt a new technology if it does not overcome their constraints and if it does not provide them with a new market opportunity.

Environmental Change as a Catalytic Factor

In the short term, transformation of a farming system is very often associated with a sudden change in the farming environment. For example, in the advent of livestock diseases is often viewed as the catalyst for the development of tree crops in Timor. Earthquake damage to a plantation was cited to explain the development of new crops. A crisis is not the sole reason to justify a change, but it may play a catalytic role.

Land Shortage and Population Density

The switch from animals to tree-crop production in West Timor was not just a matter of a sudden disease outbreak. The disease was a sign of an increasing imbalance within the environment; as human and cattle populations increased, the pressure on natural resources required changes in the farming system. One of the classic changes is a switch to tree crops that may require less land but are more labor intensive.

Another spur to innovation directly related to land shortage, and one of major economic importance, is tree-crop replanting. As long as land and forests are abundant and available, farmers never cut down their coffee, clove, or coconut trees. They abandon them, at least for a few years, and keep clearing forest to create new plantations. However, they return to their previous plots, clearing the old trees after a long period of "forest fallow." This process can be called "tree-crop shifting cultivation." When land becomes scarce or new forest protection rules are implemented, farmers usually diversify their crops, but they sometimes choose to replant the same crop (reintensification of the same crop as production raises again). Of course, the choice between replanting the same crop and diversification to new ones is influenced by price and market factors.

Price and Market Factors

Changes in relative prices are an important incentive for farmers. Faced with a combination of land shortage and sudden price hikes, many do not hesitate to cut down tree plantations in order to convert to a new and more profitable crop. This explains why apple production declined in Java Timur in favor of new crops and why cloves in South and Central Sulawesi were poorly maintained in the 1990s, with some plots abandoned and even cut down (Ruf 2001a). Again, the main determining factor seems to be access to land and not just price.

Nonetheless, one unsurprising aspect of our review concerns prices and their role in farming decisions. There are very few examples of sustainable adoption of innovations where markets do not provide additional cash to the farmer. For a coffee-ginger rotation, for example, low prices may encourage farmers to cut trees earlier than expected, but price increases then may trigger replanting the very same year or the next year.

Direct Market Accessibility

In addition to demand, a market also implies market accessibility, and thus relatively free markets, free trade, and competition between traders. One positive but extreme example concerns the policy to let local farmers and traders from East Kalimantan smuggle their cocoa to the neighboring Malaysian city of Tawau (Chapter 7).

One of the less positive examples of low competition is sometimes offered by the Kooperasi Unit Desa (KUD) village cooperatives, which are present in numerous villages of the country and theoretically able to buy all type of agricultural products and to sell inputs. Although the cooperative concept is attractive, its implementation is often uneven and arbitrary. In some regions such as East Kalimantan and Flores, KUD seems to hamper agricultural production through partial marketing monopolies, thus paying low prices for agricultural outputs and charging high prices for inputs. Many farmers and middlemen simply bypass KUD.

Market Accessibility through Infrastructure

Even though the impact of road construction on rural development is well understood, we think its role in making markets accessible to farmers must be emphasized. The overall impact of upland development and conservation projects is not easy to assess, but their contribution to the extension of feeder road networks is undoubtedly a valuable asset for the future of uplands. These secondary roads not only play a crucial role in agricultural marketing, but also greatly facilitate the supply of agricultural inputs to farmers. The use of chicken manure in upland areas of Java Timur would certainly not have spread as rapidly nor had such a positive effect as it did if the road network had not been developed.

Production may also create an infrastructure of its own. Migrants, for example, crossed the Bone Gulf in small boats and trod up the hills to their plots. Step by step, year after year, they enlarged the foot path until it was wide enough for a cart or even a truck. In some cases, the farmers have contributed financially to road construction.

Availability of Capital

The influence of capital on farmer attitudes toward a new technology is variable. As expected, richer farmers are more keen to test new solutions, and some input-intensive agricultural production such as garlic is not accessible to all types of farms. For ginger crops, capital availability clearly shows the importance of continuous rates of adoption (Feder 1982). If the definition of ginger adoption is to plant at least 0.1 hectare of ginger every two or three years, a number of smallholders have adopted it; however, very few of them planted more than 0.3 hectare on an annual basis (chapter 6). Beyond the land factor, availability of capital is the main determinant. Not all farmers have the capital required to grow crops that require a heavy investment cost.

However, if the agronomic and economic risks of adopting an innovation are acceptable, even poor farmers will find a way to mobilize the initial capital. Credit programs may influence a farmer's ability to invest in inputs, particularly for important food crops in the cropping pattern sequence. Often the cash generated by a project may offer new technical solutions, sometimes outside the project scope. A project can help ease the cash constraint at the farm level, which may allow farmers to use their traditional source of income to invest in a new technology, but not necessarily the one triggered by the project. On-farm reservoirs and hand tractors are good examples. For example, in Central Java, the revolving fund set up during the SYGAP project to ensure input purchases for soybean production was eventually used by the farmers' group to purchase hand tractors (chapters 3 and 4).

If the innovation is scale-neutral, like most new tree crops, the farmer can adjust the investment to his financial capacity. If the innovation is not scale-neutral, projects have a more important role. They may overcome capital constraints by grouping farmers around one investment such as on-farm reservoirs. Such an investment may be only temporary if there is no social organization to manage the investment.

The best success stories in the uplands happen without much capital. In the hills of Sulawesi, up to 35 percent of migrants do not have any capital or credit (chapter 14). The little money that they had was devoted to transportation costs. Smallholders have long overcome a shortage of capital by institutional arrangements such as land sharing. Even though tree crops are scale-neutral, it is impressive to consider that these farmers generate millions of dollars with very little if any public or official private funding.

From Migrations to Labor Shortage

Migrations are always a source of innovation and more rapid adoption because the migrants bring an additional supply of labor and knowledge. The continuous rate of adoption is important—native people may plant half a hectare of cocoa in five years, while migrants may convert 2–5 hectares of forest or fallow to cocoa in the same time period.

Communities that have not experienced migrations for one or two generations are usually short of manpower. Farmers often cite labor shortages as a constraint, a complaint that does not seem consistent with the image of upland areas as overexploited. If adequate incentives are available, most villages can occasionally mobilize enough manpower for special projects such as building terraces, but labor is a constraint for intensive agricultural operations such as harvesting. Farmers may call on family members, labor exchange, or hired labor, but they may also find astute ways of reducing labor requirements. For example, the apparent lack of fermentation and drying of Sulawesi cocoa beans is partially the consequence of frequent rains that make drying difficult, but it is also a strategy to pass postharvest tasks on to middlemen and save time on the maintenance and harvesting (chapter 14).

A better example of overcoming labor shortages is the development of *tebasan* contracts, under which the trader is responsible for harvesting the fruit orchards in Java Timur. When such arrangements are not possible, farmers may have to abandon crops, as they did with coffee production in Ngantang subdistrict in Malang district. Higher wages in surrounding areas for off-farm jobs prompted a few farmers in this area to reduce the size of their coffee plantations and replace coffee with fast-growing trees for pulp factories. A good manager of any estate would doubtless make exactly the same decision (chapter 11).

Labor Shortages and Off-Farm Opportunities

The growing attraction of off-farm opportunities, even after the 1998 crisis that temporarily reduced off-farm opportunities, has a marked effect not only on labor availability in upland areas, but also on innovation adoption. In Garut district, western Java, for example, the dissemination of more sophisticated crop management practices, including more fertilizer and pesticide applications, was hindered by the prolonged absence of heads of household who work for two or three weeks at a time in western Java's main urban centers. When farmers are away from the field for several weeks, they are unable to monitor their plot and to follow project recommendations. This is one reason why, despite its comparatively low price, farmers still prefer to grow cassava, which does not require any special attention between planting and harvesting.

This leads to nuances about competition between on-farm and off-farm activities. In Bengkulu, smallholders have grown robusta coffee for decades. Bengkulu is also a place where families often have a part-time nonagricultural job, at least before the 1998 monetary crisis that led to a temporary but spectacular coffee windfall. The part-time nonagricultural job is triggered by the high concentration from the coffee harvest and thus the unequally distributed coffee income over the 12 months of the year. Except during the 3-month period of peak harvesting, revenues are insufficient (chapter 16).

Off-Farm Activities and Infrastructure

Improved transportation facilitates regular travel of labor between remote areas and main urban centers or even more active rural areas. This movement may have some effect on modernizing upland farming. Reduced availability of labor may trigger the adoption of labor-saving technologies such as herbicides. Reduced population pressure means lower demand on food crops, and upland systems can more easily target cash crops. Temporary migration also allows upland areas to benefit from additional manpower during harvest periods to collect fruit and perennial products. On top of that, off-farm revenues can be invested in these changes and innovations. The effects of off-farm employment on agricultural labor shortages depends on distance and farmer living conditions, but even in the most isolated villages, farmers are concerned about migration of the younger generation. These temporary migrations also affect gender distribution and the respective responsibilities of men and women. In this context, the wife of the household head wife may manage the farm in addition to her duties as a mother.

Physical Environment and Land Tenure

The quality and quantity of available natural resources also affect the adoption process. Any innovation has an agroecological range of validity that defines its potential area of application. Cocoa production in Flores, for example, developed in the upper part of volcano saddles where the moisture level is high enough for cocoa to flourish. The development of cocoa in Sulawesi is also the result of forest availability and accessibility. Population pressure also affects technological change, for example, by reducing fallow periods and forcing farmers to replant tree crops on fallows rather than clearing forests.

Innovations can also lead to increased population density, which may constrain natural resources. The expansion of *Leucaena leucocephala* in Amarasi subdistrict, for example, allowed rapid growth of livestock production and attracted many farmers from surrounding districts; soon not enough land was available to support all the people and the livestock. The system is in crisis and may likely shift to new production (orange trees or cashew trees as in other districts in West Timor and Nusa Tenggara (chapter 5).

Increased population pressure is not solely the result of migration and natural growth. In several sites natural resources available to farmers have been sharply reduced by implementation of a reforestation program. The justifications for these programs aside, farmers who have no guarantee of land ownership will clearly be reluctant to apply any technology that has a slow rate of return, such as building terraces.

Our work did not throughly investigate land tenure, but contrary to many opinions, clear land tenure is not a prerequisite to massive smallholder investments such as tree crops. Recent cocoa and coffee booms are evidence. We interpret this as a sign that migrants are ready to invest in a mid-term perspective of 10–15 years. Of course they hope to keep the land, but they are willing to settle for a good return on their investment for the shorter term. For any more sustainable investment, clear and balanced land tenure is probably as useful for agriculture as it is for social peace between estates and farmers, between migrants and natives. More data on this issue are needed.

Farmers' Self-Help Action and Policy Issues in Upland Development

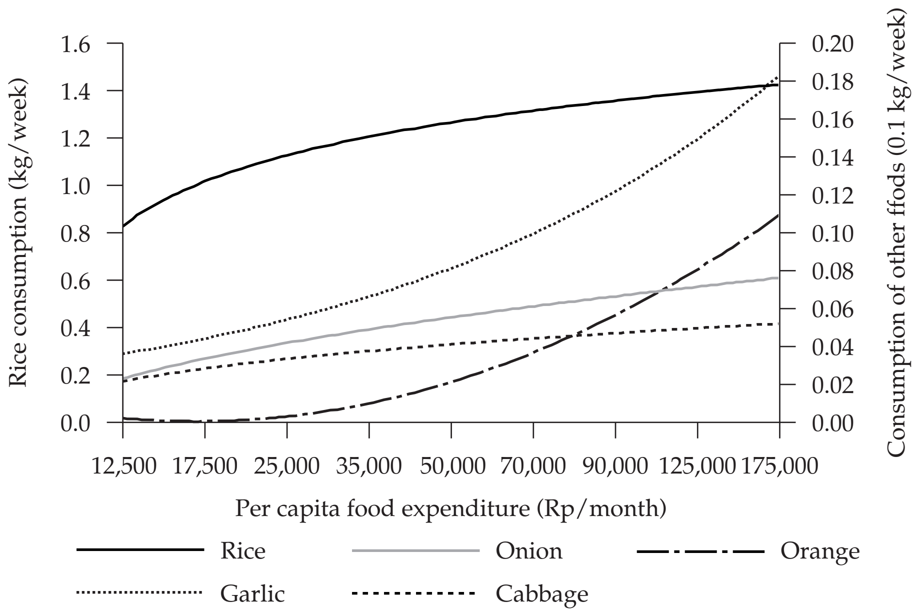
Strong Dynamism in the Uplands

Our field review confirms the strong dynamism of upland agriculture that responds quickly to market opportunities when markets are accessible. This dynamism prevails in very different agroeconomic settings and can be observed even in the most remote and isolated areas.

TREE CROPS AND VALUE-ADDED ANNUAL CROPS. With the exception of local improved maize varieties in East Java, influenced by extension services and policies, staple food crops do not play a main role in the dynamism of the uplands. Even new upland rice technology has not seemed to develop rapidly. The cassava boom is another exception, especially in highly densely populated regions of Java, but more in relation to fluctuations in world markets than food policy.

DEMAND FOR DIVERSIFIED FOODS. The adoption of tree crops such as oranges and other tree fruits and high value-added annual crops such as garlic represents a response to the growing demand of urban markets for greater diversity in daily diets—a demand that is supported by the increasing per capita income in Indonesia and across Asia. This change is providing new opportunities for tropical agricultural development (figure 18.1). After referring to livestock and horticultural commodities, Mellor (1996, 4-5) stresses: "One of the changes of the last 40 years is a shift to a potential for higher growth rates in agriculture than was previously thought possible. Concurrently, agricultural growth has become more like non-agricultural growth with respect to its growth rate potentials and demand elasticity—but has maintained its uniqueness in its broad geographic and income class participation." What can be added is that most of these new opportunities may occur in the uplands. This is exactly what is symbolized by traders who send trucks full of workers from the plains to harvest oranges in the hills.

Figure 18.1. Trends in Weekly Food Consumption with Growth in Monthly Per Capita Food



Difficulties of integration. Upland development does not respond very well to large projects that prioritize environment protection at the expense of more economically oriented farmers' objectives, such as those implemented in Java in the 1980s and 1990s. There is probably a need for smaller projects that try to combine and integrate rehabilitation of the environment and short-term returns and that adapt their priorities over time. Candlenut in Flores and arabusta coffee in Sinjai are examples—indirect terracing has a better chance of remaining if it is combined with additional tree crops that improve the return to labor. This is what happened. Then, even if this indirect terracing does not remain when tree planting density increases, the terraces are still an important step in the establishment of a sustainable farming system. Despite these difficulties of integration and adaptation over time, several agricultural (and nonagricultural) projects have a positive impact on farming systems by supporting the development or improvement of land management (terraces, hedgerows) and improving road networks to enhance market access.

Uplands versus lowlands

Externalities

The impact of upland projects is also affected by recurring costs related to terrace maintenance, as well as by questions of expansion and dissemination of this technique in a more permanent framework. This is part of a broader issue—who will bear the costs of soil erosion control, and who benefits from such actions? Upland sites are supposed to develop more sustainable cultural practices to the benefit of lowland farmers. If upland farmers implement anti-erosion practices, the first beneficiaries may well be the lowland farmers who will run lower risks of flooding and various environmental accidents. In the short term, official projects have been the major, if not the only, instruments for disseminating such technologies. A more permanent and sustainable policy requires carefully addressing how costs and benefits can be more evenly shared between uplands and lowlands. What kind of institutional mechanisms (taxation and subsidy) will be most efficient to manage this externality?

Complementarity between Uplands and Lowlands

Several complementarities are developing at regional and farm levels. Laborers sent from the plains to work in the hills are an example of labor adjustment between uplands and lowlands. Conversely, in the mornings, bicycles and motorcycles from upland villages converge on cities in the lowlands, illustrating the increasing importance of off-farm opportunities for upland farmers. Within the same households, families try to own plots in both places, say, an irrigated field in the lowlands and orchards in the uplands. The food security brought by raising *sawah* (irrigated rice) in the lowland plot helps support innovation risks in the uplands. Innovations and land constraints in uplands may accelerate innovation adoption in the lowlands. In other words, the Green Revolution in the lowlands has already had an impact in the uplands. For example, In the Sulawesi lowlands labor-saving technologies such as herbicides and hand tractors helped to free labor and encourage migrations to the cocoa pioneer fronts. Fertilizers promoted for paddy cultivation were massively used in cocoa farms. By providing extra revenues and savings, rice surpluses also played a catalytic role in by funding migrations and accelerating the adoption of cocoa in the hills (Ruf 1995c, pp. 229–31).

Market Demand

If national and international markets bring a favorable economic environment for tree crops, many smallholders in the lowlands will give up their rice fields and turn to tree crops. This has already started in lowland rainfed areas in Java where plots originally devoted to rice production are now planted with mango.

More generally, there is a clear trend of tree crops overtaking paddy fields and other annual crops. In Sulawesi lowlands and uplands, thousands of hectares of paddy, soybean, and tobacco were converted into cocoa farms from 1985 to 1990 (Ruf 1993c). In Semarang, Java, farmers who once grew paddy became clove planters in the 1970s, then turned to intercropped coffee before totally converting their plots to coffee. Recently, they diversified with milk cows.[2]

The coffee-dairy combination is a well-known farming system in the uplands of East Africa (Ruthenberg 1980) and looks like an irreversible trend in Semarang that will not be changed by projects. Sometimes projects may even accelerate the switch from food crops to tree crops. That was the case with the Batumarta transmigration center in Sumatra, which promoted rubber planting. As soon as the rubber trees began producing, farmers completely abandoned food crops (Levang 1997). This trend can be controlled when urban demand increases, making food crops oriented to the market more attractive to farmers. There is wide potential for exploration and experimentation of this topic.

Food Security

In a country of 200 million people, most of whom eat rice, there is no alternative to the long-standing rice policy—to guarantee self-sufficiency in order to avoid risks related to imports from the international market. At the world level, rice exports as a percentage of total production are much too small to be reliable. A sudden change in climate or in policy within the few rice-exporting countries could lead to a rapid fall in rice available on the world market. This would lead to a social disaster in a major rice-consuming country such as Indonesia.

Rice self-sufficiency has been losing ground since 1994, when Indonesia resumed importing rice. But even before that, the government was trying to guarantee food security by promoting the development of food crops in the uplands. Although maize and potatoes have more potential than paddy in the uplands, Indonesia cannot rely much on the uplands for its food security. The Green Revolution in the uplands is mostly oriented toward tree crops.

This leaves one major question: if the uplands cannot solve the food security problem, is there an alternative to importing cereals, perhaps a range of cereals, to satisfy diversified consumption patterns and lower the risk of depending on rice imports?

If the primary objective of official agricultural projects in the uplands is still solely to guarantee food security for Indonesia, clearly they will continue to fail. The best strategy from the perspective of upland farmers is to combine tree crops and annual crops, especially in replanting schemes. Annual crops include food crops that can be locally consumed and sold as well as cash crops oriented toward the national and export markets. Coffee-ginger or coffee-chilli rotation systems invented by smallholders of southern Sumatra have already proved their efficiency.

Conclusion

Indonesian upland smallholders seem to be dynamic innovators and entrepreneurs—converting slash-and-burn agriculture into commercial agroforestry systems or monocropped tree farms and adopting a wide variety of innovations. Although some farming systems are not always sustainable, the most important point is that the potential of upland agriculture has been widely underestimated. Indonesia is a showcase that has lessons for other countries.

We examined some 40 upland situations scattered along the entire Indonesian archipelago (except Irian Jaya). Although this is a wide range, we still did not study anywhere near all of the diverse innovations undertaken by Indonesian smallholders. For example, we did not describe in detail the reasonable use of herbicides that helps farmers replant cocoa trees on land covered by *Imperata cylindrica*. We did not describe the extraordinary network of water pumps and pipes developed everywhere on the slopes of the Merapi to irrigate potato terraces. We did not analyze situations where forestry and wood have become smallholder cash crops. We did not discuss the future of pulp trees adopted by smallholders, as well as the spectacular oil palm boom, which deserves more research. There is still much research to be done with upland farmers. Some ideas are reported in annex 6 along with other proposals.

Regarding innovations and their transmission, it must be stressed again that smallholders are well able to pick up information and innovate. They are enormously helped by their social environment, especially the traders who have a direct interest in the innovation. Traders, exporters, and individuals are especially efficient vehicles of information when they belong to a network, whether commercial, familial, social, religious, or even military. Such informal networks put them in contact with both ends of the chain, from upland producers in their mountainous and remote Indonesian islands to final consumers in neighboring countries, Europe and the United States. These networks can efficiently transfer the information on innovations because they have the confidence of upland farmers. Networks are usually more efficient than official projects. When projects look successful, one should look for information that may have reached farmers from other sources. This aspect of innovation transferral probably applies to any country and typography, not only uplands, but it is especially true in uplands at great distance from consumers and markets. Official projects do contribute to spreading information in the uplands, but in most cases are relatively poor informers among many other sources.

Two complementary logical conclusions derive from this finding. One is to try to improve and invest in further information through official institutions and projects. Official projects should include a large array of planting material and other technical inputs, but they should also address price and market information To repeat, farmers are unlikely to adopt technical innovations unless they are reasonably sure that their income will improve as a result. Another pragmatic conclusion is the need to encourage participation of private, local institutions and personal initiatives in information diffusion and communication networks. An initiative undertaken in the past by ARRD and DGE, and which should be resumed and enhanced, is the organization of farmers' meetings bringing together farmers from different regions of the country, and even possibly from other countries.

The enormous potential of trees and fertilizers as innovations must be stressed. Despite, or because of, critical price cycles of commodities such as cocoa and coffee, rubber and palm oil, pepper and vanilla, fruits and timber, and because trees provide shade, erosion control, and fodder, one must repeat that trees and tree crops are essential to uplands. They form the main capital of its agriculture and the main patrimony of upland farmers. One of the conditions for improved sustainability is the diversification of revenues within households. This diversification can take the form of vegetables and any products oriented toward the domestic market if cities develop nearby. Nevertheless, whether for domestic or export markets, the first diversification objective is to reduce the impact of price collapses and pest and disease outbreaks. Indonesian farmers demonstrate this pattern again and again. From 1999 to 2002, against a background of collapsing cocoa prices and the pod borer outbreak, one can find some Sulawesi smallholders progressively moving to orange trees for the domestic market. They are also reconsidering their previous neglect of associated coconuts. Others adopt pepper in combination with or beside cocoa plots. Finally a few innovative farmers have managed to get seedlings of "jati super," literally "super teak." Diversification may be implemented through agroforestry systems or a juxtaposition of small monocropped farms, or intermediate forms such as the box system (for instance, a cocoa plot surrounded by one or two rows of orange trees).

Although it is not an original observation, one must note again that fertilizers and herbicides used with moderation have also brought a major agricultural revolution in many uplands, not only in Indonesia. There is a need to go further with integrated pest management techniques and complement chemicals with more environmentally friendly inputs and techniques, but these inputs definitely have changed the nature of the sustainability problem in the uplands. Too large a reduction in their use can have quite a negative impact in terms of upland smallholders' revenues and the sustainability of their farms whether in hybrid maize or tree crops, and in Africa or Asia (Holden 1993, 1997; Reardon and Barrett 2001, chapters 13 to 17).

The last words of this study must be the key ideas—*trees,* as the main patrimony of farmers in the uplands; *replanting,* which has specific technical and financial difficulties and deserves specific policies; *a reasonable amount of fertilizers, herbicides, and other inputs* to make up for the loss of the forest rent and help trees recolonize degraded land—all this in an active trade and relatively free-market environment.

Other key words are *location rent,* which means that investment in infrastructure is decisive for sustaining upland agriculture, *progressive diversification* after a period of monocropping, and *commercially oriented agroforestry* rather than a generous ecological ideal agroforestry. Although upland farmers in Indonesia and many other countries proved that they can invest by clearing tropical forests and planting trees without any land certificate and security, there is probably a need for some land and tree tenure over years.

When land gets scarce, when it comes to replanting, when the first generation of migrants starts transferring its tree-crop patrimony to the next one, social conflicts about land often increase in importance. The same can be said about credit. As long as forests are abundant, pioneer farmers find ways to invest without credit. Once forest has gone and land is scarce, credit schemes are more important.

A further obvious and unavoidable conclusion is the recognition that subsidies and taxes may sometimes be necessary to complement market forces. If and when local upland agriculture generates relatively high revenues, especially through tree crops at certain periods of time, taxes may be applied, but a significant percentage of these taxes should be reinvested locally to improve upland infrastructure and landscape management. If local upland agriculture is insufficient to enable a decent rural life, subsidies and the principle of paying smallholders for landscape maintenance for the common good should also be implemented. The multifunctionality of tropical upland agriculture is an issue that will have to be revisited in the near future in order to fund upland development and to generate new ideas and new farming systems.

Note

1. The *damar* (*Shorea javanica*) is a tree exploited for its resin used by the painting and varnish industry (Mary and Michon, 1985).
2. Pascal Perez, 1997, personal communication.

Annex 1

Upland Agriculture and Alternatives to Slash-and-Burn: A Brief Review of the Recent Literature

For decades, governments have been considering slash-and-burn techniques as obsolete and inefficient. Rightly called the "politics of ignorance" (Dove 1983), this attitude has changed in most countries, including Indonesia. The technique of slash-and-burn is currently acknowledged as quite efficient as long as the population density is low enough to let the forest regenerate after a fallowing period of several years.

When the fallow time is shortened for some reason, slash-and-burn loses its sustainability and is said to lead to erosion, loss of soil fertility, increasing weed pressure, and other environmental degradation. Yields and revenues are thought to fall, and they probably do, at least for the period of time needed for introducing innovations. But to what extent do degradation and declining yields and revenues actually occur?

A Data Problem But Boserup Theory Often Works

Any effort to examine land degradation problems soon runs into formidable data limitations (Pagiola 1999, 6). Most studies have generally lacked a long-term view that tracks the relationship between changes in local economies and changes in the environment (Dewees 1999, 301). How do population increases affect these changes?

The pessimistic still believe in the old Malthusian law and think that all population increase end up with crisis, an output of the degradation of the economy and environment. Most Economists are more optimistic and acknowledge the rather opposite view brought by the famous Boserup's study published in 1965. Couty summarizes Boserup's theory in one sentence: "When the population increases, there is less land available, which leads, through an automatic adjustment, to more intense labor consumption relative to the amount of arable land." (See Box 1.) Boserup's theory may

Box 1. Introduction to Boserup's Theory

Couty (1996, pp. 137–49) accurately summarizes E. Boserup's theory in one sentence: "When the population increases, there is less land available, which leads, through an automatic adjustment, to more intense labour consumption relative to the amount of arable land."

An updated and more detailed version of Boserup's intensification theory is highly pertinent today when put forward with the innovation theories.

In Africa, since the 16th century or earlier, agricultural intensification levels have differed according to population densities. Boserup's theory thus applies more readily in space at a given time, than in time for a given space.

For the temporal evolution, there are two main difficulties:

—less space, therefore evolution toward the disappearance of fallow with, a priori, a negative impact on crop yields and on the environment, even though this is not always clear;
—more work per hectare, but intensification of the labor factor would likely abide by the law of diminishing returns.

This indicates that innovations are essential, as they bring new techniques that are linked or not with capital.

well face numerous counterexamples, but the few existing documented case studies confirm that the rule remains predominant: the adoption of new technologies is itself an outcome of population growth (Boserup 1965, quoted by Dewees).

In Kenya, the Overseas Development Institute survey explicitly endorses the Boserup theroy with its title "more people, less erosion." Among other things, the survey found that "the Machakos people have not destroyed their environment despite their poverty and the riskiness of their climate. . . . Soil erosion has been eliminated on much cultivated land. . . . The fuel shortage first noted in densely populated areas in 1910, has never reached the often predicted crisis point, and there are now more trees, grown for many different purposes." (Tiffen and others 1993, p. 263). In El Salvador, where the common perception is that 75 percent of the country surface is degraded, Pagiola and Dixon (1997) found that only about a one-third of farmers' fields experience erosion, and only a fraction of those appear likely to suffer productivity declines as a result. None of these studies suggests that land degradation is not a problem, but all seriously question the common perception of the severity and nature of land degradation (Pagiola 1999, p. 7).

Grassland and Yields

The popular description of all grassland as degraded land is questionable. Some grasslands can be considered as a "kind of land reserve, able fairly easily to be converted to more intensive agricultural systems when this is required" (Potter 1996, quoted by Brookfield 1997). However, Brookfield (1997, p. 46) continued, "Some grasslands areas are on soils that are naturally very infertile; once stripped of a forest cover slowly established over centuries, they are unlikely to carry either farms or forest in the foreseeable future." On less poor soils, some grassland can be managed by tillage and displaced under arable and agroforestry systems or shaded by tree plantations.

In fact, consistent with the forest rent approach (chapter 1), whatever the soil qualities are, most crops planted after grassland need more weed control than they would planted after forest clearing. As population and deforestation usually increase together, the process of more time devoted to weed control as a first step followed by the adoption of labor-saving technology such as herbicides is close to the Boserup approach (box 1).

Changes in weed control technologies are widely discussed in the literature on Indonesia. With regard to the Banjarese of Kalimantan, for example, Michael Dove (1981, p. 187) describes a successful indigeneous technology for the exploitation of the grasslands. The grasslands are cultivated using brush-sword, fire, and a cattle-drawn plough. One dry-rice crop can be cultivated each year for up to seven consecutives years, at which point the land is fallowed for three years. Yields average 3,000 liters of threshed and unhusked rice per hectare. According to Dove, this case is an exception to Boserup's theory. In Banjares, the intensification of agriculture was done, not because of an increase in population density, but purely for ecological and economic reasons, which subsequently led to an increase in population density. Beyond the debate about causes or consequences of agricultural intensification and population increase (and which we believe does not go drastically against Boserup's theory), what matters here is that Banjares is in the lowlands where it is easier to maintain yields and almost permanent cultivation.

Sherman (1986) describes a more classical constraint of *Imperata* in the uplands of Sumatra, where he found that most dry farms were used for only three to five years before being left fallow. According to the author, Sumatran farmers consider that yields start decreasing by 25 percent after as few as three years. Sherman's study recorded yields of upland paddy for two years; many of the observed fields had already been in use for three years. The average yield was 34.1 *kaleng* of rice per *kaleng* of seed planted. With an additional year of cultivation, the average yield declined to 25.1 *kaleng*, which Sherman said corresponded to farmers' reports of 25 percent decreases in yield.

Sherman also reported that he "was surprised to find Huta Ginjang villagers adept at growing rice on land opened from nearly pure stands of the much-decried 'swordgrass,' *Imperata cylindrica*." According to conventional wisdom, *Imperata* was considered to be impossible to eradicate once it was established. Geertz (1963, p. 25) wrote that the grass had "turned . . . much of Southeast Asia into *a green desert.*"

Sherman (pp. 144-45) went on to say that

> the reputation of *Imperata* and other such grasses, while inaccurate, is not entirely undeserved in one respect, eradication is not "economical" of time and effort in Western terms. According to Beukering (1947), *it*

> *requires twice as much time to open comparable areas of grassland and jungle swidden*, and the figures he gives for grassland are compatible with my findings. On the other hand, the maintenance of *Imperata* grassland is largely the result of livestock raising, and since bovine livestock cannot forage in jungle, there is complementarity between farming grassland and raising livestock.

These remarks and the figures given by Sherman also summarize changes linked with reductions of fallow times and forest substitution by grassland, at least in situations where soil erosion is limited (flat to hilly topography). Hence, under these circumstances yields can be sustained for several years with a significant increase in labor for weed control.

As mentioned by Brookfield (1997, p. 48), "Only some grassland is truly a 'green desert' and a very large part is reclaimable for agriculture or is naturally reclaimable by the forest." Some grassles such as *Imperata* may be also used for making roofs and can even be sold for that purpose, as it is in Flores. However, an agricultural recolonization of these grassland fallows usually requires additional labor or capital compared with a first agricultural cycle after forest clearing. That is why the description of grassland as degraded land, although sometimes too strong, is partially deserved.

Preliminary Definitions of Uplands

Nibbering (1997, p. 153) defines uplands as follows:

> The terms "upland farming" and "upland cultivation" are used after Ruthenberg (1980), Palte (1989) and many others, to indicate rainfed (or "dry") permanent cultivation of annual crops in the tropics without the use of impounding rain water or irrigation. The term has been derived from the fact that this type of farming predominates in the uplands, usually hilly or mountainous areas, with small catchments. As such, the uplands contrast with the relatively flat irrigated plains and plateaux in the periphery of which the uplands are usually situated.

This definition, however, does not take into account one of the more important tehnical advances made in the uplands-irrigated terraces. Are the nicely irrigated paddy terraces in Java, Bali, Nepal, or Sri Lanka not obvious showcases of this? Terracing and irrigation in the uplands are progressive. They start under demographic pressure, when labor is sufficient to undertake such heavy investments. They cannot be left out of the scope of uplands; they are one of the major and ultimate breakthroughs in upland farming systems.

Permanent Cultivation of Annual Crops

As a corollary of this first definition of upland farming (with the notion of "permanent cultivation of annual crops"), case studies do exist showing innovation linked to population increase and hence to reductions in fallowing time and finally to abandonment of slash-and-burn systems. Anthropologists such as T. Murray Li (1999, p. xix) underline this contribution made by historians in her book:

> Contrary to the myth of unpeopled and unproductive upland terrains, and also to the administrative and scholarly obsession with lowland rice and colonial cash crops, Peter Boomgaard describes the early and spontaneous transformation of upland agriculture initiated around 1600 with the adoption of a New World staple, maize, and small holder tobacco. . . . He establishes a correlation in time and space of these two crops, together with livestock rearing. He uses his data to outline a complex, productive, and relatively sustainable agrarian system that was found in many areas of the archipelago and persisted for several years. . . . Maize cultivation increased the carrying capacity of upland terrain, permitting more people to live at high altitudes. It was politically significant, therefore in enabling some people to escape the oppression and insecurity of lowland polities and reconstitute themselves as "highlanders" or "tribes" on the peripheries of state control.

Peter Boomgaard ends his chapter by stressing the relative absence of the state in the adoption of the two crops. The building of this sustainable complex system made of two new crops and associated with livestock seems to have been spontaneous (Boomgaard 1999). Beyond this maize-tobacco-livestock complex, other case studies in Java show how farmers responded to erosion and declining fertility in the first decades of the 20th century. These measures already included oblique drains, grass lines, earth bounds, terraces, and hedges of *Eupatorium* (Nibbering 1997; Schuitemaker 1949 quoted by Nibbering).

Associated Trees

Upland farming cannot be strictly limited to annual crops but must embrace significant breakthroughs brought to upland farming by associated trees. For instance leguminous trees, which have multiple uses including fertility regeneration and fodder, have sometimes proved to be defensible systems especially on tight slopes. The leguminous tree rows introduced by Father Boland on Flores slopes in the 1970s was clearly one of the most interesting cases examined by our team during its preliminary study in 1997. A terracing tradition using logs existed before any project, but the joined actions of Catholic missions and governmental structures introduced *Leucaena* hedges to reduce the duration of fallow (Perez 1997, 48). However, these hedges did not last very long. Attacks by a psyllid in the mid- and late 1980s destroyed most of the trees. After a successful experience, it was a major setback. Examples of leguminous tree used in systems derived from slash-and-burn techniques are numerous and are one component of sustainable farming systems in the uplands. In many Indonesian regions either official projects or individual farmers innovated in that direction.

Tree-Crop-Based Systems

Entire regions of unirrigated hills and plateau have been exploited for decades by tree crop-based farming systems. Trees such as cocoa, coffee, and even rubber, all intercropped with annual crops during the investment phase, grow in the uplands and provide relatively high revenues to farmers. In many upland stories, the simple adoption of cocoa, coffee, rubber, pepper, or cashew trees may be considered as a breakthrough, enabling farmers to achieve previously unmatched revenues. Nevertheless, the export-driven revenues may also suddenly collapse as happened in Indonesia in 1999, just after the 1998 peak (Gerard and Ruf 2000; Sunderlin and others 2001). Massive deforestation triggered by most tree crops is also part of the upland problem, and tree crops do not answer the challenging question of what to do once the forest has gone. More than planting, successful cases of replanting tree crops are a major progress in upland agriculture. The problem is precisely that these successful replanting cases remain rare (Ruf 2000).

Agroforestry

Especially in Indonesia in the tree crop sector, one cannot forget highly complex agroforestry systems such as the famous jungle rubber covering entire regions of Sumatra and Kalimantan and the Krui agroforests based on the *damar* tree in the uplands of West Lampung in southern Sumatra. These systems provide the monetary revenues while irrigated lowlands produce the rice. Their sustainability, proved over centuries, has been put forward by both botanists and economists. These complex agroforestry systems were established decades ago after dense forest clearing, but they can be replanted easily.

One of the contributions of surveys of alternatives to slash-and-burn is the classification of agroforestry systems into "rotational" and "permanent" systems. In the former type, the rotation has a clear end point at which the farmer decides to fell the trees and replant. Jungle rubber is clearly a rotational system (chapter 12). In the second case, "rejuvenation takes place at a patch level of one or a few trees, without slash-and-burn land clearing. The system approaches the character of a permanent, forest-like vegetation, even if it started in the same way as a rotational agroforestry system. Prime examples are *damar* agroforests of Krui and mixed fruit tree gardens (Tembawang) of Kalimantan and Sumatra" (ASB 1998, p. 84).

Beyond that classification, what may matter more is that some of these complex agroforests such as that of cocoa in the Sikha district of Flores are not created after forest clearing but rather are pure reconversions of *ladang*. In other words, slash-and-burn systems devoted to food self-sufficiency are converted into commercially oriented agroforestry.

Infrastructure and Exports

No doubt one should mention the recent universal infrastructure changes that may favor innovation. In most uplands, at least in Indonesia, tracks and roads have improved. They narrowed the distance and reduced the costs of access to large markets, either domestic or export-oriented (Lançon and Ruf 1997; Nibbering 1997). Infrastructure also promotes some exchange of inputs, including labor, between the lowlands and the uplands.

Fertilizers versus Soil Conservation

Nibbering (1997, p. 178) concludes his three-case study in Java with the following sentences:

> When upland cultivation in Java intensified, a general decline in productivity of the land followed. Diemont et al (1991, page 221) indicated that in much of the colonial and also more recent literature soil erosion is considered to be the main cause of the decline of the productivity in upland cultivation rather than the exhaustion of nutrients. When in the 1980s it was noted that yields in the uplands had been increasing again, this rising productivity was connected primarily with the increasing use of mineral fertilizers in upland areas . . . . This led to some controversy on what had been more important in the productivity decline in the past, soil erosion or soil exhaustion, and, similarly, what has been more conducive to rising yields in recent decades : soil conservation or soil fertilization . . . . Clearly the two are closely connected, fertilization pays off best on the best-protected soils, as may appear from the three case-studies.

The debate about the relative importance of erosion and fertility loss may be complicated by other factors such as the weed constraint and even pest-and-diseases, usually large components of what is called "land degradation" when grassland takes place of the forest.

Following the same principle, although fertilizers and other modern inputs make farmers more dependent upon markets and policies and may raise new pollution problems as happens in the lowlands, a reasonable use of these inputs may be extremely useful, especially for the reconversion of degraded uplands into tree crop-based systems, including various forms of agroforestry.

Why This Study in Indonesia?

The questions are raised in the Indonesian context because the country seems a perfect showcase. A brief historical outlook can be borrowed from Nibbering (1997, p. 155):

> Of old, Java's population was concentrated in the lowlands and on the intermontane plains where irrigated cultivation on rice was the prevailing mode of agricultural production. However, upland clearance and occupation must have been going on well before the nineteenth century, most likely facilitated by the spread of maize . . . The occupation of uplands accelerated during the last century . . . It involved the

> clearing of new land in the largely forested and sparsely inhabited hilly and mountainous upland regions . . . As long as land was still abundant, fertility management in upland cultivation still relied on fallowing the land. With continuing population growth, however, the pressure on land increased and intensification of land use became necessary when the expansion of arable land was outstripped by the population growth. This situation had come to prevail in all of Java after 1920.

This description could certainly apply to a number of countries and much more recent periods, and it reminds us that these upland cultivation trends are both typical in Indonesia and relatively ancient.

More recently, Indonesians have accomplished a successful Green Revolution in the lowlands. Associated with wonderful Javanese and Balinese farmers' expertise in paddy farming, and backed by policies on investment in irrigation, input subsidies, extension work, and transmigration policies, major technical breakthroughs on paddy helped Indonesians to achieve full self-sufficiency in rice from the mid-1980s up to the mid-1990s. In such a heavily populated country, this is a major political stake and success. It was mostly achieved in the lowlands. Precisely at this period, the country was experiencing a 7–8 percent annual economic growth, and urban and industrial development was swallowing up lowlands areas. The country rediscovered the limits of the Green Revolution, no longer able to fully feed its population of 200 million inhabitants. Imports of rice resumed around 1995.

Annex 2

Cocoa Farm Budgets and Methodology

The method used to evaluate budgets and rents is based on trusting relationships that have been established with planters in Noling and Tampumea for a number of years. We compared budgets based on their farms and experience. Thus, forest rent in the hills was evaluated by questioning the rare planters who had experience planting cocoa after forest and after grassland, and without herbicide. Likewise, alluvial plain rents were compared to situations in the hills—farmers who had cleared forest and planted cocoa on the plains and in the hills were questioned.

In each annex, the difference between the two types of plantation is more important than the absolute values. For example, when a planter reported that it takes 25 days to fell a forest plot on the plain and 35 days in the hills, the interesting point is the 10-day difference.

This method results in slightly different agricultural calendars and job durations for the same type of situation. For example, a cocoa farm established in the hills after clearing forest is represented in slightly different terms in Annex 2 and Annex 3. These slight differences reflect variety in job management and perception from one planter to another. However, one of the interests of this study is that very similar data were found for the same type of plantation.

The main assumptions used for the calculations, made in July 1997, apply to this period:

Price of cocoa	Rp 3,000/kg
Cost of labor	Rp 8,500/day
Exchange rate	Rp 2,600/$1

Depending on the region, labor costs of Rp 7,000 to 9,000/day in mid-1997, just before the dire monetary depreciation, may have been very slightly overestimated.

The opportunity cost of land has not been incorporated in the farm budgets. This assumption matches reality for the hills. While awaiting possible access for farmers to an oil palm project that might take place, there are very few alternatives to cocoa in the hills, therefore the opportunity cost of the

Table A2.1. Estimated Labor Productivity of Cocoa Harvesting and Pod Breaking in Sulawesi

	Plains	*Hills*
Yield (kg/ha)	2,200	1,500
Harvesting and pod breaking (kg/day dry beans)		
Peak season	50	40
Middle season	40	30
Lean months	30	20

land evaluated by the net profit of an alternative crop is close to zero. On the plain, an opportunity cost could be calculated on the basis of alternative crops such as orange or soybean, but it would also be limited. The aim here is to calculate the costs involved in the cropping system.

Important data resulting from field observations and used in the calculations concern harvest times, which may account for part of the plain rents and economies of scale related to high yields (see Chapters 14 and 15).

It must be stressed that these estimates were done before CPB had spread widely. This pest infestation increases not only the cost of pest control, but also labor and operating costs. Just after pod breaking farmers must split beans from the placenta. Prior to the outbreak of CPB, this was an easy operation that consumed a very small portion of the pod breaking time. When CPB strikes, splitting the beans that are stuck to their placenta by the CPB larvae becomes a time-consuming operation.

Annex 3

Cocoa Farm Budgets—Sulawesi Hills

Table A3.1. Appraisal of Forest Rent in the Sulawesi Hills during the Investment Phase of Cocoa Farms. Comparison of Forest Clearing to Grassland Clearing with No Use of Herbicides

		Days/ha after		*Input costs (Rp)*		*Output (Rp)*	
Month	*Agricultural operation*	*Forest*	*Grass*	*Forest*	*Grass*	*Forest*	*Grass*
Year 0 of cocoa planting (forest clearing)							
Year 1 of cocoa planting (grassland clearing)							
Jul/Aug	Slashing undergowth, manual tree cutting, and cutting wood in pieces	40					
Sep	1st burning	1					
Oct	Gathering unburned material and second burning						
	If fine weather	7					
	If bad weather	(45)					
Dec	Laying out rows and digging	10					
Oct/Nov	Nursery preparation (40 pods @ Rp 200)			8,000	8,000		
	With plastic bags	5	5	1,500	1,500		
	With coconut husks						
Oct	Path in the grassland, hole digging, and stick planting		10				
	Cocoa planting, including transport	7	7	50,000	50,000		
	Shade tree planting	1	2				
	1st clearing of grasses and small trees		30				
	1st special *Imperata cylindrica* clearing by 'subbe' uprooting		15				
	2nd special *Imperata cylindrica* clearing		15				
	Total—1st year	**71**	**84**	**59,500**	**59,500**		

Table A3.1. ***continued***

Month	Agricultural operation	Days/ha after		Input costs (Rp)		Output (Rp)	
		Forest	Grass	Forest	Grass	Forest	Grass
Year 1 of cocoa planting (forest clearing)							
Year 2 of cocoa planting (grassland clearing)							
	Planting various food crops	30	30				
	1st manual weed control	10	20				
	Harvesting food crops	40	40			300,000	250,000
	Replanting cocoa trees	1	2	800	1,600		
	Manual weeding	20	30				
	Formation pruning of cocoa trees	2	1				
	Pesticide spraying (3 rounds of DDT)		3		7,500		
	Fertilizer (0.20 bag urea × Rp 21,000)		1		4,200		
	Total—2nd year	**103**	**127**	**800**	**13,300**	**300,000**	**250,000**
Year 2 of cocoa planting (forest clearing)							
Year 3 of cocoa planting (grassland clearing)							
	Manual weeding	20	50				
	2nd formation pruning of cocoa trees	4	2				
	Replanting	0	2.5		1,600		
	Fertilizer (0.30 bag urea × Rp 21,000)	0	1		6,300		
	Pesticide spraying with DDT	0	3		7,500		
	Fungicide	0			6,000		
	Manual stem borer control	0					
Oct–Dec	Cocoa harvesting and pod breaking						
	Yield						
	After forest	4				240,000	
	After grassland						
	Harvests (5)	2.5					
	Fermentation						
	Drying	2.5					
	Total—3rd year	**30.5**	**58.5**		**21,400**	**240,000**	

Table A3.1. *continued*

Month	*Agricultural operation*	*Days/ha after*		*Input costs (Rp)*		*Output (Rp)*	
		Forest	*Grass*	*Forest*	*Grass*	*Forest*	*Grass*
Year 4 as an additional investment year for a cocoa farm established after grassland							
	Planting various food						
	Manual weeding		30				
	Formation pruning of cocoa trees		7				
	Replanting						
	Fertilizing		2				
	1 bag urea @ Rp 21,000				21,000		
	0.5 bag Kcl @ Rp 27,000				13,500		
	0.5 bag TSP @ Rp 34,000				17,000		
	Pesticide						
	Fungicide						
	Manual stem borer control						
	Cocoa harvesting and pod breaking						
	After forest						
	After grassland		4				240,000
	Fermentation						
	Drying		2.5				
	Total—4th year		**45.5**		**51,500**		**240,000**
Total (investment phases)		**204**	**315**	**60,300**	**145,700**	**540,000**	**490,000**
Theoretical cash flow (if rice were sold) (on 3 years if after forest, 4 years if after grassland)						**479,700**	**344,300**
Number of days devoted to food crops (planting and harvesting)		**70**	**70**				
Total (investment phases without food crops) 134		**245**					

Source: Survey by François Ruf and Yoddang in Noling, 1997.

Annex 4

Cocoa Farm Budgets—Sulawesi Plains

Table A4.1. Appraisal of Fertility and Lcation Rents on the Alluvial Plains of Sulawesi during the Investment Phase of Cocoa Farms after Forest Clearing. Comparison between Plains and Hills with No Use of Herbicides Assumptions of June 1997 (see annex 2)

		Days/ha after		*Input costs (Rp)*		*Output (Rp)*	
Month	*Agricultural operation*	*Forest*	*Grass*	*Forest*	*Grass*	*Forest*	*Grass*
Year 0 of cocoa planting							
Year 1 of forest clearing							
Jul/Aug	Slashing undergrowth trees and manual tree cutting	25	25				
Sep	1st burning	1	1				
Oct	Gathering unburned material and second burning						
	If fine weather	10	10				
	If bad weather	(30)	(35)				
	Laying out rows and stick planting	4	6				
Oct/Nov	Nursery preparation	7	9				
	40 pods on the plains, 50 pods in hills			8,000	10,000		
	With plastic bags made from rolls of plastic			6,000	8,000		
	Nursery maintenance (watering seedlings, spraying, 1 hour/day every two days for 3 months)	4	5				
Dec	Digging (average 100 holes/day)	8	11				
	Total—1st year	**59**	**77**	**14,000**	**18,000**		

Table A4.1. *continued*

Month	Agricultural operation	Days/ha after Forest	Days/ha after Grass	Input costs (Rp) Forest	Input costs (Rp) Grass	Output (Rp) Forest	Output (Rp) Grass
Year 1 of cocoa planting							
Year 2 of forest clearing							
Jul/Aug	Slashing undergrowth						
Jan/Feb	Planting cocoa seedlings (400 seedlings a day in average)	3	4				
Feb	Planting shade tree cuttings	1	1				
Feb	Planting paddy (+ some maize)	12	12				
Apr	1st manual weeding	8	8				
Jun	Harvesting paddy (900 kg)	35	40			504,900	504,900
	Slashing paddy stalks (mulch)	8	10				
Jul–Dec	2nd manual weeding	6	8				
	Pesticide spraying (2.5 packs of Sevin)	1	1	7,200	7,200		
	Formation pruning of cocoa trees	5	7				
	Fertilizer	0	0				
	Total—2nd year	**79**	**91**	**7,200**	**7,200**	**504,900**	**504,900**
Year 3 (calendar year 2 after planting)							
	3rd manual weeding	15	18				
	Replanting	1	1	800	1,000		
	2nd formation pruning of cocoa trees	10	15				
	Pesticide spraying						
	With Matador	2	3	72,000	72,000		
	Foliar fertilizer/ stimulants (atonic, metallic)			36,000	36,000		
	Manual stem borer control	2	2				
Oct–Dec	Cocoa harvesting and pod breaking (yield: plains, 120; hills, 80)	5	4			360,000	240,000
	Fermentation	0	0				
	Drying (5 harvests)	3	3				
	Total—3rd year	**35**	**43**	**108,800**	**109,000**	**360,000**	**240,000**
Total (investment phase)		**172**	**211**	**130,000**	**134,000**	**864,900**	**744,900**
Theoretical cash-flow (if rice were sold)						**734,900**	**610,700**

Table A4.2. Farm Budget during a Productive Year (Farm Established after Forest Clearing). Comparison between Plains and Hills with No Use of Herbicides

Month	Agricultural operation	Days/ha after		Input costs (Rp)		Output (Rp)	
		Forest	Grass	Forest	Grass	Forest	Grass
Year 5 of planting (year 6 after forest clearing)							
Yield assumption (kg/ha) (plains, 2,100; hills, 1,500)						6,300,000	4,500,000
Producer price assumption, July 1997, 3,000 Rp/kg							
All year	Harvesting + pod splitting with yield assumptions (kg/ha)						
	Peak months (3); plains, 1,270; hills, 960	25	25				
	Middle months (3); plains, 650; hills, 480	16	16				
	Lean months (6); plains, 180; hills, 60	6	3				
	Total harvesting + pod splitting	48	44				
All year	Fermentation						
	Two days of drying (no. of harvests)						
	Peak months (3); plains and hills, 6 each	9	9				
	Middle months (3); plains and hills, 6 each	6	6				
	Lean months (6); plains and hills, 6 each	3	3				
	Total drying labor	18	18				
	Removing suckers						
	Peak season	7	7				
	Middle/lean months						
	Canopy pruning	14	10				
	Manual weeding	7	7				
	Leaf collection						
	1st round before fertilization	10	7				
	2nd round	10	7				
	Fertilization (50 kg bags, 4 bags of each on both plains and hills, Rp/bag)	4	8				
	Urea (21,000)			84,000	84,000		
	KCl (27,000)			108,000	108,000		
	TSP (34,000)			136,000	136,000		
	Fertilizer transportation				6,000		
	Total fertilization			**328,000**	**334,000**		

Table A4.2. *continued*

Month	*Agricultural operation*	*Days/ha after*		*Input costs (Rp)*		*Output (Rp)*	
		Forest	*Grass*	*Forest*	*Grass*	*Forest*	*Grass*
	Insecticide (price/unit)	2	4				
	Drusban (7,500)			11,250			
	Lebacyd (12,500)				12,500		
	Hand sprayer depreciation			4,000	4,000		
	Manual stem borer control	3	3				
	Total	**123**	**115**	**343,250**	**350,500**	**6,300,000**	**4,500,00**
	+ 2–3 additional days of drying by middlemen (1,000 kg/day)	4	3				
	Total	**127**	**118**	**343,250**	**350,500**	**6,300,000**	**4,500,00**
	Cash-flow/year (daily wage assumption, Rp 8,500						
	If all work done by family					**5,956,750**	**4,149,500**
	If all work done by daily labor					**4,878,525**	**2,793,763**

Source: Survey by François Ruf and Yoddang in Noling, 1997.

Annex 5

Cocoa Farm Budgets with Herbicide

Table A5.1. Cocoa Farm Budget during the Investment Phase in the Uplands, Including Herbicide to Clear *Imperata cylindrica*

July 1997 rupiah

Month	*Agricultural operation*	*Number of days*	*Input costs (Rp)*	*Output (Rp)*
Year 0 of cocoa planting				
Year 1 of grassland clearing				
Nov	Slashing grasses other than mpeIrata	12		
	1st spraying of Imperata with Round Up (6 l @Rp 20,000)	2	120,000	
	2nd spraying of Imperata with Round Up (2.5 l @Rp 20,000)	1	50,000	
	Nursery preparation	8		
	With plastic bags		1,500	
	With Sevin		1,500	
	Pods (40)		8,000	
Dec	Hole digging	3		
	Total—1st year	**26**	**181,000**	
	Cash-flow			**(181,000)**
Year 1 of cocoa planting				
Year 2 of grassland clearing				
	Planting cocoa (without laying out rows)	3		
	Weeding in circles around the cocoa trees	3		
All year	12 insecticide spraying with 12 packs of Sevin @Rp1,000/unit	6	12,000	
All year	12 fertilizer rounds with 1 bag of urea @Rp21,000	6	21,000	
	Land preparation by hoe (and manual weeding)	6		
Mar	Paddy planting	12		
	Weeding by hoe	15		
	Paddy harvesting	35		297,500
Jul	Paddy stalk slashing	12		
	Cocoa pruning and replanting	2	1,600	
	Total—2nd year	**100**	**34,600**	**297,500**
	Cash flow			**262,900**

Table A5.1. *continued*

July 1997 rupiah

Month	*Agricultural operation*	*Number of days*	*Input costs (Rp)*	*Output (Rp)*
Year 2 of cocoa planting				
Year 3 of grassland clearing				
	10 fertilizer rounds with 2 bags of urea @Rp 21,000/bag	8	42,000	
	10 insecticide sprayings with 4 packs of Sevin @Rp 1,000/pack	6	4,000	
	Planting shade trees	1		
	Planting chili and tomatoes (3 cycles)	9		
	Manual weeding	9		
	Harvesting chili and tomatoes	30		
	Chili—20 l × Rp 300 × 24 harvests			144,000
	Tomatoes—Rp 4000 x 24 harvests			96,000
	Pruning	2		
	Replanting	1	800	
	Manual stem borer control	1		
	Total—3rd year	**67**	**46,800**	**240,000**
	Cash flow			**193,200**
Year 3 of cocoa planting				
Year 4 of grassland clearing				
	Last harvest of chili and 3 cycles of tomatoes	30		144,000
	6 rounds of fertilizer	6		
	2 Urea bags @Rp 21,000		42,000	
	1 KCl bag @ Rp 27,000		27,000	
	1 TSP bag @ Rp 34,000		34,000	
	10 insecticide sprayings with Sevin and Ripcord	6	35,000	
	Manual weeding	9		
	Formation pruning of cocoa trees	3		
	Replanting	0		
	Total—4th year	**54**	**138,000**	**144,000**
	Cash flow			**6,000**

Table A5.1. *continued*

July 1997 rupiah

Month	*Agricultural operation*	*Number of days*	*Input costs (Rp)*	*Output (Rp)*
Year 4 of cocoa planting				
Year 5 of grassland clearing				
	1 round of fertilizer	6		
	2 Urea bags @ Rp 21,000		42,000	
	2 KCl bags @ Rp 27,000		54,000	
	2 TSP bags @ Rp 34,000		68,000	
	10 insecticide sprayings with Ripcord	6	30,000	
	Manual weeding	7		
	Selective pruning of cocoa trees	3		
	Cocoa harvesting and pod breaking (80 kg, 5 harvests)	4		240,000
	Fermentation			
	Drying	3		
	Total—year	**29**	**194,000**	**240,000**
	Cash flow			**46,000**
Total—investment phase, Including food crops		**276**	**594,400**	**921,500**
Cash flow			**327,100**	
Number of days of labor Devoted to food crops		**128**		
Total—investment phase, Without food crops		**148**		

Source: Survey by François Ruf and Yoddang in July 1997.

Annex 6

Short-Term Technical Follow-Up Actions

Short-term technical follow-up actions are proposed in three categories:

- Additional socioeconomic data and research
- Technical but participative research, conducted by researchers with the active involvement of extension workers and farmers
- Possible direct recommendations for extension and development operations.

The Need for Additional Data Collection and Research

Unless recent surveys fill the gap, more needs to be known about the issues discussed below. The last one mentioned—tree-crop replanting—may be the most important because rubber, cocoa, and coffee involve tens of thousands of families, millions of hectares, and billions of dollars.

Fruit Trees and Fruits

How did fruit tree farming systems, such as orange, mango, *salak,* and even bananas, and their marketing chains develop? Our study highlights a strong and spontaneous dynamism. Do official projects promoting fruit trees give enough consideration to this smallholder dynamism? Are policies too focused on estates and corporate projects?

Livestock and New Technologies

Have Indonesian policymakers conducted a complete analysis of husbandry systems and their potential on national and regional urban markets?

Downstream Activities

How can the incomes and sustainability of upland farmers be improved through downstream activities such as agricultural products processing?

With the very limited exception of small coffee-dehusking mills and simple ginger processing units, usually controlled by middlemen, we did not find any examples of this often-mentioned concept.

Gender Issues

Gender issues and the impact of various innovations on them are not studied in this report and clearly should be addressed in a future survey. Any such survey should be sure to look at how the family divides its time between farming and other work. In some cases, the man works off the farm, and the wife and children work the farm. In other cases, women work in factories while men stay on the farm. More data are required on these situations and their impact on innovation decisions. For example, when women become the household head, what types of support do they need? What type of initiatives do they take that may need to be shored up?

Tree-Crop Replanting after Grasslands

Our study found that under some tree-crop-based systems, such as the coffee-ginger system in Bengkulu, it is possible to erase shifting cultivation for several decades. Some cocoa and rubber farmers have begun to show strong interest in replanting their trees on land reclaimed from *Imperata cylindrica* grasslands. The use of herbicides to clear the grasslands seems on the way to being widely adopted throughout Java, Sulawesi, Sumatra, and Kalimantan. Can these herbicides be used moderately and efficiently to recolonize these "degraded" lands? The need is great for more evidence and observations on farming systems being able to lower the fallow duration and to fight or cleverly use *Imperata cylindrica* and other "weeds" to reclaim so-called degraded land. In addition to data collection on farmers' current practices, innovations, and experiments, a participatory research should be launched on the same issue.

Additional Participatory Research

Tree-Crop Replanting after Grasslands

A network of on-farm trials involving replanting tree crops such as cocoa, coffee, and rubber on land reclaimed from *Imperata cylindrica* and other weedy grasslands should be set up in selected uplands. In addition to smallholders' participation, the trials might involve producer and exporter associations and perhaps even an international importers' association. The trials could be set up in only two provinces to keep the costs low. It is important that a long-term budget be established for these trials. Although signficiant findings may emerge after 2 years (the typical length of a research project), a serious appraisal of farmers' decisions and of the behavior of the trees during their life cycle requires at least a 10-year trial period. Indonesian research and development agencies are missing the benefits of this type of long-term experiments.

The Real Effect of Erosion

To better harmonize the economic objectives and soil conservation goals of upland agricultural projects, there is a need for better appraisal of erosion and its effects both in the upland project sites and in the lowlands downstream. Being able to evaluate the direct and indirect costs of erosion could facilitate funding transfers from lowlands to uplands, in order to fight externalities.

Plantains as a Staple Food

Potatoes and other annual crops are being promoted as new staple foods in Indonesia, and plantations of sweet bananas for export are developing. Why not also think about plantain adoption in Indonesia? Under a similar ecology, millions of African families intensively use plantains as staple food. Cases of innovations that imply deep change in diet habits are not easy or common, but they have happened.

Recommendations for Extension Services

More Mobility among Extension Staff

One of the roles of extension staff is to accelerate information circulation, including information generated by smallholders' initiatives. This was done, for example, in the case of vanilla. One way to enhance this role is to move extension workers through regions of similar ecologies and farming systems. Even when they are based in one province for three or four years, they should be sent to other regions to exchange experiences with colleagues and farmers. This may help to bring information up from below more rapidly. Tactically, the ability of extension workers to identify smallholders' innovations should be encouraged and clearly used as a criterion of professional promotion. This may help reluctant extension staff to recognize that they can learn from farmers as well as teach them.

Technical Options Open to Farmers

If alternatives for resolving a problem exist, extension staff should let farmers choose the one they want to use, or at least have open discussions with them about what to do. This is not a new concept, but it is not always implemented. One example concerns various attempts at cocoa pod-borer control. Enforcement of solutions may be theoretically justified by externalities and free-riding. Farmers who do not apply one solution may harm their neighbors' farms and benefit from the actions for which other farmers pay. However, in practice, authoritarian measures do not prevent some farmers from escaping their obligations. Moreover, smallholders may question the technical efficiency of measures imposed on them by the extension service and prefer to use an alternative solution. In the pod borer case, rather than enforcing doubtful solutions, the role of extension services would be to work with the farmers to test alternative solutions (as presently done by ASKINDO, ACRI, and Jember researchers in two regions of South Sulawesi) and in the interim let farmers carry out their activity freely and eventually encourage efficient collaboration in neighboring regions.

Leave Marketing Options Open to Farmers

It is highly recommended that the KUD monopoly be prohibited from trying to take control of any marketing chain, either of agricultural inputs or commodities. Cooperatives should be encouraged, but they must compete with other marketers, as is already the case in several regions.

Recommendations for Projects and Policies

Planting Material Certification

Planting material is the major input in tree crops and thus the main capital of the farming system. Germplasm manipulation is one of the best ways to improve planting material but also the most risky. As was shown in chapter 13, widespread adoption of a certain type of cocoa hybrid would have been a disaster because it proved to be extremely sensitive to pod borer. Fortunately, farmers obtained their planting material from various sources, which probably lower the incidence of the borer infestation. Although a free market and tight competition may be the best way in the long term to guarantee high-quality planting material, there is a need for a relatively homogeneous product. Therefore, scientific means of evaluating clone features must be used to guarantee both the quality of the planting material and conditions of "perfect competition."

Credit Issues

Obtaining credit is a classic issue in agriculture. The dilemma is that credit is often proposed to those who do not need it and when they do not need it. For instance, it is useless for the government to subsidize credit to finance a technical package that has not convinced farmers. A prerequisite would be to fund information, through demonstration plots, for example, and wait for the copying effect to play its role before launching subsidized credit at a regional or national level. It may also be also a waste to deliver credit to people who already have decided to invest.

The main difficulty is thus to identify when it is the right time to devote funding to credit. Tree crops offer a number of examples and part of the answer. According to our surveys on cocoa and coffee in several countries, formal credit is often not necessary in a smallholder pioneer phase. Farmers are still young and have low family expenses. They also benefit from forest and new crop rent effects. Once the boom is launched, credit can even be dangerous as a strong investment multiplier that may contribute to a surplus on the international market and more important give bad habits to landowners. However, when replanting time comes, trees are getting older and incomes are dropping, while family expenses tend to increase. This is the time when credit is needed, but often none is proposed or is offered much too late.

So when is the right time to propose credit to smallholders? With regard to tree crops, it is in part when farmers recognize that replanting with high-quality planting material is worthwhile. All indicators seem to show that the rubber clones have reached that stage (chapter 12). It also might be the right time for credit to replant cocoa and other tree crops after clearing *Imperata* and other grassland types (chapter 15).

Landownership

Some innovations such as tree-crop adoption do not require official land titles, since many smallholders are ready to take the risk of being expelled after a few years of good returns. Nonetheless, better land security and respected rules remain a factor of more sustainable agriculture. At least extension services and regional projects should show that they are sensitive to this issue and that they take it into consideration in their approaches. They may also participate in collecting data and forwarding information in this field.

Small Factories and Increased Value Added in the Uplands

Increased value added in smallholdings through more downstream activities, such as processing of agricultural products, is an ancient and universal concept, but it still requires additional support to be efficient in the uplands. One of the successes of the Green Revolution has been the development of many small rice mills in the villages. Some coffee regions have also introduced small processing operations. Could something relatively small also be set up for palm oil production? We did not select oil palm schemes in the case studies because most schemes are recent and set up in the lowlands and under large-scale projects with a corporate "nucleus" and smallholder "plasma." However, it remains to be seen whether small-scale oil palm projects might be successful in some uplands.

With possibly more direct impact in the uplands, public policies should also explore and encourage investments in small-scale fruit juice processing units. For instance, the development of orange trees has been studied in several upland regions of Indonesia. This type of diversification towards fruit trees is also observed in uplands of South America and West Africa. It is an international trend in tropical countries because it goes along with increasing population and cities in the humid tropics, increasing national and regional markets (within Southeast Asia or within West Africa). There is also an enormous potential in tropical fruits, more oriented toward exports to Europe and US. These trends in fruit tree adoption should be accompanied by downstream investments, hat seem to remain the best opportunities to generate linkages to non-agricultural development.

Food Processing Applied to Food Trees

Because trees are a key component of upland agriculture, one way of maintaining the uplands contribution to Indonesia's staple food supply could be to increase the value of food trees such as jackfruits and breadfruits. One can even imagine converting these traditional home garden trees into "miracle" commodities that would promote their own Green Revolution. The idea, however, is to achieve such a revolution not so much by genetics as by food processing technologies. The challenge, then, is to find ways to process food from these trees for either or both human and livestock consumption.

Promoting Nonagricultural and Service Activities in the Uplands

One reason for the decline in rice production is the progressive takeover of irrigated land by housing and industrial buildings. Development of service activities in the uplands could help make farms and households more sustainable in the uplands. Services require less land, less hardware and capital than industries. Service companies can more easily set up in uplands than can industries. For instance, if a large multinational company needs a communication center with 50 persons answering phone calls from customers, the main input is people with an excellent English level. These companies may now put this type of center in the uplands of Bangalore in India rather than in expensive Boston or London suburbs. This type of service activity also may be developed by national companies. Finally, if such activities attract infrastructures and people in the tropical uplands, they may reduce non-agricultural pressure on the most fertile lowlands.

Glossary

Agroforestry. Agroforestry covers a large spectrum of concepts. In its broadest perspective, agroforestry can be defined as a set of land use practices involving the deliberate combination of trees (including shrubs, palms, and bamboos) with agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence. The spatial and temporal organization of the components is manipulated directly to achieve positive ecological and economic interactions between the components (definition held by a group of researchers contributing to a book entitled *Agroforestry and Biodiversity Conservation in Tropical Landscapes*, edited by G. Schroth and others, forthcoming 2004).

According to that definition, especially with the "temporal" adjective, one can say that shifting cultivation with long rotation enabling fallows to return to a forest stage is one of the very first agroforestry systems. When one refers to shifting cultivation, the crops are usually only annual, but the tree function is brought by natural forest regrowth. This also applies to the concept of *tree crop shifting cultivation* put forward in this study about the alternatives to *shifting cultivation.*

According to that definition, a system with only one tree species can fit the concept that the tree is manipulated directly to achieve positive ecological and economic interactions.

However, in this book, when we refer to *agroforestry systems*, we usually consider a combination of at least two trees.

- A *simple agroforestry* subsystem, such as shaded cocoa or coffee farms, consists of one tree species that is more or less cropped exclusively and that is shaded by another tree.

- In *complex agroforestry* subsystems, farmers combine various tree species on the same unit of land, even though one tree species may temporarily or permanently dominate. An example is the jungle rubber systems in south Sumatra.

Differential rent. The concept of *differential rent* was introduced by Ricardo in 1815. He observed that farmers usually grew wheat on the most suitable soils. As population and demand increased, farmers grew wheat on less and less suitable soils. This led to a cost difference between varying ecological settings. As long as the price of wheat covered production costs in the least suitable areas, farmers cultivating the best land enjoyed extra profits, which Ricardo referred to as *differential rents*.

Fertility rent. The *fertility rent* is a typical differential rent in the sense of Ricardo. For instance, the fertility rent of alluvial plains is approached through the difference in the number of days of labor and through the difference in the operating capital required to produce a metric ton of cocoa in the plains and in the hills. However, the *alluvial plain rent* also integrates a location rent.

Forest rent. The *forest rent* is a differential rent applied to a commodity, defined as the difference in production and investment costs between a ton produced on a farm established just after a forest is cleared and a ton of the same commodity produced by replanting on fallow land or after felling of the first plantation. The cost difference is directly related to ecological changes and reduction in the benefits provided by the forest. This is not a simple problem of fertility or erosion in the uplands. The benefits include low frequency of weeds; good top soil fertility; moisture retention due to high levels of organic matter in the soil; fewer problems with pests and diseases; protection against drying winds; and the provision of food, timber, and other forest products.

Indirect terracing. An indirect terrace is a small terrace wall of 20 to 40 cm, which is not high enough to make the surface terrace horizontal. As a result, the terrace profile remains oblique but the terrace reduces erosion.

Intercrop. This is the basic practice of planting two crops or more than two crops in association in the same field. For instance, young coffee or cocoa seedlings can be intercropped with maize. Each coffee seedling is surrounded by maize.

Location rent. The concept of *location rent* refers to market accessibility and is used in the classic meaning of the term given by Von Thünen (1826). For instance, if it cost 6 cents a kilogram to transport cocoa from the hills to cocoa buyers based in the plain, smallholders who own cocoa farms in the plain benefit a location rent of at least 6 cents compared to smallholders in the hills. One should also include the advantages of lower costs of inputs such as fertilizers, possibly the advantages related to price information acquired earlier than those in the hills; this facilitates more efficient buying and selling strategies, resulting in higher prices and lower costs.

Plain rent. The combination of fertility of rich alluvial plains and location rents form a *plain rent*. For instance, in the alluvial plains of Sulawesi, the cost of producing and selling one kilogram of cocoa delivered to the middleman's premises is 40 percent lower than for cocoa from the hills. On alluvial plains where lowlands give way to uplands, soils are fertile, yields and revenues are high, and producers can afford to buy fertilizers and herbicides. The effect of forest rent is relatively negligible, at least in relation to soil fertility and weed control. With high soil fertility and easy access to the plains (and taking forest policies into account), farmers prefer to plant on grassland in the plains rather than forest land in the hills.

Smallholder. The term *smallholder* may describe a wide range of producers since there is no absolute criteria. The most important point is a strong reliance on family labor and limited use of hired labor. However, a relatively old coffee smallholder may well put all his coffee farm under a sharecropping contract and remain a smallholder in reference to the relatively small size of his farm and revenues. Another criterion may be little or no mechanization, but in some sectors such as cocoa, even large planters have no mechanization. Another criterion is the dependency upon middlemen and exporters, possibly cooperatives, to access to export markets. Unlike large commercial farms, smallholders usually do not export directly. One can find exceptions, but smallholders' systems are normally characterized by minimal resources and capital.

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The development of upland agriculture has become an increasingly important policy objective in Indonesia over the past decade. Despite the successful Green Revolution in the lowlands, the plight of millions of upland farmers remains a significant challenge.

Financial capital has improved the technology necessary to help maintain sustainable systems, improve crop yields, decrease loss due to pests and disease, and conserve land in ecologically fragile areas. The formation of biological capital has provided new techniques for improving the sustainability of upland agriculture and the welfare of farmers. Some of the most successful improvements have been the result of innovations by the farmers themselves. Together, these advances help make tropical agriculture in the region sustainable by enabling adaptation to ecological and market changes.

This book reports the results of fieldwork conducted by the editors and other experts in some 40 regions of Indonesia from 1989 to 2001. The authors synthesize the work of researchers from a variety of disciplines, backgrounds, and training with their own in-depth research. The result is a wide-ranging and insightful history of the successes and failures of efforts to sustain and improve upland agriculture and access to markets. It considers in a detailed way the importance of trees and perennial crops as the main patrimony of upland farmers and as privileged channels to international and regional markets, despite frequent boom-to-bust price cycles. The authors also look at the role policy can play in facilitating replanting and tree crop diversification, discuss the potential of off-farm diversification and multifunctionality, and consider other ways to enhance entrepreneurship and welfare in the uplands.

Of interest to agricultural policy specialists and development practitioners, as well as students and scholars in the field, this book helps demonstrate the ways in which appropriate sustainable development efforts can help alleviate poverty and enhance people's lives.

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