Garrity, D.P. 1998. Addressing Natural Resources Management Challenges in the Humid Tropics Through Agroforestry Research.
*In:* Lal, R. (Ed) Soil Quality and Agricultural Sustainability. ISBN 1-57504-082-4. Ann Arbor Press. Pp. 86-111.

SEVEN

# Addressing Key Natural Resource Management Challenges in the Humid Tropics Through Agroforestry Research

Dennis P. Garrity

## INTRODUCTION

The countries in tropical Asia have begun to lay the foundation for sustained economic growth. Their remarkable progress has been heralded as a source of encouragement for developing countries throughout the world. This optimism is well-deserved, but should not be misinterpreted as victory achieved. Hundreds of millions of people remain in poverty, and the momentum of development has frequently accelerated the degradation of the natural resource base. These pressures are particularly acute in uplands of the region. The rate of forest degradation and conversion has increased in recent years in those countries where significant forests remain. In other countries, such as the Philippines, Thailand, and Vietnam, deforestation rates seem to have declined, but this is due to the fact that these nations have virtually exhausted their exploitable natural forests (Figure 7.1). The expansion of degraded *Imperata cylindrica* grasslands is often the consequence of this rapid conversion process. The human populations inhabiting the uplands continue to increase. They are accelerating pressure on the fragile sloping uplands to provide their food and cash income.

Policy and technological change can have a major role in assisting national governments and farming communities to better cope with the imperative to manage natural resources more sustainably. The International Center for Research in Agroforestry's (ICRAF's) Southeast Asian Regional Research Program is engaged in both policy and technology development with a range of collaborators. Our aim is to exploit the recognized potential of agroforestry to help mitigate deforestation and land depletion, and reduce rural poverty. The two broad issues we focus on are the development of alternatives to unsustainable slash-and-burn, and the rehabilitation of degraded or degrading upland ecosystems.

Agroforestry systems already provide a major contribution to the sustainability of agriculture in the Asian tropics, and in the conservation of protected ecosystems. However, their role has only recently been given wide recognition. Agroforestry solutions must be carefully assessed. The research base for prescriptive action is still quite weak. This has led

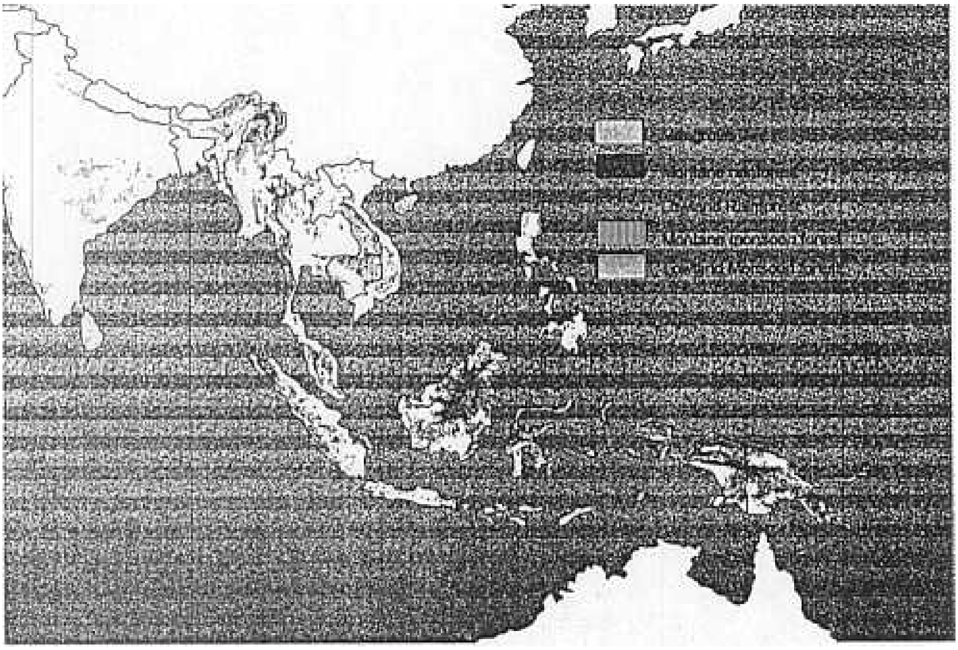

*Figure 7.1. Forest cover in Southeast Asia (data from the World Conservation Monitoring Center).*

to overoptimism in promoting some technologies resulting in disappointing results, such as with alley cropping (Sanchez, 1995). Agroforestry has only recently been approached as a scientific pursuit. We must rapidly deepen the base of practical knowledge to guide the implementation of agroforestry-based interventions.

The conventional view of agroforestry is that it is "the deliberate cultivation of woody perennials with agricultural crops on the same unit of land in some form of spatial mixture or sequence." This has led many people to see it merely as a set of distinct prescriptions for land use. This limits its ultimate potential. We now see agroforestry as the increasing integration of trees in land-use systems and conceive of it as the evolution of a more mature agroecosystem of increasing ecological integrity. Leakey (1996) has proposed that agroforestry be considered as a "dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and range land, diversifies and sustains smallholder production for increased social, economic, and environmental benefits." This definition is currently being refined by ICRAF as a more holistic concept of agroforestry. It evokes the process of integrating the variety of current agroforestry practices into productive and sustainable land-use systems. Land use becomes progressively more complex, biodiverse, and ecologically and economically resilient. This new vision of agroforestry is transforming ICRAF's approach. This chapter will show how it is imbedded into our research agenda in Southeast Asia.

The chapter reviews the issues being tackled and the progress made to employ agroforestry as a means to increase productivity while protecting the land and biodiversity resources of the humid tropics. Our work in tropical Asia is targeted toward three distinct upland ecosystems: the forest margins, *Imperata* grasslands, and hill-slope farmlands. Our work is enhanced through participation in two global programs: the CGIAR (Consultative Group on International Agricultural Research) systems-wide program on Alternatives to Slash-and-Burn (ASB) (van Noordwijk et al., 1995a), and the Sustainable Agriculture and Natural Resources Management Program (SANREM, 1996).

The first part of the chapter focuses on the hypothesis that agroforests are uniquely suited to substitute for the environmental protection benefits of natural forests when forest conversion occurs. It also examines the role of agroforestry in buffer zone management on the boundaries of protected forests and ecosystems. The second part examines key research issues that may guide rehabilitation of *Imperata* grasslands toward more intensive land use. The last part reviews the role of agroforestry in the sustainable cultivation of sloping lands.

## THE FOREST MARGINS: EVOLVING COMPATIBLE LAND USE SYSTEMS FOR FOREST PROTECTION

Successful action to mitigate tropical deforestation depends upon a more comprehensive understanding of the forces driving this process. Research in Brazil, Cameroon, and Indonesia (the core countries involved in the ASB program) has clarified that these driving forces are dramatically different across the continents, and that they vary locally within regions of individual countries as well. Mitigation efforts must address the interacting forces within each nation and locality.

We are examining two basic issues: Where forest conversion is inevitable, or has already occurred, what are the preferred land uses that best protect watersheds and provide the environmental services that natural forests would have provided? And, where forest ecosystems have been designated for full conservation, how can the boundaries best be protected? We examine the agenda for each of these cases in turn.

### Retaining Environmental Benefits when Forest Conversion is Inevitable

In the Indonesian context we observe that a substantial amount of large-scale conversion of natural forests to other land uses is inevitable in the future. This conversion is driven dominantly by pressures to convert forest land to large-scale agricultural and forest plantation enterprises, and partially by the unplanned objectives of swelling populations of local smallholders who seek to make a living through the conversion of forests to smallhold farms. We note, however, that the new land uses vary greatly in their ability to substitute for the environmental services provided by natural forests.

#### *Agroforests on Production Forest Land*

In Indonesia, much of the land designated as Production Forest has been so degraded by inappropriate logging practices that regeneration of forest has not occurred. Devastating fires have intensified the degradative processes (e.g., 1994, when an estimated 5 million hectares were burned). The Ministry of Forestry has sought to keep land designated as Production Forest from being settled by smallholders. However, hundreds of villages already existed traditionally on lands that were classified as Production Forest only in recent decades. These villagers have often evolved complex agroforest land use systems by cultivating mixed perennials with their food crops after slash-and-burn as a logical part of their livelihood strategy. These agroforests are predominantly based on rubber, dipterocarp resin, or fruit species, with timber species husbanded as a component.

Farmer-evolved agroforests often resemble natural secondary forest systems in structure and ecology. The trees provide food, fuel, and cash income. The agroforest accumulates a carbon stock that in some systems may be maintained indefinitely. There are many examples of agroforests in the humid tropics. An outstanding case is the 'damar' agroforest system in Lampung, Sumatra, Indonesia (Michon et al., 1995). Over the past century, local populations have extended the cultivation of the dipterocarp tree *Shorea javanica*, which is tapped to yield a resin that is sold for industrial products on the national and international markets. This man-made forest now extends over some 10,000 hectares on production forest land in Lampung. It harbors a major proportion of the natural rainforest flora and fauna species (Michon et al., 1995). There are many indirect sources of evidence that soil fertility levels are maintained over long periods, and that soil organic matter levels increase in these mixed systems (see the review of literature by Torquebiau [1992]).

We hypothesize that these mixed tree-crop systems, particularly complex agroforestry systems or 'agroforests,' provide a superior alternative to other land uses in protecting watersheds from soil erosion and flooding risk, conserve a greater amount of biodiversity, and provide a greater sustained source of income generation for local communities than other forms of crop or tree monocultures. Our research on these systems, and that of others, is accumulating empirical evidence that supports this (e.g., de Foresta and Michon, 1997; Salafsky, 1993; Momberg, 1993; Mary and Michon, 1987). Thus, we find that the objectives of smallholder communities practicing such systems may be more compatible with those of national governments in protecting watersheds and biodiversity than has previously been assumed.

The most widespread agroforest system in Indonesia is rubber agroforestry (or 'jungle rubber') which occupies over 2.5 million hectares (Gouyon et al., 1993). In this system rubber trees are the main component, but many other species of fruit and timber trees are combined with rubber, either intentionally or through natural regeneration. The rubber seedlings are established as intercrops planted along with food crops in a slash-and-burn cultivation system. After the 1-2 year cropping phase the plot is left alone and the rubber trees mature along with the secondary forest regrowth. Biodiversity levels often approach those of natural secondary forest (de Foresta and Michon, 1997; Thiollay, 1995).

*Tenure reform.* Official recognition of local land and tree tenure systems would underpin their security and enhance the development and expansion of agroforests. Public sector assistance would further strengthen the trend toward smallholder tree-based land use systems. Smallholder communities could then contribute substantively to the national production objectives for which the production forests exist. Complex agroforests are one of the most promising solutions to transforming unsustainable slash-and-burn systems.

Research and case study experiences are needed as a foundation for policy reform to enable communities to obtain more secure tenure and to make aggregate contributions to the economy. Detailed protocols for developing management agreements between local populations and the national government are essential. ICRAF and its partners in the ASB Program are examining how viable instruments may be designed at three levels: the household, the community, and the regional level. We are focusing on management mechanisms at the community level that provide an appropriate degree of tenurial security while ensuring that the environmental and production objectives of the national government are met. ICRAF is coordinating a project with the University of Indonesia, LATIN (an NGO), CIFOR (Centre for International Forestry Research), the Ministry of Forestry, and local government to develop new instruments of tenurial security for the *damar* agroforest communities of Krui in Lampung Province. The work is based on a solid scientific understanding of the agroecology of these agroforests developed during past several years (Michon et al., 1995). A successful outcome will provide a basis for implementation of similar tenurial instruments with the communities that are the *de facto* local managers of Production Forest land in enclaves all over the country.

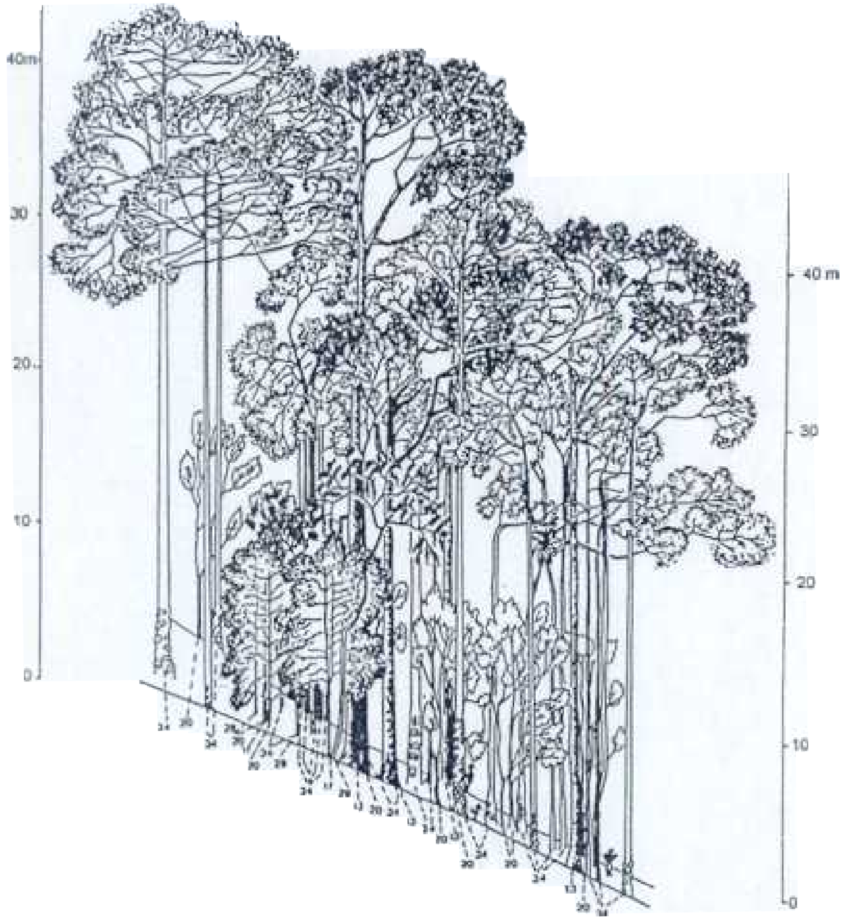


*Figure 7.2. Example of a mature agroforest designed for both profitability and sustainability in smallholders' conditions. From de Foresta and Michon (1997).*

*Environmental impacts.* Data on the comparability of the environmental services of agroforests vis-à-vis natural or plantation forests will be required. The ASB Program is estimating the implications of alternative land uses, including various types of agroforests, on carbon sequestration, greenhouse gas emissions, and soil erosion (van Noordwijk et al., 1995a). It has been shown, for example, that agroforests are significant sinks for methane, a greenhouse gas generated by wetland rice and other annual crop systems.

De Foresta and Michon (1997) have emphasized that agroforests are successful only when they meet smallholders' income needs. They note that such a system is usually composed of two sets of commercial tree species suited to local conditions, one set providing regular cash income (e.g., rubber, resin) and the other providing seasonal or irregular cash income. Such composition ensures economic and ecological viability of the forest in the long run, provided that clear tenurial rights on the basic units are recognized. Figure 7.2 is a cross-section of an Indonesian smallholder agroforest that illustrates these objectives.

## *Segregate or Integrate Nature and Agriculture?*

The issue of partially conserving biodiversity outside protected areas through complex agroforests needs to be critically assessed. Conflicts between 'nature' and 'agriculture' can

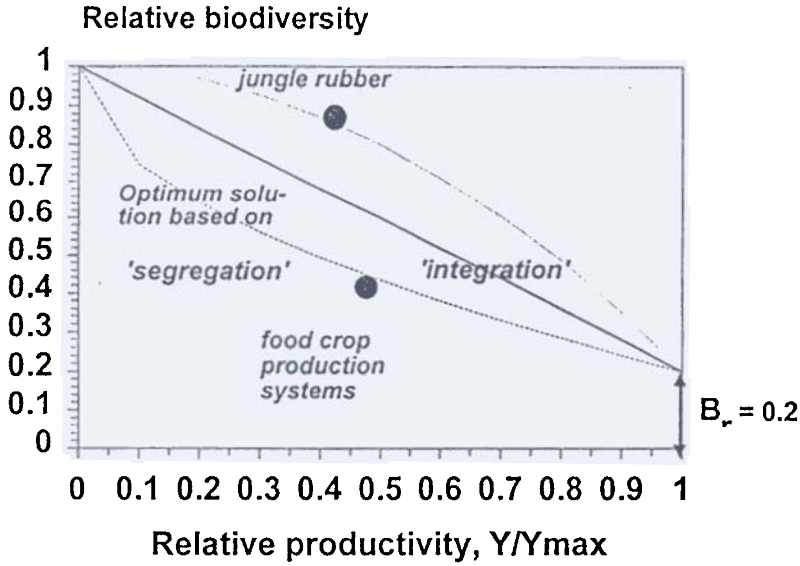


*Figure 7.3. Hypothesized relationship between relative productivity and relative biodiversity for different land use systems. From van Noordwijk et al. (1995b).*

be resolved by segregating nature from agricultural land by designating areas of full protection, or by integrating nature into the agricultural landscape through production systems that ensure conservation of a major part of the biodiversity of the natural forest (van Noordwijk et al., 1995b). Multifunctional forests and agroforests are examples of the 'integrate' option. Mixed strategies may be envisioned where nature reserves coexist with agriculture. Biodiversity will then vary among the facets of the landscape.

Our research is putting strong emphasis on assessing the viability of the 'integrate' option. Van Noordwijk et al. (1995b) proposed a simple model to examine the decision framework (Figure 7.3). The figure illustrates the hypothesis that as relative productivity of different agricultural systems increases, the rate biodiversity loss will vary among systems. It illustrates the presumption that relative biodiversity tends to decline more drastically with productivity increases in food crop systems than in jungle rubber agroforestry. This is because the rubber-based system tends to recreate a forest structure that nurtures a range of niches that can be filled by other natural species without detrimental effects on productivity. If this is the case, then relative agricultural intensification in such types of agroforest systems may be compatible with a major degree of biodiversity conservation. We are currently examining the implications of this model by surveying the level and nature of the biodiversity maintained in a wide range of agroforest types in Sumatra.

Can smallholder jungle rubber systems be made more productive while retaining substantial biodiversity value? ICRAF and GAPKINDO (the Rubber Association of Indonesia) are investigating this issue in a collaborative project implemented with smallholder rubber farmers in several parts of Sumatra and Kalimantan (Penot, 1996). Eighty-four percent of the rubber area in Indonesia is cultivated by smallholders, but the latex yields are low (generally about 500 kg/ha/annum). The most important innovation to increase productivity is the use of improved rubber germ plasm, particularly modern clones. The public sector has encouraged the adoption of estate-type monoculture systems, but these require levels of investment that are so high that project support has only touched about 10–15% of the smallholder population during the past 25 years.

We hypothesize that smallholders can substantially increase their rubber yields by incorporating new germ plasm into their present jungle rubber or mixed agroforestry systems, and that this would enable a much broader advance in productivity than investing in intensive monoculture systems. This concept for rubber development would also be more conducive to the retention of the biodiversity conservation benefits of these mixed systems. But currently no one knows how improved clones or populations perform in such systems. We've developed a network of trials with scores of farmers across a spectrum of Indonesia's smallholder rubber growing conditions in Sumatra and Kalimantan, in which we are comparing the performance of modern germ plasm with the local material under a range of management systems.

Allied with this work are a number of in-depth studies on the component interactions in rubber agroforestry systems. These seek to build a predictive understanding of the competitive environment for light, nutrients, and water between rubber and the cultivated and natural forest species associated with it. These species interactions determine the total system's productivity of rubber agroforestry. Field research on agroforest systems must cope with cycles that extend over decades. There is typically a gap of several years between establishment and production. Computer modeling is particularly well suited to assist in the design and analysis of such long-term research efforts. We have a major simulation modeling effort embedded in this work to guide and extrapolate the results of research on such systems.

At this point we have examined the issue of land uses that may best provide favorable environmental services when forest conversion inevitably occurs. What can agroforestry research contribute to protecting the boundaries of natural areas designated for full protection? In such situations we must view the research approach from a very different perspective.

## Agroforestry for the Buffer Zones of Protected Ecosystems

National parks and nature reserves are the last-ditch bulwarks of protection for the priceless biodiversity resources of the humid tropical forests. They are under enormous threat of encroachment virtually everywhere. The classical method of preserving a natural area has always been to declare it off-limits and to enforce exclusion by local people. Boundaries were delineated and guards patrolled. Unsurprisingly, this isn't working. It has often resulted in serious conflicts of interest and hostility between the enforcement agency and the local communities. Enforcement alone didn't work in most countries, either because population pressure on the land was too great, the gain captured by local elites by encroachment was too lucrative, or the costs of enforcement were too high. What might be the role of agroforestry in preventing these protected forests from degradation or ultimate conversion?

MacKinnon et al. (1986) defined buffer zones as "areas adjacent to protected areas on which land use is partially restricted to give an added layer of protection to the protected area while providing valued benefits to neighbouring rural communities." Wind and Prins (1989) defined them simply as "areas outside of parks that are designed to protect parks." The term has also been used to describe almost any initiative involving people that takes place near a protected area.

In this situation we have a domain of protected forest, a boundary, and land outside the boundary (converted forestland or agricultural land). We can specify the problem as identification of a suite of conditions that reduce or eliminate the economic 'necessity' for smallholders (or large-scale operations) to encroach across the protected-forest boundary. There are now many projects in the tropics called integrated conservation-development projects (ICDPs) that are attempting to save particular natural areas using this approach. Unfortunately, there is a widespread assumption among practitioners of the ICDP approach that people made better off by a development project will refrain from illegal exploitation of a reserve area, even if no enforcement is practiced. Wells and Brandon's (1992) global review of ICDPs found absolutely no evidence to support this. Such expectations are naïve: a social contract between communities and outside stakeholders must include enforcement mechanisms in tandem with the development benefits received.

Compensation to communities in terms of development activities may take many forms. Most projects attempt to encourage improved natural resource management practices in the areas outside the reserve. The objectives are to increase people's incomes, and to intensify their production systems away from the more extensive, environmentally-degrading systems they may currently practice. There is growing interest in the development of more intensive land use systems on the margins of protected forests and to identify policy and technology directions to underpin these efforts.

Let us first examine the simple case which assumes that no net immigration is occurring. In this case, boundary protection may be conceived as a function of reasonable enforcement combined with provision of more favorable conditions for the intensification of land use. The hypothesis is that if local livelihood systems can be improved, then the propensity to encroach into the protected area will be reduced. Since there is some risk to local people associated with encroachment, advances in the alternative livelihoods outside the boundary increases the perception of their gains exceeding their risks. The threshold risk is a 'cost' to the encroacher, and these costs increase relative to the returns in other enterprises.

After examining the base conditions of the local actors and the land use systems currently practiced, a range of alternatives (or combination of alternatives) may be proposed that meet global environmental objectives and local economic objectives. A subset of these may then be selected that would evidently reduce the propensity for encroachment. Then the type and level of outside investment to assist local actors to implement these land uses is determined.

So far we have dealt with protection as a function of enforcement and land use intensity. In many real-world situations (but not all) there are two other important factors: migration and off-farm employment. If immigration is occurring, the accelerated population pressure will destabilize the balance between intensification and enforcement. Migration must be controlled in the communities on the boundary. In some areas this has been successfully achieved in mature communities through local land tenure systems (see Cairns, 1994 for an example in mature Minangkabau communities in Indonesia). But in most pioneer communities, local control of migration is problematic. A further complication is that if success is achieved in increasing land productivity, this may actually attract new migrants and exacerbate inmigration pressure.

Conditions in the wider economy play a major role in affecting migration. Migration trends may at some point be reversed, and net outmigration become dominant as the national economy develops. Also, off-farm employment for village residents in the buffer zone may be increased or decreased. Figure 7.4 illustrates the protection nexus as a function of the four factors of intensity (I) of land use, enforcement (E), migration (M), and off-farm employment (OFE). ICDP programs must consider the implications of all of these factors and their interactions. Unfortunately, very little analytical work has been done on approaches to cope with these complexities. The result is that the solutions attempted tend to be too simplistic. To date there are few successful ICDP examples (Wells and Brandon, 1992). Systems thinking and a long-term involvement of highly committed individuals will be critical to making ICDPs a success.

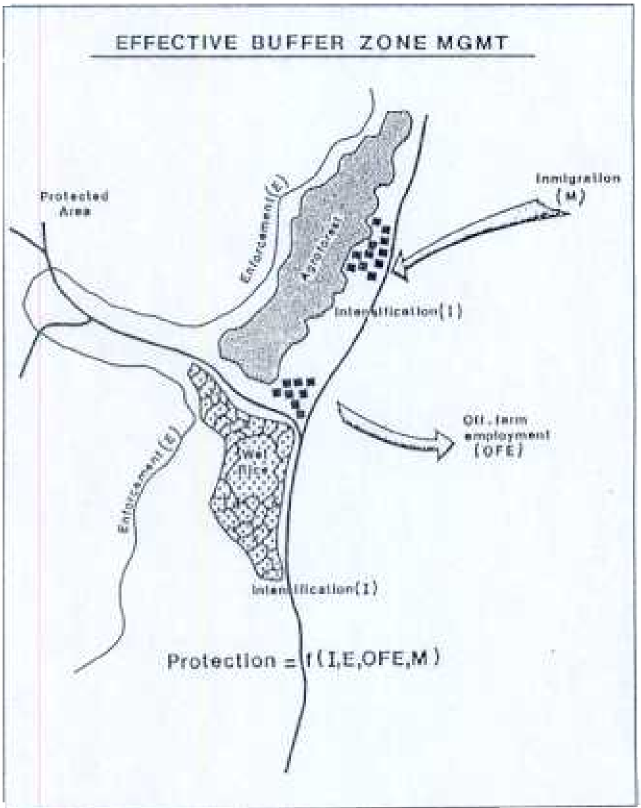


*Figure 7.4. The protection of a natural area through effective buffer zone management is a function of land use intensification (I), enforcement (E), off-farm employment (OFE), and migration (M).*

With the above caveats as a backdrop, improved agroforestry systems have frequently been cited as a path toward appropriate intensification in the buffer zones of protected areas (Wells and Brandon, 1992; Garrity, 1995; Cairns et al., 1997). Tree seedlings are often a highly desired intervention by recipient communities near protected areas. Provision of seedlings through nursery programs has therefore been one of the most popular ICDP development interventions. Farm families can increase their nutrition and economic welfare through a greater quantity and diversity of fruit and timber trees in the home garden area and on their farms. In many areas there is an encouraging trend toward tree crop farming as an alternative to practicing shifting cultivation (Garrity and Mercado, 1994).

Where there has been a history of tree crop cultivation in the vicinity of a protected area, the environment of the farming zone outside the boundary develops ecologically favorable characteristics for protection, and even extension, of the biological diversity of the park itself. The 'damar' agroforest systems on the boundaries of the Barisan National Park in Lampung, Indonesia, harbor a major proportion of the natural rainforest flora and fauna species (Michon et al., 1995), and effectively act as an extension of the biodiversity of the park itself. Rubber agroforests on the boundary of Kerinci-Seblat National Park in Jambi Province play a similar role (van Noordwijk et al., 1995a). Even in areas where smallholder agroforestry systems do not yield such striking levels of protection or extension for natural biodiversity, the benefits of increased tree cover on the landscape may be important.

Do households on the boundaries of protected areas that cultivate agroforests show less propensity to encroach on protected resources compared to households with simple farm types? We examined this question in a study on the northeastern boundary area of the Kerinci-Seblat National Park in the benchmark area of the Alternatives to Slash-and-Burn Program (ICRAF, 1996; Murniati et al., 1998). The boundary area was comprised largely of village forests that were gradually converted to agriculture, particularly mixed-perennial gardens or agroforests. The upper story of these gardens is dominated by rubber, along with durian (*Durio zibethinus* Murr), jengkol (*Pithecellobium lobatum*), petai (*Kleinhovia hospita* L.), and coconut (*Cocos nucifera*), with fewer individuals of a range of other species. The understory generally contains bananas and coffee. Interviews with 60 respondents indicated that the gathering of forest products inside the park took place on both a routine and an occasional basis. Products routinely gathered were timber (for lumber and poles) and fuelwood. Rattan, incense, palm fibers, game animals (deer and monkeys), and fish were also gathered.

We observed three general farm types outside the park: farms with only wetland rice fields, farms with only mixed-perennial gardens; and farms composed of both of these components. The families interviewed were grouped by farm type and the data set adjusted to remove the effects of differences in total farm size. For farms of similar size (< 1 ha) we found families with both rice fields and mixed gardens extracted 87% less value of products from the park than those with only rice fields. Thus, farmers that integrated rice production with tree crops exhibited only minor extractive pressure on the park, compared to farmers with only one enterprise type. Families having mixed gardens, and no rice fields harvested 24% less value from the national park than those that had only rice fields (Table 7.1). They had more opportunity to supply their wood needs, but were short of cash to buy rice, so they harvested some timber and other products from the park to help supply their cash needs. Harvest of forest products from the park was negatively correlated with nonfarm income across all farm types. Thus, reliance on income from the forest declined if other sources of income were available. Most respondents claimed that an integrated farm, composed of both rice and perennial gardens, was the ideal farm type. This is also the situation most conducive to park protection. The work showed that agroforest farming in the boundary area may contribute significantly to national park protection.

Research will play an increasingly important role in providing options and insights for ICDP development. The Sustainable Agriculture and Natural Resources Management (SANREM) Collaborative Research Support Program is a global program that takes a landscape approach with a strong participatory bias. At the SANREM research location in the Manupali Watershed in Mindanao, Philippines, ICRAF is coordinating a consortium that is developing the elements of a practical social contract for buffer zone management, developing improved agroforestry systems for the buffer zone, and assembling a

**Table 7.1. Average Annual Value of Forest Products Gathered by Villagers from Kerinci-Seblat National Park (May 1993–May 1994)[a]**

| | Annual Value of Harvest ($) per Family | |
|---|---|---|
| Farming Types | Routine | Occasional |
| Rice field | 171 a[b] | 8 a |
| Mixed gardens | 131 b | 13 a |
| Rice field + mixed gardens | 22 c | 8 a |

[a]From Murniati et al., 1998.
[b]Amounts with the same letter in a column are not significantly different at the 10% error level

natural resource management system for the Katanglad National Park. The research team is composed of scientists and practitioners from institutions including ICRAF, NGOs, universities, the tribal community, and local and national government institutions.

We found that the natural resource management strategies of the indigenous Talaandig communities living on the boundary provide a strong foundation for park protection (Cairns, 1995). However, population increase and commercialized vegetable production are causing serious encroachment pressure. The buffer zone area surrounding the park (classified as national production forest land) has high agricultural settlement pressure and is now dominantly grassland and shifting cultivation. The emerging path for household farming systems intensification is small-scale vegetable production combined with timber and fruit tree production. We have surveyed and mapped (Glynn, 1996) the performance of current tree species by elevation in the watershed (200 m to 1800 m), and have initiated trials to evaluate the most promising farm forestry species. We are working with scores of farmers on conservation farming practices and tree nurseries to elucidate more effective methods of diffusing new practices that will sustain crop yields and increase tree cover. Our policy group is tackling the challenge of combining these technical innovations with stronger community-level resource management systems that will support measures to build a 'safety net' of active enforcement of the park's integrity. This entails assisting in the development and implementation of a municipal-level natural resource management plan as well as a management plan for the national park and its buffer zone. The lessons of this approach will be scaled up through partnership with the Integrated Protected Areas Network in the Philippines.

In northern Thailand ICRAF is working with numerous partners in a similar effort to incorporate individual fields as components of a broader landscape management system in a key watershed. The concept is to move beyond individual households to include management functions at a community level (Thomas, 1995). The agroforestry system is a community watershed land-use mosaic that includes forest, tree, and crop components which interact in numerous ways.

## *IMPERATA* GRASSLAND REHABILITATION

When forests are opened for food crop production throughout Southeast Asia the land becomes infested with *Imperata cylindrica* grass within a few years. Farming the grasslands becomes increasingly laborious and crop yields generally decline. Smallholders then leave the grasslands behind and move to the forest margin where their returns to labor are higher. Currently there is about 35 million ha of *Imperata* grasslands distributed among the tropical Asian countries from India through mainland southeast Asia and Indonesia and the Philippines (Garrity et al., 1997). Can the initial degradation into *Imperata* be avoided? Can the grasslands be reclaimed and used more intensively?

Tenure insecurity is a key factor depressing effective conversion of *Imperata* grasslands to more intensive uses (Tomich et al., 1997). The ideal response may be to establish secure property rights, but this may not be practical because of the political sensitivity of national governments over their control of state land. The recent international workshop (Garrity, 1997) on improved agroforestry systems for *Imperata* grassland rehabilitation (sponsored by ICRAF in Indonesia) offered a major policy recommendation on this issue. It recommended that for large blocks of state forest land covered by *Imperata* grassland, farmers who convert that grassland by planting and managing trees in small plots should receive property rights over all their products, including the timber. This policy recommendation would apply only to existing grasslands, not to forests cleared in the future, avoiding perverse incentive to accelerate conversion of forest to grassland. ICRAF is implementing a major Southeast Asian regional policy project that will test this recommendation on a pilot scale, and provide further analysis to assist the Indonesian Ministry of Forestry and other national governments in implementing it on the ground.

Turning to the question of suitable smallholder technologies for intensification in the grasslands, we find that purely annual crop-based production systems have only limited scope to be sustainable under upland conditions prone to infestation by *Imperata* if animal or mechanical tillage is not available (van Noordwijk et al., 1997). However, where farmers have access to animal or tractor draft power, continuous crop production has been sustained in many *Imperata* areas. A wide range of agroforestry systems that evolve from shifting cultivation have shown particular potential (Garrity, 1997). We now review our work on some of the most promising options.

## Building on Indigenous Strategies of Intensification

Natural fallows work eminently well in regenerating soil fertility, if the local fallow species diversity and soil quality have not been degraded (e.g., Szott et al., 1991). But where natural fallows in shifting cultivation systems have been degraded to the point where grasses, particularly *Imperata* cylindrica, dominate the abandoned fields, natural regeneration is usually infeasible. Annual nutrient accumulation in *Imperata* fallows levels off after 1–2 years and is far inferior to that of woody vegetation. The result is a fallow incapable of regenerating adequate nutrient accumulation, yet is very laborious to reopen for cultivation.

Farmers prefer to locate their prospective plots in woody vegetation, and avoid grassland whenever possible (Cairns, 1994). *Chromalaena odorata* is an important pioneer fallow species that naturally suppresses *Imperata* in the absence of frequent fires, accumulates many times more biomass, and regenerates crop productivity much more efficiently. Shifting cultivators throughout Southeast Asia find it a highly desirable fallow species (Dove, 1986; de Foresta and Schwartz, 1991), even compared to secondary or primary forest.

*Austroeupatorium inulifolium* is a similar non-native invasive species common at mid-elevations above 600 m, that has proved very beneficial to farmers practicing shifting cultivation in West Sumatra (Cairns, 1994). It spread widely after its introduction in the late nineteenth century. Farmers found that it halved the necessary fallow period to regenerate soil fertility. This was a major contribution since land pressure was intense (Stoutjesdijk, 1935). Cairns' (1994) work showed that *A. inulifolium* fallows accumulated several times more biomass and nutrients beneficial to crop growth in a two year period (over 150 kg N/ha and 20 kg P/ha) compared to nearby *Imperata* fallows (25 kg N/ha and 6 kg P/ha) of the same age.

We believe that one of the most promising approaches to identifying biophysically workable and socially acceptable technologies is to document, verify, and disseminate cases of indigenous adaptations. If successful indigenous strategies for managing fallow land can be refined and diffused to other upland areas with degrading shifting cultivation, this will enable intensified land use and improved living standards for some of the most marginalized communities in the region. Unfortunately there is little documentation of such innovations to feed into the national and international research agenda or to inform policy makers. Indigenous strategies are either unobserved or misinterpreted.

ICRAF is collaborating with local partner institutions in a regional research initiative on 'Indigenous Strategies for Intensification of Shifting Cultivation.' Teams in several countries are investigating a variety of improved fallow systems that have evolved in different ecozones. These vary from herbacious to shrub-based to tree-based fallows (Figure 7.5). The approach is identifying a range of pragmatic and adoptable solutions for wider extrapolation among communities facing similar swidden degradation problems. Some of the most important indigenous systems combine elements of local practices with new exogenous technology. One fertile example is that of a slash-and-burn community in Indonesia that is harnessing new conservation tillage technology.

### *Shifting Cultivators Use Herbicides to Manipulate Fallow Vegetation*

South Kalimantan has one of the largest areas of sheet *Imperata* in Indonesia (623,000 ha). The grassland lies in a north-south belt on the western side of the Meratus Mountains. Farming in the village of Belangian, Riam Kanan, is based on a manual slash-and burn system. Farmers confine their cultivation to those areas dominated by *Chromalaena odorata* and try to avoid opening *Imperata* due to the enormous amount of work involved. But *Imperata* has spread over most of the village lands, so there is progressively less secondary vegetation available for new fields every year. About three years ago the entire village started using glyphosate herbicide to control *Imperata* when their fallow land was opened for cultivation. The vegetation is first slashed and burned. When the grass grows back to a height of 20-40 cm after 2-4 weeks, the grassy patches are sprayed. The field is burned a second time. Planting is then done by dibbling the seed. All farmers are now using glyphosate as part of their management system. They found that glyphosate enabled them to reopen fields with a substantial amount of *Imperata*. They relate that the use glyphosate not only controlled *Imperata,* enabling zero-tillage annual cropping, but also caused the post-cropping fallow vegetation to shift back to *Chromalaena*. They observe that the area dominated by *Imperata* is now declining.

Successful zero-tillage food crop systems using herbicide are rare in the tropics. Thus, the fact that such a system was developed independently by a village of shifting cultivators is remarkable. The glyphosate system does not replace slash-and-burn; rather, it enhances it through more effective weed management during the cropping cycle, and a favorable vegetation shift during the fallow period. Both aspects improve sustainability and reduce pressure on the local forest boundaries. The extrapolation value of this system is not trivial because *Chromalaena* is such a widely-preferred fallow species for slash-and-burn in Southeast Asia (including western Indonesia, Philippines, Laos, and Thailand). Other species of the *Compositae* family have been shown to play the same role in other environments. We are documenting this in more depth in the context of the Indigenous Strategies thrust of the global program on Alternatives to Slash-and-Burn (ICRAF, 1996).

### *Food Crop/Tree Crop Systems for Grasslands Without Tillage.*

Growing crops or trees in *Imperata* grasslands is difficult. Intensive and repeated tillage is usually essential to maintain annual cropping, or to establish perennial crops or timber plantations. *Imperata cylindrica* regrows rapidly, competes vigorously, and creates a major fire hazard for young plantations. Recent on-farm trials by the Agency for Agricultural Research and Development (A. M. Fagi, pers. comm.) have tested a promising system for food and tree crop establishment based on the judicious use of glyphosate herbicide. The grass is killed by an initial application of the herbicide, and upland rice or other crops are direct-seeded by dibbling into the thick residue mulch. Tree crops such as rubber, fruit trees, or timber trees, are established as intercrops with the food crops. Successive crops of annuals may be grown for two or three years while the canopy cover of the trees develops. More research is needed on a number of aspects. The global Alternatives to Slash-and-Burn Program (ICRAF, 1996) is collaborating with Indonesian researchers to examine the constraints and potential solutions in using herbicides as part of an integrated approach to annual and perennial crop establishment to rehabilitate large parts of Indonesia's nine million hectares of sheet *Imperata*.

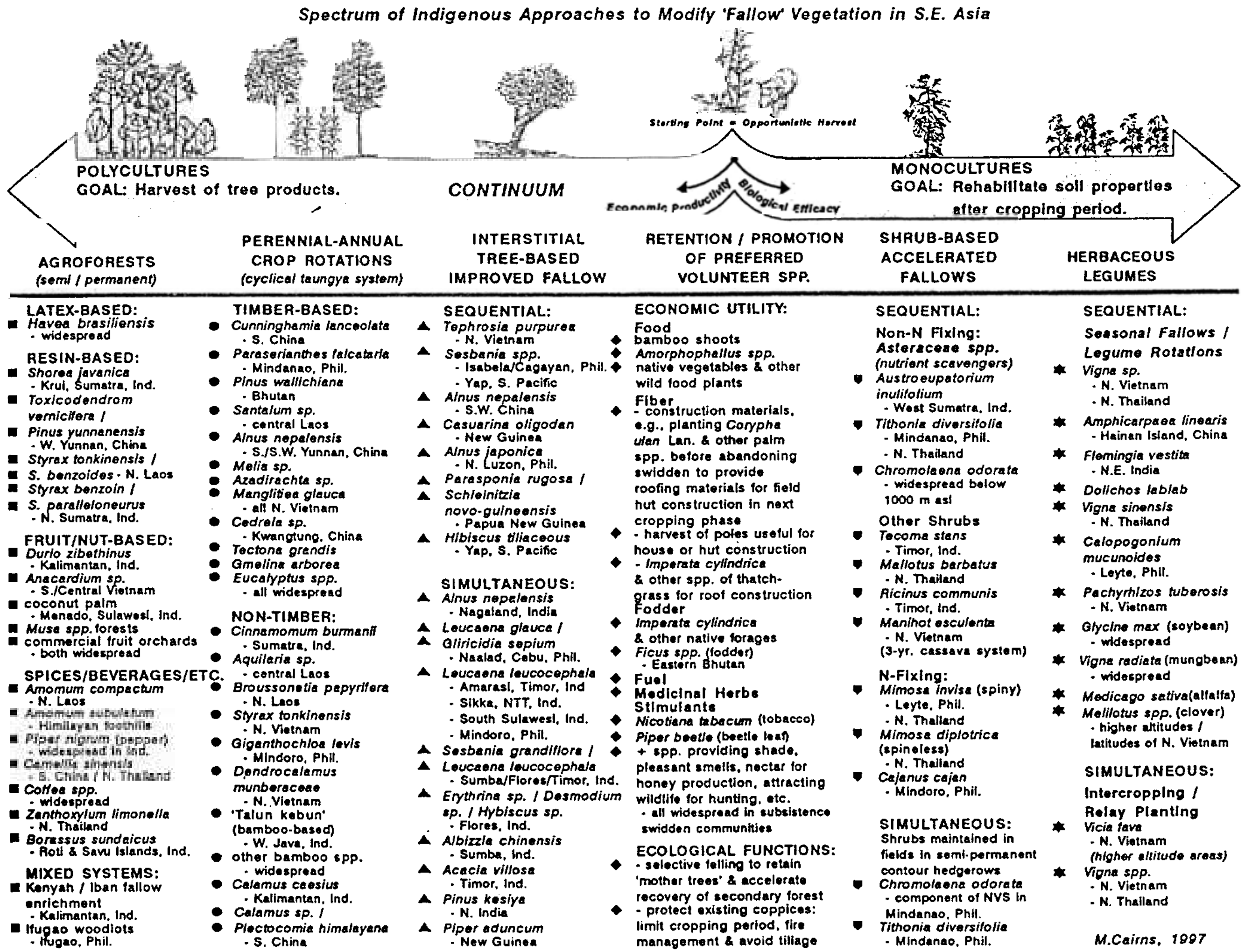


*Figure 7.5. Spectrum of indigenous approaches to manipulate 'fallow' vegetation in S.E. Asia (Cairns and Garrity, 1997).*