# 11 Natural Resource Management on a Watershed Scale: What Can Agroforestry Contribute?

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## INTRODUCTION

Successful watershed management is built on two pillars: Sound, practical technical innovation and participatory institutional innovation. Agroforestry has a key role to play in both. Although conventionally seen as a set of technical options applied at the field level, agroforestry is increasingly conceived as a framework for whole-landscape management within a community and ecological context. Watershed degradation poses a threat in many countries in Asia, but past watershed management programs have most frequently been ineffectual. Asian watersheds have the highest sediment loads in the world. Nevertheless, within limits, the evidence indicates that it is possible for smallholders to engage in farming and management of natural forest resources in both a productive and conservation-effective manner. Agroforestry research and development is creating a much wider array of practical solutions that reduce the tension in achieving both the environmental service functions of watersheds and the productivity functions essential to the livelihood of the dense rural populations that inhabit them. "Best-bet" agroforestry systems are reviewed for the three major upland ecosystems within Asian watersheds: the forest margins, *Imperata* grasslands, and permanently farmed hillslopes. The environmental impacts of complex agroforests, smallholder timber- and fruit-tree production systems, improved indigenous fallow management systems, and contour vegetative strip systems are discussed in the context of the above issues. Selected watershed management projects in Thailand, the Philippines, and Indonesia are then examined to draw conclusions on the effective pathways toward effective land husbandry and local natural resource management. Application of the concept of community landscape mosaics as a tool is highlighted. Lessons from these cases, and from two global research programs (ASB and SANREM), indicate that if local communities are allowed to capture the direct benefits of improved systems through tenurial security and involvement in decision making, they will be firm partners in reversing the environmental degradation of Asian watersheds.

## STRATEGIC ISSUES IN TROPICAL WATERSHED MANAGEMENT

As increasing populations expand into steeper, more fragile areas in the tropical uplands, more catchments are affected by severe soil erosion, declining soil productivity, and environmental degradation. Watershed degradation now poses a threat to the economies of many countries in Asia, and to the livelihoods of the ever-growing populations that depend on these resources. Unfortunately, past watershed management programs to arrest and reverse this trend have been largely ineffectual. But the lessons learned from these failures have been instrumental in promoting a major change in thinking with regard to watershed management (Douglas, 1996). The two key elements underlying this approach are better land husbandry practices and active people's participation.

Better land husbandry represents a shift in emphasis away from a fixation with soil conservation to a more holistic care of the land for sustained production. It follows recognition that, although there will be trade-offs, the farmer's market objectives can be reconciled with society's watershed objectives such that neither loses and both gain. This affirms that the adoption of appropriate management practices that increase yields can likewise combat land degradation.

Emphasis on active people's participation in watershed management (catchment management in the British terminology) is a recent phenomenon in the tropics. It arose from the glaring pattern of failures observed in past "top-down" methods used by the public sector to implement watershed management projects in which the residents were passive recipients of external interventions. These failures have fostered more serious recognition that success depends upon enhancing rural people's inherent abilities to apply and adapt new and indigenous technologies, and to involve local institutions to manage and conserve resources.

Successful watershed management in the tropics is built on two pillars:

- Sound, practical, suitable technical innovation, and
- Participatory institutional innovation.

Agroforestry has a key role in both. Although conventionally seen as merely a set of technical options applied at the field level, the concept and definition of agroforestry have expanded to envision a role at whole-landscape level. This chapter will explore the role of agroforestry in watershed management in the context of this broader, more holistic vision. This first section summarizes key information concerning watershed management in Asia and some of the major issues that have been highlighted by past experience. The second section explores the role of agroforestry in tropical watersheds, particularly in the context of community landscape mosaics. The third section examines agroforestry in upper watersheds and examines projects in the Philippines and Thailand that are instructive case studies. The succeeding sections look at agroforestry in the context of landscapes dominated by grasslands and continuous cropping, with additional case studies from Indonesia. The chapter concludes by summing up the key points learned that point the way to greater success in future watershed management initiatives.

What has been learned about effective ways of promoting local management of natural resources in the Asian context? Early approaches to soil conservation were developed for large landholdings in temperate regions and were based on structural and engineering treatments (for example, bench terracing). Attempts to apply these approaches to developing country agriculture, characterized by smallholdings, diverse farming systems, extremes of climate and topography, wrenching poverty, weak government institutions, and very limited skills, have been disappointing (Magrath and Doolette, 1990).

Fortunately, alternative technical and institutional approaches are emerging. The concept of conservation-oriented farming in the uplands in which farming systems and realistic farming practices combine to conserve soil and improve total production is now recognized. Two complementary strategies for the development of conservation-oriented upland farming are evolving. The first is the adoption of a problem-solving approach aimed at identifying the key constraints on a site-specific basis. The second is the promotion of a suite of agroforestry-based practices that can form the basis of a comprehensive approach to farming system evolution in the uplands.

One example among these are simple vegetative strip systems that provide a foundation for eventual conversion to tree-based systems. Another is recognition of the immense potential for smallholder complex agroforests that provide robust, sustainable incomes while conserving soil and water resources in ways that closely mimic natural forests themselves.

Conventional approaches to watershed management have had little effect because they were dominated by top-down solutions to problems perceived by external stakeholders, not by the people that live there. External stakeholders, whether national governments or international entities, prescribed solutions, usually large-scale reforestation, on lands managed by local smallholders whose economic implications were diametrically opposed to the de facto land managers food and income security objectives. Forced reforestation has been time and again passively resisted by the destruction or neglect of the plantings. Fire control is essential, and that can only be possible with active and self-interested support of local people. Recognition of reasonable and appropriate land-use rights is also fundamental.

After 50 years of disappointment decision makers have been forced to revisit their assumptions, and to wake up to the potential for collaborating with local farmers on solutions which both increase farm productivity and meet watershed protection objectives. This evokes a new era in which the smallholder is beginning to be seen as a critical part of the solution, not simply the scapegoat for the entire problem.

## ASIAN WATERSHEDS

A watershed (or catchment) is defined as the land area drained by a common river system. In Asia, the land area located above 8% slope is operationally considered as watershed area. Land above 30% slope is considered upper watershed. Thus, the conventionally accepted watershed area of Asia is 900 million ha or 53% of the landmass (Magrath and Doolette, 1990). About 65% of the region's rural population of 1.6 billion live in these watershed areas. The managers of these lands are smallholder farmers in rural villages. They are severely constrained by poverty and technology. Therefore, as they seek more farm and grazing land to support their families, they have profound effects on the land and water resources of both the uplands and lowlands.

The population occupying the upper watershed areas is roughly 128 million (Magrath and Doolette, 1990). Increasing populations are accelerating pressure on scarce land and forest resources throughout the region. Approximately 19% of the region is under closed forest. Most of this remaining closed forest is tropical rain forest, the reservoir of about 40% of the biodiversity on the planet Earth. Degradation through overcutting and grazing is reducing productivity on much of the remaining stand (Doolette and Smyle, 1990). The forest cover is receding at a rate of about 1% a year. The most recent estimates suggest that the rate of deforestation is not slowing, but is accelerating. In much of the region, forest resources are integral to the agricultural system as sources of fodder and many other products.

The seriousness of soil erosion is not adequately known, but may be deduced from indirect evidence. The most striking picture is that presented by the rate of sediment passing into the oceans from the major river systems of the world. The global data highlights Asia as being in a class by itself: rates of sediment deposition in the oceans are an order of magnitude higher than from comparable-sized areas anywhere else in the world (Milliman and Meade, 1983). Human pressure on the resource base is by no means the only major driving force for these enormous rates of sediment detachment and deposition. Southeast Asian landscapes tend to be geologically young, and exceptionally steep. These factors are also important; but the densest populations in the world are transforming these watersheds at a tremendous rate, and exacerbating their degradation.

The nations of Southeast Asia are progressively opening their economies, and participation in global markets is accelerating. This is causing profound changes on upland livelihood systems, and on the upland environment. The economies of mainland Southeast Asia are interacting more vigorously than ever before, as borders open and roads and railroads facilitate cross-border trade. World market demand for key perennial tree products produced in insular Southeast Asia is spurring smallholder expansion of rubber, oil palm, tree resins, and various fruits, as well as timber production on farm. These forces will continue to impact land-use change in complex ways well into the future.

Watershed degradation does not have to be an inevitable consequence of using land for agriculture or forestry. It is possible for smallholders to engage in farming and management of natural forest resources in both a productive and conservation-effective manner. Despite the availability of a wide range of options, most development projects have relied on a limited and generally high-cost set of interventions. The issue is the development of the technical capital in resource management, but to an even greater extent it is the social capital to facilitate this process. It is now becoming clear that agricultural productivity in upland areas can be intensified in an environmentally sound and sustainable manner. But new approaches will have to be applied to make this a reality.

## Service vs. Production in Watersheds

Outside stakeholders such as lowland populations, national government institutions, and the global community (i.e., all others besides the upland residents themselves) tend to be most deeply concerned about the service functions of watersheds. The attention of national policy makers is naturally drawn to the concerns of the more affluent lowland populations and the impact of upstream–downstream linkages on these groups.

The key *service functions* of concern to outside stakeholders follow:

- *Regulate water flow* to the lowlands to reduce flooding and to provide a dependable water supply to the lower watershed for irrigation and power generation;
- *Prevent soil loss* to protect power generation reservoirs and irrigation structures;
- *Conserve biodiversity* and protect natural ecosystems;
- *Sequester carbon* to alleviate the threat of global warming.

Although these concerns may also be shared to some extent by the resident populations of the watersheds, they are most urgently concerned about the *productivity functions* of watershed resources, that is, to

- *Sustain agricultural production*, and
- *Retain forest resources for local uses: timber, fuel, grazing, nontimber products.*

Can there be practical solutions that can meet both needs? In many circumstances, it is possible to improve the environment and increase the output of goods and services at the same time. One of the major goals of agroforestry research and development in Southeast Asia is to reduce the tension between these two goals by developing a range of choices that are both "service" and "market" oriented (Thomas, 1996). Economic losses from watershed degradation may be divided into on-site and off-site costs. On-site costs derive from the direct effects of degradation on the quality of the natural resources, expressed in terms of declining yields, reduced livestock-carrying capacity, and decreased supply of forest products. Off-site costs result from the indirect effects of degradation on the service functions of the watershed.

The primary justification for watershed management is usually a reduction in off-site costs, particularly when the watershed is upstream from dams or flood-prone valleys or plains. However, it is generally unappreciated that the off-site costs may be of a much lower magnitude than the on-site costs. For example, in Java, Indonesia, annual estimated off-site costs (U.S.$25.6 to 91.2 million) were only a fraction of the on-site costs of U.S.$335 million because of productivity losses. In practice, it is the on-site costs that are the primary economic justification for undertaking a watershed management program. Any reduction in off-site costs should be seen as a secondary justification (Douglas, 1996).

Watershed management involves a range of activities. Each activity would be expected to contribute to the aims of improving the sustained productivity of the natural resources, protecting designated natural ecosystems, and improving rainwater management to provide the quantity and quality of water to meet the different needs of water users within and downstream of the watershed.

## THE ROLE OF AGROFORESTRY IN TROPICAL WATERSHED MANAGEMENT

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 it as the evolution of a more mature agroecosystem of increasing ecological integrity. Leakey (1996) proposed that agroforestry be considered 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 the International Centre for Research in Agroforestry (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 the ICRAF approach.

Sanchez (1995) noted that although agroforestry systems have been classified in a number of different ways, ultimately there are two functionally different types, simultaneous systems and sequential systems. Thomas (1996) showed that these may be further classified according to two subcategories based on the land management unit: field-based systems at the household level and landscape-based systems at the village or watershed level. Field-based sequential and simultaneous systems have received dominant attention. These are closely associated with the conventional perception of agroforestry as a suite of farming practices in which trees and crops interact in a field over space and time. Sequential field-based systems are exemplified by fallow rotation or shifting cultivation: crops and secondary (or managed) tree fallows occupy the field in a rotation sequence. Simultaneous systems are typified by alley cropping or complex associations of trees and crops managed in the same field at the same time, such as home gardens or agroforests.

The concept of landscape-based agroforestry systems is much less appreciated, but is most relevant to a discussion of the role of agroforestry at the watershed scale. In these systems, the boundary of the management unit is drawn around a larger landscape unit than an individual field. The determination of an appropriate landscape unit will depend on local conditions, but it would generally extend to the lands in a subwatershed, and directly influenced by whole villages or a group of villages (Thomas, 1996). Landscape-based agroforestry systems incorporate individual fields as components of a broader landscape management system. It moves beyond individual households to include management functions at a community level.

## AGROFORESTRY IN UPPER WATERSHEDS: THE FOREST MARGINS

Successful action to mitigate tropical deforestation depends upon a more comprehensive understanding of the forces driving this process. The driving forces vary locally within regions of individual countries. Mitigation efforts must address the interacting forces within each nation and locality. Here we examine 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?

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 smallholder 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 Forestland.** 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. 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 ha on production forest land in Lampung. It harbors a major proportion of the natural rain forest 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 (Torquebiau, 1992).

These mixed tree-crop systems, particularly complex agroforestry systems or "agroforests," provide an alternative to other land uses to protect 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 most other forms of crop or tree monocultures. Research on these systems is accumulating empirical evidence that supports this (e.g., Mary and Michon, 1987; Salafsky, 1993; Momberg, 1993; de Foresta and Michon, 1997). Thus, we find that the objectives of smallholder communities practicing such systems are more compatible with those of national governments in protecting watersheds and biodiversity than has previously been assumed.

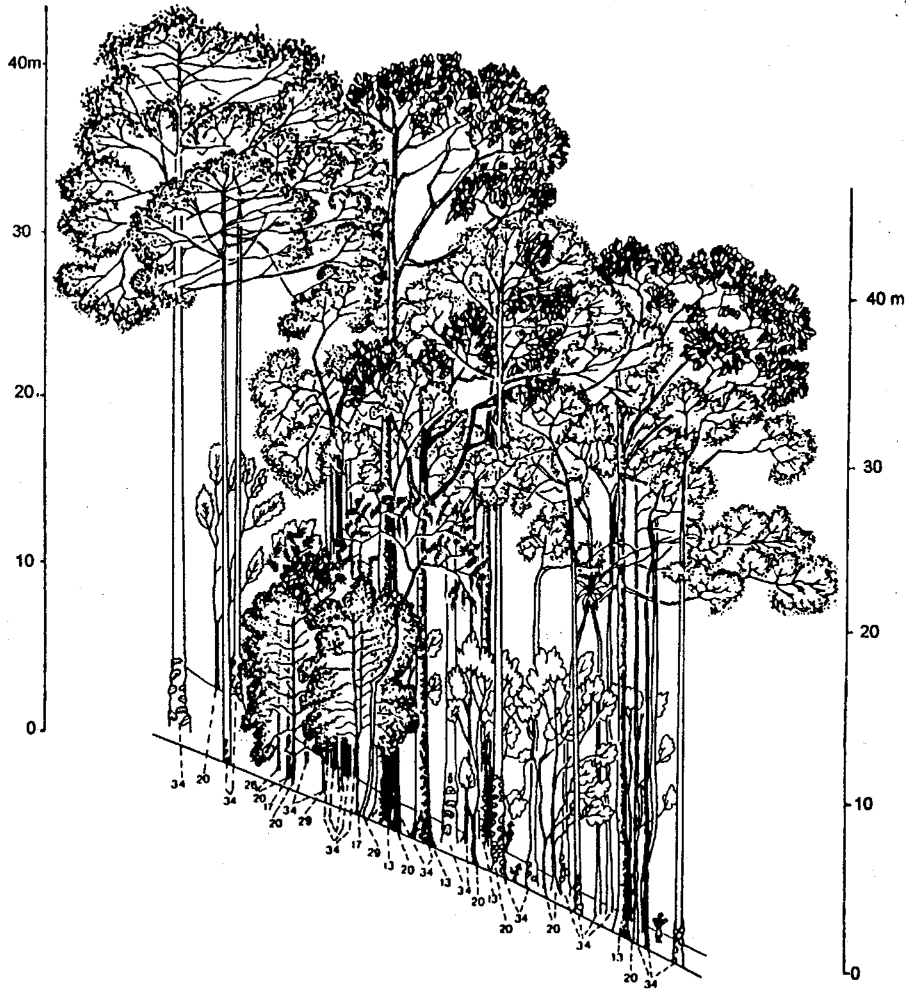
The most widespread agroforest system in Indonesia is rubber agroforestry (or "jungle rubber") which occupies over 2.5 million ha (Gouyon et al., 1993). In this system rubber trees are the main component, but many other species of fruit and timber trees are combined with rubber, either intentionally 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 to 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 (Thiollay, 1995; de Foresta and Michon, 1997). Can smallholder jungle rubber systems be made more productive while retaining substantial biodiversity value? We hypothesize that smallholders can substantially increase their rubber yields by incorporating new clonal 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. 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).

**Tenure reform.** Official recognition of local land and tree tenure systems would underpin their security and enhance the development and expansion of agroforests. Smallholder communities could then contribute substantively to the national production objectives for which the production forests exist. 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 Alternatives to Slash-and-Burn (ASB) Program are examining how viable instruments may be designed at three levels: the household, the community, and the region. 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.

**Environment 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. Tomich et al. (1998) have developed a framework for comparing the economic and environmental impacts of different land-use systems on the forest margins and the trade-offs inherent in land-use choices.

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 11.1 is a cross section of an Indonesian smallholder agroforest that illustrates these objectives.

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




Legend:

34: resin producing tree species, tapped every month and forming the upper canopy as well as the main frame of the forest; valuable timber,
20: understorey fruit tree species, with high commercial value, but seasonal production,
26: understorey fruit tree species, with low commercial value and seasonal production,
17: understorey fruit tree species, with high commercial value, but seasonal production,
29: medium to upper canopy tree species, with valuable timber,
13: upper canopy fruit tree species, with high commercial value and more or less continuous production; valuable timber.

**FIGURE 11.1** Example of a mature agroforest designed for both profitability and sustainability in smallholders' conditions.

"agriculture" can 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) have proposed a simple model to examine the decision framework. It presumes 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 agricultural intensification in such types of agroforest systems may be more 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.

In the highland watersheds of northern Thailand, fruit tree gardens are spreading rapidly (Turkelboom and van Keer, 1996). They are popular because farmers expect higher, more stable income with less labor than with their annual cropping systems. They are also seen as a way to bolster the household's claim to avoid land expropriation by the state. Do fruit tree gardens have similar watershed functions as a forest? Moisture relations were compared over a 2-year period for a litchi (*Litchi chinensis*) garden without undercover, a mixed deciduous forest with limited disturbance, and an annual cultivated field with a short fallow cycle (Figure 11.2). The soil profile was drier in the litchi orchard than in the forest or annual crop field throughout both the wet and dry seasons. The difference was related to human activity in the orchard which caused greater soil compaction that inhibited infiltration in the wet season. In the dry season water consumption was highest in the orchard because the evergreen fruit trees continued transpiration whereas the deciduous forest shed its leaves. These observations suggest that the orchard will increase stream flow in the wet season, and reduce the base flow in the dry season. The data highlight the importance of compaction by human traffic in tree-based systems as a determinant of the water conservation value of an agroforestry practice.

Commercial forest plantations of single, even-aged species have some of the same characteristics of fruit tree gardens (Bannerjee, 1990). Neither may be as good as natural forest, but if forestry departments are content to pursue commercial timber plantations as a means of protecting watersheds, there is little justification for disallowing fruit tree gardens as an alternative for these lands. 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

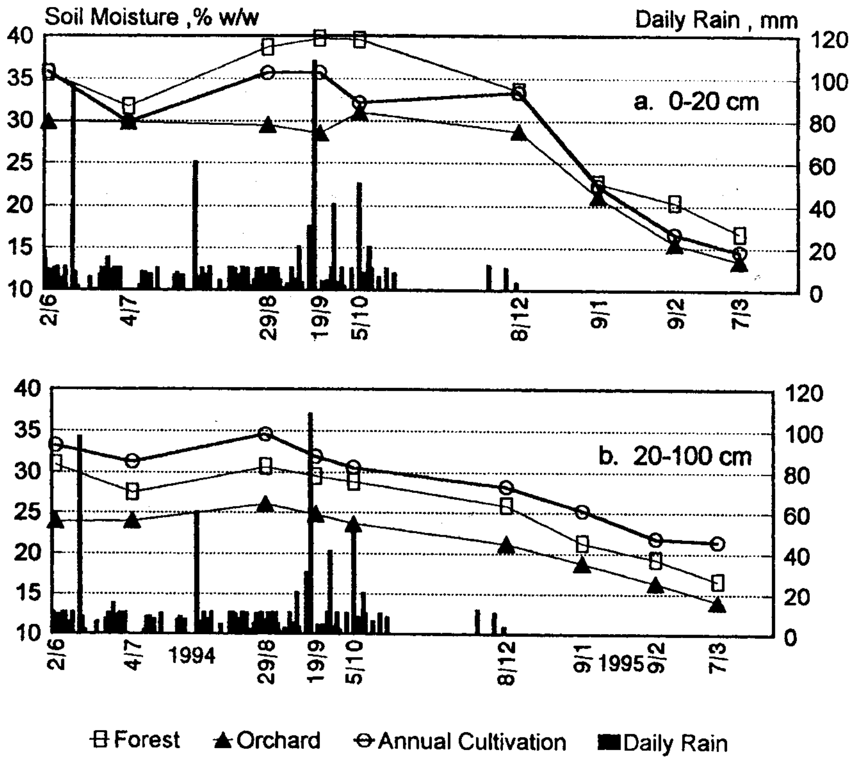



**FIGURE 11.2** Average soil moisture content at Mae Sa Mai, northern Thailand, under three contrasting land-use systems. (From Turkelboom, F. and van Keer, K., Eds., *Land Management Research for Highland Agriculture in Transition,* Mae Jo University, Thailand, 1996. With permission.)

threat of encroachment virtually everywhere. The classical method of preserving them has been to declare them off-limits and to enforce the exclusion of local people. Boundaries were delineated and guards patrolled. Unsurprisingly, this is not working. It often results in serious conflicts between the enforcement agency and the local communities. Enforcement alone does not work in most countries because population pressure is too great, the gains captured by local elites by encroachment are too lucrative, or the costs of enforcement are too high. How might agroforestry contribute to alleviating the degradation or ultimate conversion of natural areas? Part of the solution in many cases lies in identifying 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. 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 the identification of policy and technology directions to underpin these efforts.

In addition to enforcement and increased land-use intensity there are two other important factors: migration and off-farm employment. If in-migration 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.

Conditions in the wider economy play a major role in affecting migration. Off-farm employment for village residents in the buffer zone may be increased or decreased. Figure 11.3 illustrates the park protection problem as a function of four factors: 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. 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, 1995b; Cairns et al., 1997). Tree planting is often a highly desired intervention by recipient communities near protected areas. Provision of tree germ plasm 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 rain forest 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.

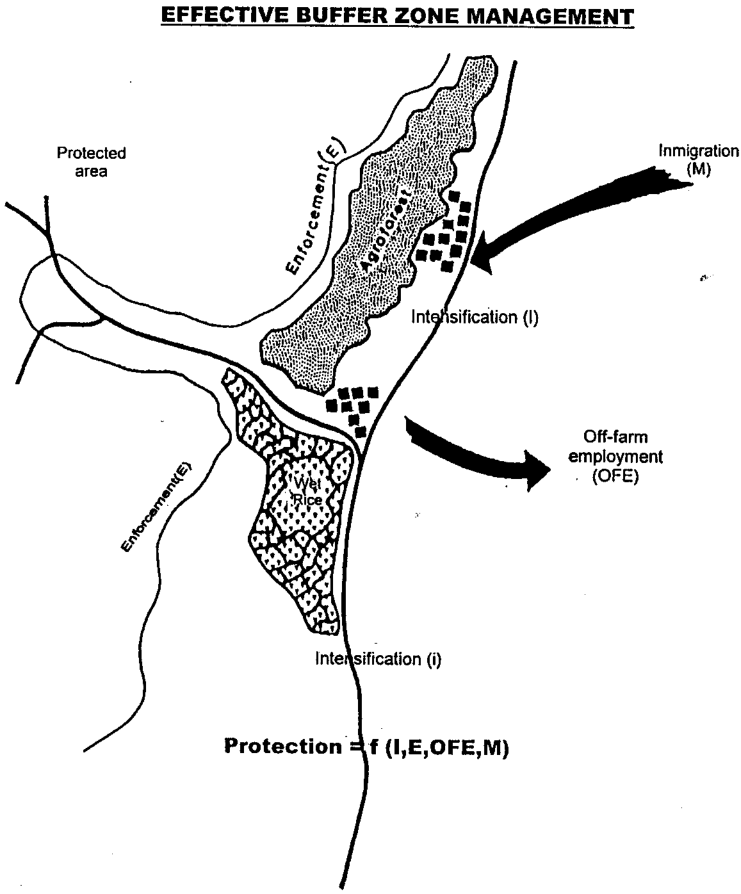



**FIGURE 11.3** The protection of a natural area through effective buffer zone management is a function of land-use intensification (I), boundary enforcement (E), off-farm employment (OFE), and migration (M).

## Case Study of the Manupali Watershed, Mindanao, the Philippines

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 collaborating in 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 natural resource management system for the Katanglad National Park. The research team is composed of scientists and practitioners from institutions including ICRAF, non-governmental organizations (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 forestland) 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 perceptions of local farmers on the performance of current tree species by elevation in the watershed (200 to 1800 m). On the basis of these results we have initiated trials with farmers across this entire transect of elevations to evaluate the most-promising agroforestry species for the range of ecologies and farmer circumstances. We are also 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. The 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. Only with democratization and decentralization of power can natural resource management at the local level succeed. Fortunately, this process is well under way in the Philippines. Local governments have begun to have the resources and authority to respond to local needs. In other parts of Southeast Asia such devolution is farther down the road.

In Vietnam some remarkable experiments in participatory resource management are in progress. State lands, including nearly all the forestlands in the country, are being allocated in small chunks to individual households under management contracts. These contracts give the rural family a real stake and responsibility for sustainable management of these lands. The family receives an annual honorarium from the government along with clear and mutually determined management conditions relating to the protection of the ecosystem, the sustainable extraction of forest products, grazing regimes, and others. This is a case of the privatization of natural resource management that is groundbreaking. There will be some remarkable lessons from this experience.

## Applying the Landscape-Based Agroforestry Concept: The Case of the Sam Muen Project, Northern Thailand

In Thailand, forest destruction and watershed degradation are of particular concern in the northern highlands, which are the headwaters of all major tributaries of the country's major river artery, the Chao Phraya River. Hundreds of farming villages exist in the upper watersheds, which has spurred the forest department to attempt to reforest lands with timber plantations, to remove populations from protected areas, and to enforce regulations against farming there, resulting in conflict with the resident villagers. These efforts have had limited effect. A framework was necessary that recognized the legitimate rights of communities to reside in upper watersheds and that explored ways in which the service functions of the watershed could be maintained or enhanced while enabling the communities to pursue farming activities that were in reasonable harmony with these objectives.

ICRAF is working with numerous partners to develop landscape management systems in key watersheds. The concept is to move beyond individual households to include management functions at a community level (Thomas, 1996). The agroforestry system is a community watershed land-use mosaic that includes forest, tree, and crop components which interact in numerous ways. The utility of the landscape-based agroforestry concept is illustrated by the experience of the Sam Muen Highland Development Project (Limchoowong and Oberhauser, 1996). This was a pioneering example of the development of a community watershed mosaic system that is having major impact in spurring a rethinking of the whole approach of the Thai government in managing upland watersheds.

The realization gradually advanced that a framework was necessary that recognized the legitimate rights of communities to reside in upper watersheds and that explored ways in which the service functions of the watershed could be maintained or enhanced while enabling the communities to pursue farming activities that were in reasonable harmony with these objectives. A project to experiment with the concept was initiated in 1987.

The boundary was drawn around the perimeter of a small highland subcatchment. A participatory land-use planning approach provide a mechanism for villagers and the forestry department to negotiate and implement a mutually suitable solution. Three-dimensional models of the portion of the watershed occupied by the village proved to be conducive tools by which land-use zoning was done. Watershed committees were established that identified the problems and developed community-enforced land-use rules in place of rigid government regulations. The landscape was categorized into a mosaic of areas for various types of land use, which may include appropriate simultaneous combinations of protected natural forest, managed natural forest, field-based agroforestry, boundary plantings, annual crops, rice paddies, and others (Thomas, 1996). Zones for field agroforestry and annual crops are managed by individual households, subject to necessary conditions imposed by the community. After realistic boundaries were established for protected forests, and the security of land-use rights was confirmed in areas designated for agriculture, the communities became active agents in forest protection. The result has been dramatic improvement in the watershed environment (Figure 11.4). Forest cover has increased substantially and the area in annual cropping has decreased. The establishment of fruit tree gardens has diversified income sources while enhancing soil conservation. Intervillage relations are managed through a watershed management network, which is authorized by the local subdistrict government.

Such a community watershed mosaic system is an agroforestry system at a larger scale. The landscape unit includes forest, tree, and crop components which interact through on-site watershed functions, fire and grazing management, allocation of investments and benefits at household and community levels, as well as through nutrient concentration and cycling, weed and pest dynamics, and other biophysical

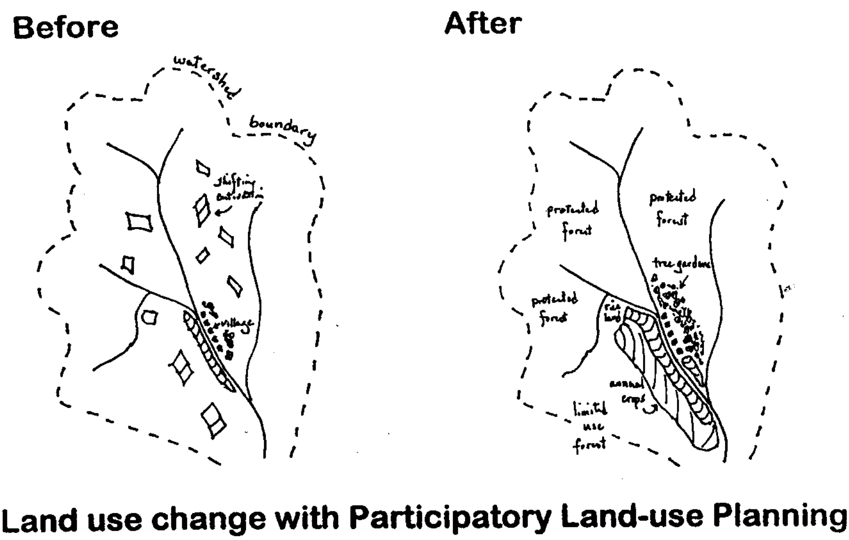



**FIGURE 11.4** Land-use change with participatory land-use planning.

factors that interact across field boundaries (as well as within). Such a framework is conducive to the management of land-use rights at the community level that are conditional upon the maintenance of the landscape management system. The experience demonstrated clearly that local communities can become enthusiastic partners with government to solve watershed management problems. This may be particularly true on land claimed by the state on which villagers have tenuous land rights and seek to gain recognition of their *de facto* occupation. However, a major challenge remains in sensitizing the bulk of personnel in the responsible government agencies if the lessons are to be applied on a wide scale in the upper watersheds throughout Thailand.

## AGROFORESTRY AND *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 from labor are higher. Currently there are 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., 1997a). 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. A recent international workshop (Garrity, 1997) on improved agroforestry systems for *Imperata* grassland rehabilitation offered a major policy recommendation on this issue. It recommended that for large blocks of state forestland 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, 1997a). We examine three types of 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 *I. cylindrica,* dominate the abandoned fields, natural regeneration is usually infeasible. Annual nutrient accumulation in *Imperata* fallows levels off after 1 to 2 years and is far inferior to that of woody vegetation. The result is a fallow that is incapable of regenerating adequate nutrient accumulation, yet that 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 with secondary or primary forest. *Austroeupatorium inulifolium* is a similar nonnative invasive species common at midelevations 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 19th 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) showed that *A. inulifolium* fallows accumulated several times more biomass and nutrients beneficial to crop growth in a 2-year period (over 150 kg N/ha and 20 kg P/ha) compared with 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 and to intensifying shifting cultivation 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. The approach is to identify 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 example is that of a slash-and-burn community in Indonesia that is using glyphosate as part of the management system (ICRAF, 1997). Farmers independently found that glyphosate enabled them to reopen fields with a substantial amount of *Imperata*. The glyphosate not only controlled *Imperata*, enabling zero-tillage annual cropping, but also shifted the postcropping fallow vegetation from Imperata to *Chromalaena*, a desirable fallow species. They now observe that the area dominated by *Imperata* in the village is declining.

## Smallholder Timber Production Systems

In countries such as the Philippines, Vietnam, and Thailand, which are experiencing extreme forest encroachment pressures on the remaining natural areas, there is a concurrent trend toward major increases in the value of farm-grown timber. Smallholders, even shifting cultivators on the frontier, are now engaging in farm forestry for the first time in great numbers, in response to recent strong price incentives (Garrity and Mercado, 1994). This situation dramatically increases the prospect of stimulating smallholder timber production systems as a major vehicle for rapidly increasing overall tree cover in the landscape. In the Philippines, ICRAF is evaluating smallholder timber production systems and more effective methods to disseminate improved tree germplasm, through private and village nursery systems.

## Pruned-Tree Hedgerow/Fallow Rotation Systems

Alley cropping was originally conceived as a sustainable replacement for fallow rotation on degrading lands. But pruned-tree hedgerow systems may extend the cropping cycle beyond that possible with natural fallows, but cannot eliminate fallowing unless fertilizer or manure is used. And the labor to maintain the pruning regime is too high. We are conducting studies to characterize the hedgerow/fallow system and its prospective sustainability in both the Philippines and Indonesia. Crop productivity and overall profitability from fields with fallowed hedgerows of *Senna spectabilis* (syn. *Cassia spectabilis*) that were reopened for maize cropping increased compared to cropping in adjacent plots with natural fallow vegetation (Suson and Garrity, unpublished data). We observed a major shift in fallow vegetation in the alleyways as a consequence of hedgerow/fallowing. After 3 years the alleys were intensely shaded and dominated by broad-leaved species. *Imperata cylindrica* was effectively suppressed. Fire is a frequent threat on grassland farms because it is very difficult for the individual cultivators to protect their fields from fires that spread from elsewhere. Experiments in Lampung, Sumatra have shown that *Peltophorum dasyrachis* shows greater promise than *Gliricidia sepium* as the hedgerow component because *Peltophorum* is more resistant to fire (van Noordwijk et al., 1997). We hypothesize that the extrapolation domain for pruned-tree hedgerow/fallowing is most likely to be areas where farmers practice slash-and-burn cultivation in *Imperata* grasslands with manual cultivation and no access to fertilizer inputs.

## Applications in Indonesia

Soekardi et al. (1993) estimated the area of *alang-alang* (*Imperata*) in Indonesia to be about 9 million ha (5% of the total land area). Most alang-alang areas are located on land registered as state forestland. Utilization of alang-alang areas for expanding agricultural land is less environmentally destructive than clearing of forests. Adiningsih and Mulyadi (1993) found that for alang-alang land, phosphorus deficiency, aluminum toxicity, and low organic matter content were the main constraints limiting productivity. They demonstrated that soil fertility improvement in the mostly acid alang-alang soils could be attained with the application of phosphate rock and the use of leguminous cover crops. Sukmana (1993) recommended for alang-alang land integrated farming systems involving annual and perennial crops (agroforestry systems) and livestock production. Minimum-tillage practices in combination with cover crop management are superior to conventional tillage in terms of lower labor input and higher crop production. Table 11.1 shows the effectiveness of agroforestry

**TABLE 11.1**
**Soil Loss (t/ha/yr) as Affected by Hedgerow Treatments on a Typic Eutropept with Slopes Ranging from 10 to 15%**

| | Year of Observation | | | |
|---|---|---|---|---|
| Treatment | 1989/90 | 1990/91 | 1991/92 | 1992/93 |
| Control | 66 | 107 | 133 | 68 |
| Caliandra | 8 | 22 | 19 | 20 |
| Flemingia | 0 | 0 | 1 | 0 |
| Vetiver | 12 | 14 | 0 | 2 |

After Rachman et al., 1995.

systems, especially those using *Flemingia* as hedgerow species, in controlling erosion in Indonesia. Besides its effectiveness in controlling erosion, *Flemingia* produces about four times as large a biomass as vetiver (Ai et al., 1995).

## AGROFORESTRY FOR HILLSLOPE CONSERVATION FARMING

Slash-and-burn farmers were the initial adherents of conservation tillage. But as population density increases, fallows are shortened and the biomass and richness of the fallow vegetation declines. Clean tillage for weed control is frequently practiced even on steep slopes, and accelerated soil loss is common. Smallholders who have farmed sloping lands with clean-tillage for some years are well aware of the threat of soil erosion, and are keen to learn about and apply conservation measures (Fujisaka, 1993), as long as such methods are practical, within their very limited resources and labor. Unfortunately, most proposed methods are not practical, in the farmer's eyes. But low-labor, low-investment practices that do the job of saving soil are eagerly awaited by small farmers. This section reviews some of the most-promising directions toward providing conservation tillage practices that may make sense to Southeast Asian upland farmers.

### THE CASE FOR NATURAL VEGETATIVE STRIPS

The main conservation farming practice prescribed for open-field intensive cultivation systems in Southeast Asia has been contour hedgerow systems (Garrity, 1995a). Contour hedgerow farming with leguminous trees has thus become a common feature of extension programs for sustainable agriculture on the sloping uplands in Southeast Asia. These systems control soil erosion effectively, even on steep slopes (Kiepe, 1995; Garrity, 1995). Data from the IBSRAM Sloping Lands Network trials in six countries have confirmed that annual soil loss with hedgerow systems is typically reduced 70 to 99% (Sajjapongse and Syers, 1995). There are also numerous reports of increased yield levels of annual crops when grown between hedgerows of leguminous trees. However, farmer adoption of these systems is very low. Constraints include the tendency for the perennials to compete for growth resources and hence reduce yields of associated annual crops, and the inadequate amounts of phosphorus cycled to the crop in the prunings. But the major problem is the extra labor needed to prune and maintain them (ICRAF, 1996). The extra labor did not pay off.

In Claveria, Philippines, some farmers independently developed the practice of laying out contour strips that were left unplanted, and were revegetated by native grasses and forbs. Researchers found that these natural vegetative strips (NVS) had many desirable qualities (Garrity, 1993). They needed much less pruning maintenance compared with fodder grasses or tree hedgerows and offered little competition to the adjacent annual crops compared with the introduced species. They were very efficient in minimizing soil loss (Agus, 1993). And they did not show a tendency to cause greater weed problems for the associated annual crops. NVS were also found to be an indigenous practice on a few farms in other localities, including Batangas and Leyte Provinces.

Installing NVS is quite simple. Once contour lines are laid out there is no further investment in planting materials or labor. The vegetative strips do not need to conform closely to the contour; they act as filter strips rather than bunds. Their biomass production, and economic value as fodder, is lower than many other hedgerow options, but labor is minimized. Vetiver grass fills a similar niche as a low value-added but effective hedgerow species. But for vetiver or any other introduced hedgerow species the planting materials must be obtained and planted out, requiring extra labor. One limitation of low-maintenance hedgerows is that they do not enhance the nutrient supply to the crops. In this respect they do not differ from many other hedgerow enterprises, including fodder grasses or perennial cash crops like coffee. With continuous cropping, NVS or other low-management hedgerow options can only be sustainable with fertilization. They have proved to be popular in northern Mindanao and have been adopted by hundreds of farmers in recent years. A land care movement has evolved around the technology which has resulted in the development of numerous farmer self-help organizations that are spreading the method among their members (Mercado et al., 1997).

A practical ridge-tillage system has recently been developed for smallholder animal-draft farming (Garrity, 1997b). It eliminates the need for primary tillage operations and thus reduces production costs substantially. The system may be used along with contour hedgerows to reduce the rate of soil redistribution from the upper alleyways, which tends to degrade soil fertility in these zones. Ridge-till may also be employed in open fields as well. Soil loss is reduced substantially. Grain yields are sustained, and may even be increased after several years. Thus, the system warrants much wider testing as a promising conservation farming method.

## Programs for Intensively Farmed Watersheds in Indonesia

As land pressure increases in the upland areas of Indonesia, farmers have started continuous cropping on steep slopes. The government of Indonesia (GOI) introduced a program focusing on structural and vegetative soil and water conservation activities using the watershed as the basic unit for planning and management. Watershed management and conservation are executed through several projects. The most prominent ones were conducted in the Upper Solo Watershed in the early 1970s, followed by soil conservation projects in the Citanduy River Basin and in Yogyakarta. These assisted farmers in building bench terraces, provided agrotechnology packages of seeds and fertilizers, reforested government land, and constructed check dams and gully plugs.

The main government program in watershed management and soil conservation is the Regreening and Reforestation Program (the R&R Program). It began in 1976 with the following objectives: (1) controlling erosion and flooding, (2) improving land productivity and farmer's income, and (3) increasing people's participation in preserving natural resources. Initially, it supported mainly the supply of seedlings for planting on farmer's land (regreening) and on public land (reforestation). The present approach includes demonstrations of soil conservation and agronomical packages through Soil Conservation Demonstration Units (*Usaha Pelestarian Sumberdaya Alam* = UPSA) and through Sedentary Farming Demonstration Units (*Usaha Pertanian Menetap* = UPM).

The main approach of UPSA and UPM is to increase land cover through promoting agroforestry. Government recommendations are to increase ground cover by perennial crops to 25% on land with slopes between 15 and 25%, to 50% on slopes between 25 and 40%, and to 100% on slopes steeper than 40% (Sekretariat Tim Pengendali Penghijauan dan Reboisasi Pusat, 1996). Implementation is limited by many constraints, particularly the prevalent subsistence mode of farming, insecure land tenure that forces farmers to invest in activities with a fast return, and inaccessibility or uncertainty of markets. Thus, it is now recognized that a combination of annual crops with perennials is the only practical way forward. We briefly examine the appropriateness of the technology options being introduced under the R&R program and other farming systems development programs.

## Soil Conservation Demonstration Units

Table 11.2 summarizes the opportunities and constraints of a number of soil conservation measures for Indonesian smallholders. Although bench terracing is implemented at almost every project site, the technique is often unsuitable due to a shallow soil depth, an unstable soil structure, or to very acid subsoil (Sukmana, 1995; Agus et al., 1996). Examples of its unsuitability can be found at a few demonstration plots in shallow and unstable soils in central and south Sulawesi and in East Nusa Tenggara. When bench terraces are physically unsuitable for the site, they deteriorate soil conditions for farming by increasing the rate of mass wasting and by exposing the subsoil. Terracing costs about U.S.$900/ha, while the initial income generated from most rain-fed uplands before as well as after treatment was in the order of $600/ha/year. Such investment costs are clearly unsuitable for smallholders. High costs and labor requirements to maintain these structural conservation measures also often run counter to the reality of smallholder agriculture. The success of bench terracing has therefore been limited to parts of Java (Sembiring et al., 1989) and Bali where there is extreme land pressure and a history of making terraces for paddy fields.

The use of contour hedgerows of grasses or legume shrubs as an erosion control measure and as a source of feed is the most widely adopted packages in Southeast Asia. In general, farmers seek additional benefits apart from erosion control. Vetiver grass as a hedgerow was less preferred, although it shows almost no signs of competition with food crops and is effective in reducing soil erosion. Napier grass (*Penisetum purpureum*) which suppresses the growth of a few rows of food crops adjacent to the hedgerows was preferred because it can be used as fodder (Agus et al., 1997).

## Village Nurseries

Farmer-managed nurseries in the R&R program are intended to produce high-quality timber and fruit tree seedlings and seeds of fodder and grass. They receive technical support and limited incentives during the first year. In the second and the following years, the nurseries are expected to become self-supporting. A few nurseries have survived, but most disappear when outside support is withdrawn. Often this is due to an unpopular choice of tree species, which is often in conflict with the current

**TABLE 11.2**
**Opportunities (+) and Constraints (–) of Implementation and Sustainability of Selected Conservation Measures**

| Conservation Measure | Opportunities and Constraints |
|---|---|
| Bench terrace | + Could be recommended if labor availability is high<br>– High costs and labor for establishment and maintenance<br>– Does not increase crop yields in the short run, rather it decreases yields in the first few years after establishment<br>– Being exotic to farmers outside Java |
| Contour hedgerow system | + Provide animal feed, firewood, organic matter<br>+ If legume species is used, it alleviates the need to apply nitrogen<br>+ Effective in controlling erosion if arranged properly<br>– Hedgerows take out part of food crop planting area<br>– Could be very competitive to the alley crops for water, nutrients, and light<br>– Extra costs and labor for establishment and maintenance<br>– Could harbor pests and diseases |
| Planting of fruit tree crops | + Familiar to farmers<br>+ Won't be cut unless the production or the price drops<br>+ Long-term protection to soil compared to planting annual crops<br>+ Long-term source of income<br>– Seedling might not be easily available, expensive, or of low quality<br>– Long waiting period<br>– Cannot be adopted by farmers with insecure tenure. |
| Planting of timber or pulp tree species | + Long-term protection to soil compared to planting annual crops<br>– Farmers might not have certainty of market availability; long waiting period<br>– Upon harvesting/cutting it creates recurrent problem of land denudation<br>– Cannot be adopted by farmers with insecure tenure<br>– Unavailability of quality planting materials |
| Minimum tillage and mulching (including green mulching) | + Reduce requirement for labor<br>+ Give protection to soil surface in terms of erosion reduction, moisture conservation, and, to a lesser extent, nutrients contribution<br>– Many farmers do not see direct benefits of mulching<br>– Lack of mulching materials<br>– Extra works for obtaining materials<br>– Mulch might harbor pests and diseases |
| (Grass) strip cropping | + Supports livestock production<br>+ Effective conservation measure for slopes between 15 to 45%<br>– Requires fertilization and replanting of the grass<br>– Only applicable to areas potential for livestock production |

annual crop farming systems or to emphasis on timber species when farmers prefer fruit trees. Where the species fulfill a local need, however, the centralized village nursery may transform into individual nurseries usually managed in home gardens. These individual nurseries appear to be more sustainable because they are easier to manage and can be operated in a self-reliant manner.

### Program Adjustments to Meet Farmer Needs

Despite success, there are weaknesses in the R&R program. Among the major weaknesses is the use of less appropriate technology due to lack of involvement of the farmers and a weak linkage between research and extension. There has been too much emphasis on a few conservation measures due to a poor understanding of farmers' circumstances among the program implementors. Rather than matching technology options with the biophysical conditions and the socioeconomic situation of the farmers, a top-down approach has dominated the selection of soil conservation measures. Starting in 1994, the lessons learned have induced an improved integration of the R&R program into the regional plans, and program guidelines have evolved toward addressing local conditions and community needs. But much more needs to be done along these lines. Extension workers should not limit themselves to a very few options, but should take advantage of the wide range of options that are available (Agus et al., 1997).

Paradigm shifts are taking place in hillslope conservation management as indicated by Garrity and van Noordwijk (1995): (1) the engineering approach has shifted to a biological approach, (2) the top-down approach is yielding to a bottom-up approach, and (3) the classical alley farming concept is diversifying to a wider array of agroforestry. In most cases, low-cost vegetative soil conservation measures can be applied. Sanchez (1995) and Lal (1991) warned not to oversell agroforestry technologies as many of their benefits have still to be scientifically proved. Future research should vigorously address these issues.

## CONCLUSIONS

What will it take to turn things around for Asia's fast-degrading watersheds? Watershed management requires an integrated and multisectoral approach to sustainable development, but government departments are compartmentalized and geared for top-down operations. They will need to change. Participatory approaches transfer principles rather than standard solutions, and make available a basket of choices rather than a set package of practices. Problem analysis must not simply be done by outsiders for the community, but must be done by the community itself with backstopping by the outsiders. The solution is not to transfer some known technology, but to assist farmers to adapt technologies to their own circumstances. This is predicated on the recognition that rural people, educated or not, have a much greater ability to analyze, plan, and implement their own development activities than was previously assumed by outsiders.

What can agroforestry contribute? As a highly integrative field on the interface between the agricultural, forestry, social, and environmental sciences, agroforestry will play a critical central role in helping to provide key technical and institutional innovations at the landscape scale. As a natural resource management system that involves the increasing integration of trees into the agricultural landscape, it will play a major role, holistically and comprehensively, in the process of providing options that increase rural livelihoods, and yet are conducive to the conservation of fragile watershed resources.

## REFERENCES


Adiningsih, J.S. and Mulyadi, D.1993. Alternatif teknik rehabilitasi dan pemanfaatan lahan alang-alang [Alternatives of rehabilitation and utilization of *Imperata* grassland], in S. Sukmana, Ed., *Pemanfaatan Lahan Alang-alang Untuk Usahatani Berkelanjutan,* Prosiding Seminar Lahan Alang-alang, Bogor, 1 Des. 1992. Pusat Penelitian Tanah dan Agroklimat, Bogor.

Agus, F. 1993. Soil Processes and Crop Production under Contour Hedgerow Systems on Sloping Oxisols, Ph.d. dissertation, North Carolina State University, Raleigh, 141 pp.

Agus, F., Gintings, A.N., and Ai, D. 1996. Sumberdaya alam daerah aliran sungai Cimanuk Hulu dan teknologi konservasi [Land resources of the Upper Cimanuk Watershed and conservation technology], in B.R. Prawiradiputra et al., Eds., *Prosiding Lokakarya Pembahasan Hasil Penelitian dan Analisis Pengelolaan Daerah Aliran Sungai,* Pusat Penelitian Tanah dan Agroklimat, Bogor, 113–128.

Agus, F., Abdurachman, A., and van der Poel, P. 1997. Daerah aliran sungai sebagai unit pengelolaan pelestarian lingkungan dan peningkatan produksi pertanian [Watershed as a unit of environmental management and conservation and agricultural production], Prosiding Pertemuan Teknis Pusat Penelitian Tanah dan Agroklimat, Bogor.

Ai, D., Suganda, H., Sujitno, E., Tala'ohu, S.H., and Sutrisno, N. 1995. Rehabilitasi lahan alang-alang dengan sistem budidaya lorong di Pakenjeng, Kabupaten Garut [Rehabilitation of *Imperata* grassland using alley cropping systems at Pakenjeng, Garut District], in D. Santoso, *Prosiding Pertemuan Teknis Penelitian Tanah dan Agroklimat,* Pusat Penelitian Tanah dan Agroklimat, Bogor, 31–41.

Bannerjee, A.K. 1990. Revegetation techniques, in Doolette, J. and Magrath, W.B., Eds., *Watershed Development in Asia: Strategies and Technologies,* World Bank Technical Paper No. 127. World Bank, Washington, D.C., 109–130.

Cairns, M. 1994. Shifting Cultivation on the Perimeter of a National Park, MSc thesis, York University, Toronto, Canada.

Cairns, M. 1995. Ancestral Domain and National Park Protection: A Mutually Supportive Paradigm? International Center for Research in Agroforestry, Southeast Asian Regional Research Program, Bogor, Indonesia.

Cairns, M., Murniati, Otsuka, M., and Garrity, D.P. 1997. Characterization of the Air Dingin-Muara Labuh Area of the Kerinci Seblat National Park: farm and national park interactions in *Proceedings of the Workshop on Alternatives to Slash and Burn,* Central Research Institute for Food Crops, Bogor, Indonesia, June 1995, 135–172 (in press).

Carson, B. 1989. Soil Conservation Strategies for Upland Areas of Indonesia, Occasional Paper No. 9, Environment and Policy Institute, East-West Center, University of Hawaii, Honolulu.

de Foresta, H. and Michon, G. 1997. The agroforest alternative to *Imperata* grasslands, *Agroforestry Syst.* 36:105–120.

de Foresta, H. and Schwartz, D. 1991. *Chromalaena oderata* and disturbance of natural succession after shifting cultivation: an example from Mayonbe, Congo, Central Africa, in R. Nuniappau and P. Ferrar, Eds., *Ecology and Management of* Chromalaena odorata, BIOTROP Spec Publ. No. 44: 23–41.

Doolette, J.B. and Smyle, J.W. 1990. Soil and moisture conservation strategies: review of the literature, in Doolette, J.B. and Magrath, W.B., Eds., Watershed Development in Asia: Strategies and Technologies. World Bank Technical Paper No. 127. World Bank, Washington, D.C., 35–70.

Douglas, M. 1996. *Participatory Catchment Management,* 2 Vols., HR Wallingford, Oxon, U.K.

Dove MR. 1986. The practical reason of weeds in Indonesia: peasant vs. state views of *Imperata* and *Chromalaena, Human Ecol.* 14:163–190.

Fujisaka, S. 1993. A case of farmer adaptation and adoption of contour hedgerows for soil conservation, *Exp. Agric.* 29:97–105.

Garrity, D.P. 1993. Sustainable land-use systems for sloping uplands in Southeast Asia, in *Technologies for Sustainable Agriculture in the Tropics,* American Society of Agronomy Special Publication 56, Madison, WI, 41–66.

Garrity, D.P. 1995a. Improved agroforestry technologies for conservation farming: pathways toward sustainability, in *Proc International Workshop on Conservation Farming for Sloping Uplands in Southeast Asia: Challenges, Opportunities and Prospects,* IBSRAM, Bangkok, Thailand, Proc. No. 14, 145–168.

Garrity, D.P. 1995b. Buffer Zone Management and Agroforestry: Some Lessons from a Global Perspective, International Centre for Research in Agroforestry, Southeast Asian Regional Research Program, Bogor, Indonesia.

Garrity, D.P., Ed. 1997a. Agroforestry innovations for *Imperata* grassland rehabilitation, *Agroforestry Syst.* Special Issue 36, 276 pp.

Garrity, D.P. 1997b. Conservation Tillage: A Southeast Asian Perspective, International Center for Research in Agroforestry, Southeast Asian Regional Research Program, Bogor, Indonesia, 26 pp.

Garrity, D.P. 1997c. Addressing Key Natural Resource Management Challenges in the Humid Tropics through Agroforestry Research, International Centre for Research in Agroforestry, Bogor, Indonesia, 29 pp.

Garrity, D.P. and Mercado, A. 1994. Reforestation through agroforestry: market-driven smallholder timber production on the frontier, in Raintree, J.B. and Francisco, H.A., Eds., *Marketing of Multipurpose Tree Products in Asia,* Winrock International, Morrilton, AR, 265–268.

Garrity, D.P. and Van Noordwijk, M. 1995. Research Imperative in Conservation Farming and Environmental Management on Sloping Lands: An ICRAF Perspective, ICRAF, Bogor, Indonesia, 5 pp.

Garrity, D.P., Soekardi, M., Van Noordwijk, M., de La Cruz, R., Pathak, P.S., Gunasena, H.P.M., So, N., van Huijin, G., and Majid, N.M. 1997. The *Imperata* grasslands of tropical Asia: area, distribution, and typology, *Agroforestry Syst.* 36:3–29.

Glynn, C. 1996. Overcoming Constraints to Agroforestry Adoption in Tropical Highlands: Part I: An Investigation of Performance by Elevation Patterns for Some Commonly Grown Timber Species in the Manupaly Watershed, Bukidnon, Philippines, M.Sc thesis, Tropical and Subtropical Horticulture and Crop Science, Wye College, University of London, London.

Gouyon, A., de Foresta, H., and Levang, P. 1993. Does "Jungle Rubber" deserve its name? An analysis of rubber agroforestry systems in southeast Sumatra, *Agroforestry Syst.* 22:181–206.

ICRAF. 1996. Annual Report For 1995, International Centre for Research in Agroforestry, Nairobi, Kenya.

ICRAF. 1997. Annual Report For 1996, International Centre for Research in Agroforestry, Nairobi, Kenya.

Kiepe, P. 1995. No Runoff, No Soil Loss: Soil and Water Conservation in Hedgerow Barrier Systems, Wageningen Agricultural University, Wageningen, the Netherlands.

Lal, R. 1991. Myths and scientific realities of agroforestry as a strategy for sustainable management for soils in the tropics, *Adv. Soil. Sci.* 15:91–137.

Leakey, R. 1996. Definition of agroforestry revisited, *Agroforestry Today* 8(1):5–6.

Limchoowong, S. and Oberhauser, U. 1996. In *Proceedings of the Discussion Forum ""ighland Farming: Soil and the Future?"* Can villagers manage highland resources well?"Maejo University, Chiangmai, Thailand. pp. 13–22.

Magrath, W.B. and Doolette, J.W. 1990. Strategic issues in watershed development, in Doolette, J.W. and Magrath, W.B., Eds., *Watershed Development in Asia: Strategies and Technologies,* World Bank Technical Paper No. 127, World Bank, Washington, D.C., 1–34.

Mary, F. and Michon, G. 1987. When agroforests drive back natural forests: a socio-economic analysis of a rice/agroforest system in South Sumatra, *Agroforestry Syst.* 5:27–55.

Mercado, A. Jr., Stark, M., and Garrity, D.P. 1997. Enhancing sloping land management technology adoption and dissemination, paper presented at the IBSRAM Sloping Land Management Workshop, Bogor, Indonesia, 15–21 September, 1997, 24 pp.

Michon, G., de Foresta, H., and Aliadi, A. 1995. An Agroforestry Strategy for the Reappropriation of Forest Resources by Local Communities: The Case Study of Damar Agroforests in West Lampung, Sumatra, International Center for Research in Agroforestry, Southeast Asian Regional Research Program, Bogor, Indonesia, 54 pp.

Milliman, J.D. and Meade, 1983. World-wide delivery of river sediment to the oceans, *J. Geol.* 91:1–21.

Momberg, F. 1993. Indigenous Knowledge Systems: Potentials for Social Forestry Development: Resource Management of Land-Dayaks in West Kalimantan, M.Sc. thesis, Technische Universitat Berlin, Germany.

Penot, E. 1996. Sustainability Through Productivity Improvement of Indonesian Rubber-Based Agroforestry Systems, International Center for Research in Agroforestry, Southeast Asian Regional Research Program, Bogor, Indonesia, 13 pp.

Rachman, A., Abdurachman, A., and Haryono, 1995. Erosi dan perubahan sifat tanah dalam sistem pertanaman lorong pada tanah Eutropepts, Ungaran [Erosion and changes in soil properties in alley cropping system on Eutropepts, Ungaran], in *Proceedings Pertemuan Teknis Penelitian Tanah dan Agroklimat Bidang Konservasi Tanah dan Air, dan Agroklimat,* Pusat Penelitian Tanah dan Agroklimat, Bogor, 17–30.

Sajjapongse, A. and Syers, K. 1995. Tangible outcomes and impacts from the ASIALAND management of sloping lands network, in *Proc. International Workshop on Conservation Farming for Sloping Uplands in Southeast Asia: Challenges, Opportunities and Prospects,* IBSRAM, Bangkok, Thailand, Proc. No. 14, 3–14.

Salafsky, N. 1993. The Forest Garden Project: An Ecological and Economic Study of a Locally Developed Land-Use System in West Kalimantan, Indonesia, Ph.D. thesis, Duke University, Durham, NC, 327 pp.

Sanchez, P.A. 1995. Science in agroforestry. *Agroforestry Syst.* 30:5–55.

Sekretariat Tim Pengendali Penghijauan dan Reboisasi Pusat. 1996. Petunjuk Pelaksanaan dan Petunjuk Teknis Bantuan Penghijauan dan Reboisasi, Jakarta.

Sembiring, H., Syam, A., Hardianto, R., Kartono, G., and Sukmana, S. 1989. Evaluasi adopsi teknologi usahatani konservasi lahan kering di DAS Brantas: Studi kasus Desa Srimulyo, Malang [Evaluation and adoption of conservation farming technologies in the upland of Brantas Watershed: a case study at Srimulyo village, Malang], in H. Suhardjo, Ed., *Prosiding Pertemuan Teknis Penelitian Tanah Bidang Konservasi Tanah dan Air,* Pusat Penelitian Tanah dan Agroklimat, Bogor.

Soekardi, M., Retno, M.W., and Hikmatullah, 1993. Inventariasasi dan karakterisasi lahan alang-alang [Inventarization and characterization of *Imperata* grassland], in S. Sukmana, Ed., *Pemenfaatan Lahan Alang-alang untuk Usahatani Berkelanjutan, Prosiding Seminar Lahan Alang-alang,* Bogor, 1 Dec 1992, Center for Soils ansd Agrlclimate Research, Bogor, Indonesia, 1–17.

Stoutjesdijk, J.A.J.H. 1935. *Eupatorium pallescens* DC op Sumatra's westkust [*Eupatorium pallescens* DC on the west coast of Sumatra], *Tectona* 28:919–926.

Sukmana, S., Ed. 1993. Pemanfaatan lahan alang-alang untuk usahatani berkelanjutan [The use of *Imperata* land for sustainable land management]. *Prosiding Seminar Lahan Alang-alang,* Bogor, 1 Dec. 1992, Pusat Penelitian Tanah dan Agroklimat, Bogor.

Sukmana, S. 1995. Perkembangan penelitian konservasi tanah dan air di Indonesia [The development of soil conservation research in Indonesia], Dalam D. Santoso et al., Ed., *Prosiding Pertemuan Teknis Penelitian Tanah dan Agroklimat,* Bogor, 10–12 Jan. 1995, Pusat Penelitian Tanah dan Agroklimat, Bogor, 153–169.

Szott, L.T., Palm, C.A., and Sanchez, P.A. 1991. Agroforestry in acid soils of the humid tropics, *Adv. Agron.* 45:275–300.

Thiollay, J.M. 1995. The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra, *Conserv. Biol.* 9(2):335–353.

Thomas, D. 1996. Opportunities and limitations for agroforestry systems in the highlands of north Thailand, in *Proceedings of the Discussion Forum "Highland Farming: Soil and the Future?"* Maejo University, Chiangmai, Thailand.

Tomich, T.P., J. Kussipalo, K. Menz and N. Byron. 1997. *Imperata* economics and policy, *Agroforestry Syst.* 36:233–261.

Tomich, T.P., van Noordwijk, M., Vosti, S., and Whitcover, J. 1998. Agricultural development with rainforest conservation: Methods for seeking best-bet alternatives to slash-and-burn, *J. Agric. Econ.* 19: 1–2, 159–174.

Torquebiau, E. 1992. Are tropical home gardens sustainable? *Agric. Ecosyst. Environ.* 41:189–207.

Turkelboom, F. and van Keer, K., Eds. 1996. *Land Management Research for Highland Agriculture in Transition,* Mae Jo University, Thailand, and Catholic University of Leuven, Belgium, 53 pp.

van Noordwijk, M., Tomich, T.P., Winahyu, R., Murdiyarso, D., Partoharjono, S., and Fagi, A.M., Eds. 1995a. Alternatives to Slash-and-Burn in Indonesia. Summary Report of Phase 1. ASB-Indonesia Report No. 4, International Centre for Research in Agroforestry, Southeast Asian Regional Research Program, Bogor, Indonesia. 151 pp.

van Noordwijk, M., van Schaik, C.P., de Foresta, H., and Tomich, T.P. 1995b. Segregate or Integrate: Nature and Agriculture for Biodiversity Conservation, International Centre for Research in Agroforestry, Bogor, Indonesia, 16 pp.

van Noordwijk, M., Hairiah, K., Partoharjono, S., Labios, R.V., and Garrity, D.P. 1997. Food-crop based production systems as sustainable alternatives for *Imperata* grasslands? *Agroforestry Syst.* 36:55–82.

Wells, M. and Brandon, K. 1992. People and Parks: Linking Protected Area Management with Local Communities, The World Bank, Washington, D.C.