Upland Agriculture in Asia

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Agroforestry and the Sustained Productivity of Asia's Humid Uplands

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Introduction

In Southeast Asia there are many serious problems of agricultural sustainability observed in all the major agro-ecosystems. But the sloping uplands are geographically the most extensive of ecosystems, and the most threatened. The unsustainability of land use systems in the uplands is associated with increasing populations of subsistence farm families cultivating infertile sloping soils, accelerating land degradation and soil erosion; the impending loss of most tropical hardwood forest, and the failure of reforestation. Inequitable and insecure access to land resources exacerbates the tendency toward inappropriate land use. More productive and sustainable land use systems must be developed under conditions of severe social and economic constraints. The crisis appears largely intractable unless systematically and innovatively addressed.

The problems of upland resource base deterioration extend across all national frontiers in the region, but they are only now beginning to be grappled with by the respective governments. Within each country the domain of the uplands is usually a complex division of responsibilities among the forestry and the agriculture departments. This greatly complicates technology generation, land tenure, and the delivery of infrastructure and service in these ecosystems.

The potential of agroforestry to solve key land use problems was not recognized by mainstream research and extension institutions until recently. But as the staple food production problems in the lowlands were successfully coped with, governments began to seriously grapple with the ecological and poverty crisis in the uplands. There is widespread interest in implementing upland agroforestry development programs, often involving non-traditional land tenure arrangements. In socialist (eg China and Vietnam) as well as in free-market economies (eg Philippines and Thailand) major programs are evolving that essentially involve the transfer of millions of hectares of hilly land from government control to family farmers.

Agroforestry has now been popularized among decision makers as an attractive conservation farming solution to sustain the productivity of fragile lands. Consequently, there is enormous demand for sound upland agroforestry technology, but a major shortfall in the research needed to provide answers.

This paper will briefly characterize the humid sloping uplands of the region in terms of three major subecosystems, and then discuss the directions in which their land use systems are evolving. Some promising land use practices will be emphasized and some of the issues surrounding their expansion briefly analyzed.

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The Asian lowlands represent only a small fraction of the total land area in the region although they are of great economic importance. The upland areas constitute from 60 to over 90 percent of the total land area of the respective countries. Permanent upland settlement that occurred prior to recent decades was mainly restricted to the more fertile volcanic soils, as encountered in Java, and parts of the Philippines. Exceptionally favorable soil resources in these limited areas made highly productive, diverse upland farming systems possible. But the Southeast Asian uplands are predominantly sloping lands of strongly acid Ultisols and Oxisols. Of the 180 million ha of acid uplands, about 118 million ha are estimated to have pH values below 5.0 (IRRI 1987).

Where crop cultivation was practiced on the acid, infertile sloping uplands, it was formerly limited to shifting cultivation systems as the only practical method of exploitation. However, during the last couple of decades, the lowlands and fertile uplands became densely occupied in most countries, and the land frontier on favorable soils virtually closed. Millions of families that could not otherwise be absorbed in the national economies began an accelerating migration into the sloping, acid uplands. As in past generations, they sought modest permanent landholdings to provide a livelihood, but encountered serious difficulties as increasing population pressure shortened or eliminated the fallows that were essential to accumulate nutrients for crop production.

In the Philippines, for example, permanent cultivation or fallow rotation within the farm boundaries, is now observed throughout the hills of the entire archipelago. The number of people living in the uplands (areas with slopes greater than 18%), was recently estimated at 17.8 million, or almost 30 percent of the country's total population (Cruz and Zosa-Feranil 1988). The population growth rate in the uplands is significantly higher than that in the lowlands.

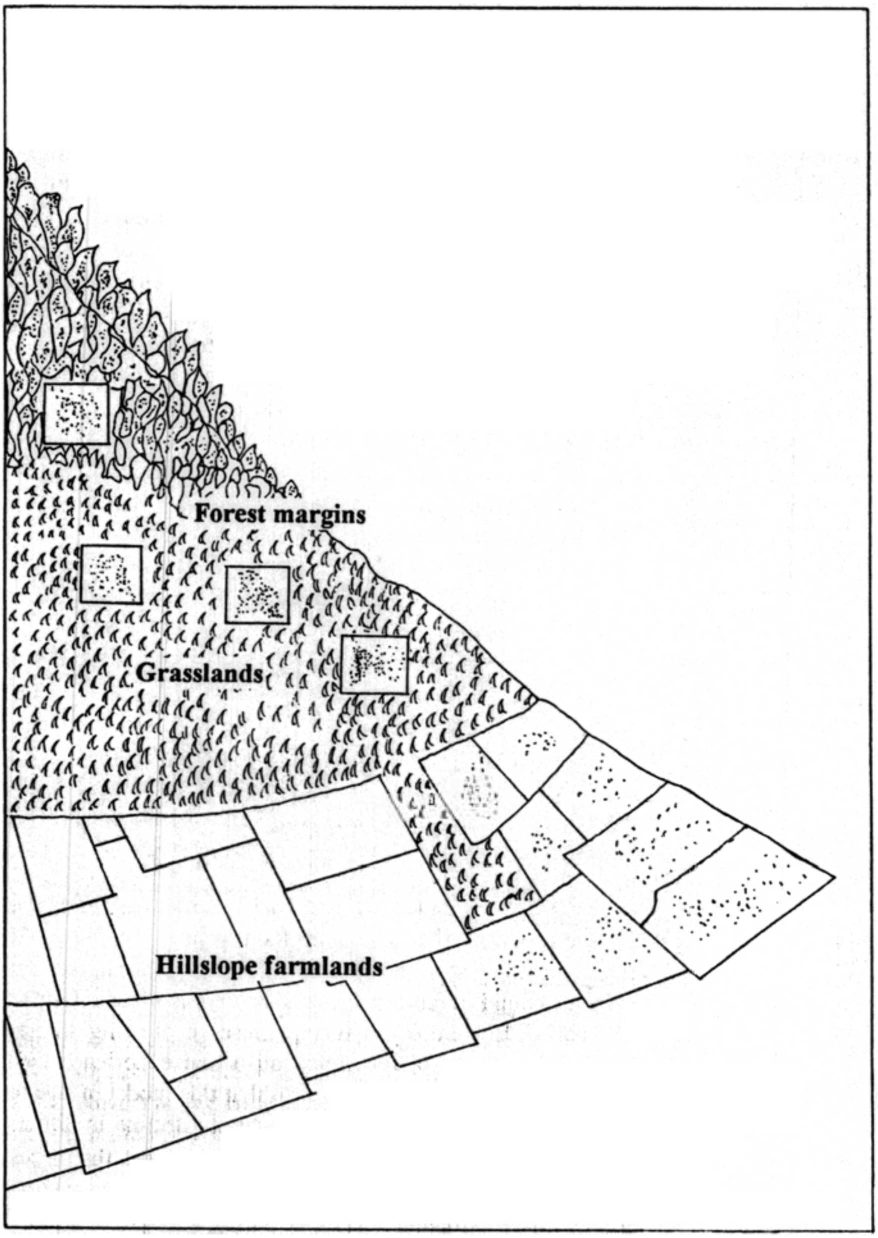
In Northern Thailand, the forest cover has predominantly disappeared within the past generation. The area has largely been transformed into farmland, and bush or grass fallows, by the cultivation of upland rice and other subsistence food crops. In China, which is ecologically contiguous with northern Thailand, there is evidence of severe pressure on the sloping red soils throughout the southern third of the country. In Indonesia, settlement of the infertile uplands of the outer islands is proceeding rapidly, due both to spontaneous migration and government-sponsored transmigration programs.

Many of the prevalent cereal-based farming systems practiced by small-scale farmers are highly unsustainable. This is widely evident in negative trends in the condition of the land resource base, and in declining production flows. Due to the relative inaccessibility, fragility, and marginality of the sloping uplands, the sustainability of utilization and production flows are inseparable from the sustainability of the resource base itself (Jodha 1990). Damage to the resource base is characteristically rapid, and it is reversible only over a long period of time.

The massive rate at which the Southeast Asian land base in degrading may be deduced from data on the rate of soil loss in the region, compared to other areas of the world. The magnitude of the discharge of sediment form SE Asia's major river systems dwarfs that of other river basins around the world (Milliman and Meade 1983). The river systems of mainland Southeast Asia discharge over 3.2 billion tons of sediment annually. The island nations of the region are nearly as prodigious as the mainland countries in production of river sediment, with 3.0 billion tons per year. Each of these areas produces more than an order of magnitude more river sediment than the Mississippi River drainage system in North America, and twice the sediment of the Amazon River basin.

These extraordinarily high soil losses result from heavy and intensive rainfall interacting with relatively steep slopes and intense human land use pressure.

Figure 1 **Three dominant subecosystems compose a landscape model that focusses on the development of sustainable upland agroforestry practices.**



The upland subecosystems

The upland ecosystem is composed of a great diversity of land use systems. This paper concentrates on the family farm sector in the sloping uplands, which relies on field crop production and agroforestry for its food supply and income. This sector dominates in terms of numbers of people involved, and land area affected, and it is unquestionably the most environmentally stressed.

The landscape ecology of much of southeast Asia follows a broadly similar pattern along a decreasing elevational gradient. In the uplands of a 'typical' watershed the land use pattern may be recognized: the forest margins, *Imperata* grasslands, and the marginal hilly farmlands (Figure 1). Admittedly, such a model is highly simplified, but it is useful to guide the discussion of ecosystem-related issues and their interactions for research and development planning.

The remnants of old growth forests are generally present only at the highest elevations (eg old growth is seldom observed at less than about 800 m elevation in the Philippines). The boundary of the forest margin is constantly moving upward due to forest conversion processes, accelerated by slash and burn. Behind the forest margins are extensive grasslands. They evolved following prior cultivation, and are maintained in a fire climax. These lands are used (depending on the area) for cattle grazing, hunting, or shifting cultivation.

At lower elevations closer to the roads, the hilly lands are more densely occupied. Here, rotation-fallow systems are gradually evolving into more permanent cropping systems. This zone grades into more gently sloping, intensively farmed uplands. Wetland rice is produced in the alluvial valleys from the uplands to the broad lowland river basins. Agroforestry is important in the rice-growing areas as home gardens and bund planting. The coastal wetlands include large areas of mangroves, which allow for unique forms of agroforestry.

Depending on the watershed size, geomorphology, and human settlement patterns, the various zones may be juxtaposed, or one or more might be missing. But the pattern repeats itself dependably enough to provide a landscape ecosystem model. This model helps isolate relationships among landscape components, and can be a useful basis to help clarify research needs.

The forest margins

Two predominant paradigms have been promoted for sustainable settlement of the forest margins in southeast Asia. The first might be termed the 'continuous food crops model'. It was based on the premise that with appropriate soil and crop management practices, continuous annual cropping could be practiced sustainably on humid, infertile Ultisols and Oxisols (Wade 1988). The transmigration program of Indonesia has widely employed this premise in clearing forest and allocating farmland to migrant families. The record of research, and actual experience by both government-subsidized and spontaneous settlers, has tended to confirm that this model of sustaining profitable small-scale food cropping is not generally feasible. A productivity decline is difficult to prevent, and the marginal returns and risk in annual cropping seldom warrant the necessary investment. Some form of perennial cropping is usually more suited to the land's inherent capability.

An alternative model, which was given particular emphasis during the late 70s and 80s, might be termed the 'monoculture estate crops model'. It was strongly supported by international development banks. This model involves the creation of large estates of perennial tree crops to replace natural forest and/or slash and burn farming. Indonesia, in particular, has pursued the largest smallholder tree crop development program in the world (Tomich 1991). Emphasis was placed on a project-based, block planting strategy. Small-scale farmers received 1-2 hectare parcels on the estate. These are designated for monoculture rubber or oil palm production, with a guaranteed market.

These tree crop-based schemes avoided some of the problems of earlier land development models, but they lacked the flexibility and crop diversity of traditional forest farming strategies. They were highly bureaucratized schemes, yet had disappointing returns. New concerns have also arisen with these models, particularly the high degree of price risk farmers face because their source of livelihood is dependent on a single commodity.

The small-holder rubber sector that was unaffected by projects covers 85% of the planted area, almost 2.5 million ha. Most of this is managed as diversified rubber agroforests, derived from shifting cultivation (Laumonier 1991). Although most of the income is derived from rubber, it is complemented by temporary food and cash crops. Fruit and timber are derived from the other perennials (including native secondary forest species) retained in the forest garden. A mounting body of studies on the agroecology of these systems has revealed that although their rubber yield per hectare is low, their diversification and labour dynamics are more optimally suited to the small-holder family with low investment capital.

The project-based focus of government has diverted the available investment in infrastructure, improved technology, planting materials, and extension, away from the open market-based small-holder sector. Nevertheless, indigenous small-holder rubber systems have been expanding enormously, but without government support. This is unfortunate since there is strong evidence that if a fraction of the investment relegated to block planting projects were targeted to market-based support for small-holders, the returns and equity of benefits would have been much greater (Tomich 1991).

Rubber agroforests have a structure and diversity of species similar to that of secondary forest (Kheowvongsri 1990). This has important implications when they occupy the buffer zones of natural protected forests. They may serve to more satisfactorily protect and extend the biodiversity of the natural forest ecosystems better than other forms of agriculture or plantation forestry. Many other types of traditional complex agroforestry systems show similar characteristics of being balanced, diversified farming systems that are highly sustainable. These include the durian agroforests of Sumatra (Michon et al. 1992) and West Kalimantan (Salafsky 1993), and the damar (*Shorea javanica*) resin-producing dipterocarp agroforests of Lampung, Sumatra (Torquebieau 1984).

As yet, the very real prospects for extrapolating and improving upon these systems is little recognized by the scientific community. Policy makers need to more seriously consider them as promising options for public sector support toward a more intensive and sustainable agriculture and forestry. What is urgently needed is a deeper understanding of the agroecology of complex agroforests, and the development and spread of technical improvements that will upgrade their productivity. Research must be aimed to guide decisions on when, where, and how complex agroforestry systems are preferable to other options. It must provide better germplasm and management practices.

Complex agroforests appear to be one of the most promising alternatives to unsustainable slash and burn. The big issue is how to translate the rich experience of the mature, indigenous forest margins communities to the circumstances of recent migrant cultivators, and how to improve upon this experience.

The grasslands

The *Imperata cylindrica* grasslands of southeastern Asia represent a vast underutilized natural resource, covering an area exceeding 20 million hectares. Most grasslands (known as *alang-alang, cogon,* and *lalang* in local languages) in the region were derived through slash and burn cultivation, linked with logging activities, and the opening up of grazing land. They are permanently maintained through the frequent occurrence of fire.

As human population densities increase on the forest margins, and worldwide concern intensifies to protect the dwindling area of humid tropical forests, increasing interest is focusing on land use alternatives for these grasslands. One of the most effective means of reducing pressure on natural forests would be to bring the abandoned lands into sustained production. Estimates of the economic benefits to farm families and to the national economy in adopting small-scale agroforestry systems substantially exceed those from shifting cultivation or large-scale industrial timber plantations (World Bank 1990).

Little systematic knowledge exists concerning the rehabilitation of degraded grasslands. Several reviews on the *Imperata* problem have been published (Brook 1989; Sukmana 1986; Holm et al. 1977; Eussen and Soerjani 1976; Soerjani 1970; Hubbard et al. 1944), but the problem tends to be viewed as one of *Imperata* weed control methods. Largely ignored is the reality that the presence of *Imperata* grasslands is symptomatic of a complex interaction of human and environmental factors (Dove 1986). A more holistic understanding of the agroecosystem is essential in developing truly practical and comprehensive ways of managing and exploiting the potential of these lands.

Plantation reforestation, particularly the many projects sponsored by national forest departments, has had a singularly disappointing history (Forest Management Bureau 1988; Reyes and Mendoza 1983). Only a small proportion of the trees survive to maturity, either due to fire, poor site conditions, or lack of care. There is increasing interest in focusing on land use alternatives for these grasslands that feature the active participation of local people.

Timber prices are increasing rapidly in Southeast Asia. Sawn wood supplies are becoming scarce in many areas. This is inducing small-scale farmers to grow trees for sale. For example, hundreds of smallholders in the southern Philippines are responding to this market demand by planting fast-growing hardwood species such as *Gmelina arborea, Peraserianthes falcataria,* and *Acacia mangium.* They are inter-cropping the trees in contour lines with their annual field crops on the farm. In Java, *P. peraserianthes* is widely planted by smallholders.

Preliminary observations indicate that the establishment of timber trees by small-scale farmers has several unique advantages:

- land preparation and weeding costs in the initial years are charged to the annual crops, making tree establishment and maintenance cheap and effective compared to large-scale plantation methods,
- the cropped alleyways between trees provide fire breaks that drastically reduce wildfire damage, and
- small farmers' more intensive field management better insures that the trees will make it to harvestable age.

Small-scale farmers may be effective agents for reforestation in the future, by integrating trees into their farming systems. Thus, the demise of the natural forests does have a positive spinoff for the upland cultivator. There is now a market-driven incentive to add timber trees as a profitable 'new' commodity group to the array of enterprises on the farm.

The incorporation of a multipurpose tree into an annual crop system may substantially increase the income generating potential of the farming system (Miah 1993). The performance of tree-crop inter-cropping systems will be sensitive to the species selected, the timing and frequency of pruning, as well as the density and geometry of the tree population in the crop field.

Policy makers need to address the potential of the small-holder to be a major agent in producing trees for timber and other uses from his land. Indeed, the smallholder may yet be the key to successful reforestation and watershed rehabilitation.

Hillslope farmlands

Annual crop farming is common on millions of hectares of hilly land in nearly every country in southeastern Asia. Much of this land is on slopes that range from 15-90%, with documented rates of soil erosion that typically range from 50-300 t/ha/yr. If urgent efforts to stabilize these soil resources are not successful, the resulting land degradation and wasted farms will further impoverish rural populations and exacerbate settlement pressure on the forest margins.

The most plausible model of sustainable independent small-holder farming in the uplands is one of diversification into mixed farming systems. Given the exceptionally high production and marketing risks in the uplands, and generally low marginal returns, the farm family must engage in a number of enterprises to provide nutritional and income stability (Chambers 1986). These enterprises seek to take maximum advantage of the complementarities among income-generating activities (eg. leguminous trees for fodder, green leaf manure, and fuelwood; cattle for draft, cash income, and manure).

The upland farm family must place primary emphasis on subsistence food crop production, but the land use systems that result from pursuing these needs are the least sustainable alternatives. The issue is how to enable the farm enterprise to move profitably along an trajectory that will continually increase the area of perennial plants, and decrease the area devoted to annuals. The gradual expansion of home gardens, ruminant livestock production, and plantation and timber tree crops, will contribute to this end. This emphasizes the tendency toward greater on-farm diversity, toward conservation farming systems to enable sustained food cropping, and toward an enlarging area under commercial perennial vegetation.

Alley cropping based on contour hedgerows of pruned leguminous trees has been promoted for over a decade in several countries as one solution to the problem (Garrity et al. 1993). Contour hedgerow systems have demonstrated an effective ability to reduce soil losses, but farmer adoption has not been widespread. The constraints to adoption include intensive labour requirements to install and periodically prune and maintain the hedgerows, limited value-added to farm income, and unanticipated problems in soil fertility sustainability. The classic alley cropping model is now being widely promoted, but researchers recognize that it has serious limitations in some situations.

Grass strips have also received major attention as contour vegetative barriers for erosion control in different parts of the world (Lal 1990). Two major problems have surfaced with their use. Often, their high biomass production leads to serious resource competition with the adjoining food crops, particularly since they are usually pruned for cut-and-carry fodder and their nutrient yield is removed from the field. Second, their tall stature often leads to shading of adjacent crops, or high labour expenditure in slashing.

New directions are urgently required. The constraints observed with both trees and forage grasses have stimulated the alternative concept of employing hedgerows that contain noncompetitive species. An approach that has received little attention is the installation of natural vegetative strips (NVS). These are narrow contour strips of field area left unplowed and allowed to vegetate naturally. These natural grasses may be suppressed by grazing, slashing, or mulching with crop residue.

After isolated observations were made of this practice among upland farmers, and their tendency to prefer this method of establishing contour vegetative barriers, work began on understanding their potential role. Recent data confirmed NVS provide excellent erosion control, with negligible installation and maintenance costs, or competition with the associated annual crops (Garrity et al, 1993). As the strips capture sediment and develop into terraces they also provide a foundation for agroforestry. We observe that income-generating cash perennials are planted on the risers along with fodder or green manure species. Thus, NVS may be a convenient way to evolve toward more sustainable annual cropping, with a gradually increasing farm area in perennials.

Research at Claveria, Mindanao, has provided important data on the management of these systems (Ramiaramanana 1993). The NVS system minimized hedgerow-crop interference with a much lower labour investment than alternative hedgerows species. Some technical issues do require attention however. It is not yet clear how soil fertility can be maintained in the upper alleyways as terraces form, and how the addition of cash perennials to the NVS may affect the food crop and overall system productivity. Subsequent pathways to sustainable farming will involve management systems based on nutrient recycling, nutrient regeneration, or nutrient importation.

Conclusion

This paper discussed some positive directions for evolving sustainable land use systems in the forest margins, grasslands, and hilly farmlands of Asia. The respective solutions emphasized were complex agroforests for the forest margins, reforestation through smallholder agroforestry in the grasslands, and natural vegetative strips on hillslope farmlands. These systems were not the contributions of researchers. They are adaptations built upon farmer knowledge and practice. In each case, the wider utility of these local agroforestry practices is not generally appreciated. However, the logic of starting with farmer-based solutions needs to be more seriously embedded in the research and development process (Fujisaka 1989).

Research to improve the technical efficiency of these practices will be crucial. Likewise, public-sector support in terms of rural infrastructure will also be necessary. And in all cases, reasonably secure land tenure will be fundamental to the application of these practices on the land.

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