

# ICRAF's Mission in Asia: A Test of Three Systems Hypotheses

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## Abstract

ICRAF's purpose is "to work towards mitigating tropical deforestation, land depletion, and rural poverty through improved agroforestry systems". The institute established a regional research program for southeastern Asia in 1992, with offices in Bogor, Indonesia. The ecological domain includes the more humid, tropical environments stretching from Indonesia and the Philippines in the south and east, through southern China, to Thailand, Myanmar, and the northeastern hill states of India.

The key themes of the program are the development of alternatives to unsustainable slash-and-burn agriculture, and the rehabilitation of degraded uplands. The target ecosystems are: The forest margins, the imperata grasslands, and the hillslope farmlands. The conceptual framework for the research is based on testing a systems hypothesis in each of the three ecosystems.

On the forest margins, we are testing the proposition that complex agroforestry systems or 'agroforests' provide a superior alternative for smallholders as an alternative to slash-and-burn. In the imperata grasslands, we are testing the concept that smallholder agroforestry systems based on multipurpose fruit, timber, and fodder trees, may be superior to plantation reforestation in terms of production, equitability, and participation objectives. On hillslope farmlands we are investigating contour hedgerow systems as a means to build agroforestry-based conservation farming systems, with emphasis on reduced labor alternatives such as natural vegetative strips. To test these hypotheses through strategic and applied research we are building a web of relationships with agroforestry researchers in the region through networks and scientist-to-scientist contacts. Improved MPT germplasm will be a fundamental element in building superior agroforestry systems.

## The Agroforestry Setting

An astounding array of agroforestry systems is observed in Asia, evolving in response to market changes, new technical options, and the inexorable

pressure of more people on the land. Agroforestry systems were always there, particularly in the uplands. But until recently their potential to solve land use problems was not recognized by mainstream research and extension institutions, and consequently they were given very little notice. But the situation has changed.

As the staple food production problems in the lowlands were successfully overcome, governments had breathing space to begin seriously grappling with the ecological and poverty crisis in the uplands. Widespread interest has mounted in implementing upland agroforestry development programmes, often involving non-traditional land tenure arrangements. In socialist (e.g., China and Vietnam) as well as in free-market economies (e.g., Philippines and Thailand) major programmes are evolving that essentially involve the transfer of millions of hectares of hilly land from government control to family farmers. Agroforestry has been popularized among decision-makers as a conservation farming solution to sustaining the productivity of these fragile lands. Consequently, there is an enormous demand for sound upland agroforestry technology.

### Program Initiation

ICRAF's purpose is "to work towards mitigating tropical deforestation, land depletion, and rural poverty through improved agroforestry systems." After joining the Consultative Group on International Agricultural Research in 1991, the institute established a regional research program in Southeast Asia in 1992. The regional headquarters is located at the Forest Research and Development Centre in Bogor, Indonesia. Our current regional scientific team includes social scientists, agronomists, and foresters, backed up breadth and depth by the headquarters staff in Nairobi.

The Southeast Asia regional offices are adjacent to those of the Asia-Pacific Agroforestry Network (APAN), which enables ICRAF to collaborate closely with this FAO-sponsored network that supports agroforestry training and information dissemination in 10 Asian countries. The offices are also adjacent to the global headquarters of the Centre for International Forestry Research (CIFOR), integrating ICRAF with the forest science community that is building at CIFOR. The Bogor location also enables ICRAF to link with the Indonesian forestry and agricultural science community centered in the many research institutions based there.

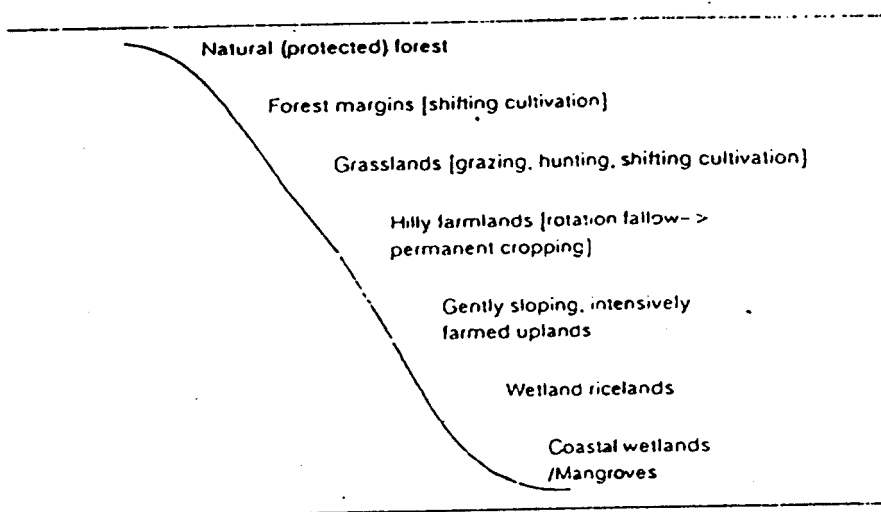
This paper reviews the current status of our vision for work in Southeast Asia. The general themes of the Regional Research Programme in south-eastern Asia are:

- 1) the development of alternatives to slash-and-burn agriculture, and
- 2) the rehabilitation of degraded uplands.

Our aim is to focus on strategic and applied research directed toward a few key objectives. The training and dissemination that we do would be directly targeted to enriching the human resource capacity for strategic and applied agroforestry research.

### Ecosystem Focus

The landscape ecology of much of Southeast Asia follows a broadly similar pattern along a decreasing elevational gradient. In a 'typical' watershed the land use pattern may be characterized as:



Although this pattern is much simplified, it is useful in conceptualizing the ecosystems and their interactions for research and development planning.

The remnants of old growth forest are generally present only at the highest elevations (e.g., 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 and 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.

ICRAFs target ecosystems in Southeast Asia will be limited to the uplands, and will encompass three ecosystems: The forest margins, grasslands, and hilly farmlands. Each of the prospective research sites for the 'alternatives to slash-and-burn initiative' have been selected to sample these landscape components.

### Agroforestry Systems Hypotheses

The conceptual framework for our research in the three target ecosystems be based on an overarching systems hypotheses. We have identified one broad hypothesis to guide our efforts in each ecosystem.

**Systems Hypothesis 1.** On the forest margins, complex agroforestry systems or 'agroforests' provide a superior alternative for small-scale farmers to either food crop systems or monoculture plantations of perennials. Complex agroforests increase production sustainability, increase biodiversity, reduce production risks, and increase returns to labor when compared to continuous food crops or monoculture plantation crops models as alternatives to slash and burn.

There have been two predominant models 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 based. The 'Food Crops Transmigration Program' of Indonesia has widely employed this premise during the past two decades. The record of research to develop sustainable food crop systems for these environments has not been promising. And the record of actual experience by both government-subsidized and spontaneous settlers and indigenous peoples has tended to strongly support the conclusion that this model is seldom applicable.

An alternative model, given particular emphasis during the past decade, is the 'monoculture estate crops model'. It has been given strong support from international development banks (e.g., the World Bank). This model involves the development of large estates to replace natural forest and/or slash and burn farming. Smallholders receive 1–2 hectare parcels on the estate that are designated for monoculture rubber or oil palm, with a guaranteed market.

These tree-crop based schemes avoid some of the problems of earlier land development models, but they still lack the flexibility and crop diversity of traditional forest farming strategies. New concerns have arisen with these models, particularly the high degree of price risk farmers face because their source of livelihood is dependent on a single commodity. Other instabilities observed are the loss of biodiversity in the production system, and the likelihood of increased pest infestation, threatening dependence on pesticide inputs.

A mounting body of studies on the agroecology of the farming systems of indigenous communities on the forest margins in Southeast Asia has now provided strong indications that there is a 'middle ground' between continuous annual cropping and monoculture plantations.

We now recognize that solutions involving the development of agroforests, or complex agroforestry systems, have been quietly occurring in some of the rural communities on the forest margins.

Some cases of 'agroforest' models that exemplify these solutions include: The 2.5 million hectares of 'rubber agroforests' in Sumatra, the cultivation of dipterocarp timber trees in several types of agroforestry systems (including the damar systems), the diverse array of fruit agroforest systems, and the cultivation of rattan in swidden fallows in Kalimantan.

These systems have now been described and documented. What is urgently needed is a more quantitative understanding of their agroecology, the ability to predict the determinants for their extrapolability, and agronomic improvements that will improve their productivity. A scientific understanding of these solutions has only begun. The prospects for building upon knowledge of these systems is largely unrecognized by the wider scientific community, even within agroforestry.

ICRAF Southeast Asia's objective in building a research program around the 'agroforest hypothesis' is to work vigorously to build deep empirical databases and working models on the agroecology of these systems to guide decisions on when, where, and how the development of complex agroforestry systems is preferable to other options. We will assemble a collaborative research team of international and national researchers to tackle the issues from the social, economic, agroecology, agronomic and silvicultural perspectives.

The team will strive to develop generalizable methods to guide the numerous local agroforestry research and development teams that are now forming. These national teams are beginning to seek to understand, promote, and improve agroforest models for their specific agroecosystems. Practical research guidelines and insights will be valuable, provided they are based on the solid experience of a team that has done work with a view to methodology development. One example of a potential spin-off for methodology development is the Bina Desa Program in Indonesia which requires every timber concession (approximately 500) to investigate ways by which local communities can build a more intensive, sustainable agricultural system.

Finally, and this is a more long-term objective, the ICRAF 'complex agroforest team' will assess the technological constraints to improving the productivity of these systems, to provide strategic direction to research that will provide better germplasm and management practices for agroforests.

One important question that should be raised in the context of this discussion is: "How relevant is the agroforestry experience of mature, indigenous communities (where many of the most promising prospective agroforestry solutions have developed) to the dramatically different circumstances of pioneer cultivators, who are responsible for most of the current pressure on the land? One view is that in some cases complex agroforests are a transitional stage at low population density, and that as the imperative for intensification increases, system complexity will necessarily decrease.

The answers are not known, but they are crucial. We see it as essential to target the research to two types of situations:

- Mature communities with promising agroforest solutions, and
- Pioneer communities facing the challenge of how to proceed toward sustainable systems.

The field research area selected for our work on the agroforest hypothesis is the watershed of the Hari River in West Sumatra, Indonesia. The work will be focussed in two locations in the watershed: A pioneer settlement recently established in the lowland rainforest on sloping Ultisols in Sitiung, and a mature Minangkabau settlement practicing annual corpping under bush fallow rotation on the boundary of the Kerinci-Seblat National Park in the upper watershed. The latter site will enable us to apply the hypothesis to buffer zone management in a major national park.

The research effort will be conducted by a consortium of institutions funded through the Alternatives to Slash and Burn Project. The consortium will include a local agroforestry development NGO, a regional university, and the national centers for farming systems on acid soils (SARIF) and forest research and development (FRDC), IRRI, and ICRAF. We will employ

a farmer-participatory land use systems research methodology, complemented by vigorous researcher-managed investigations.

The Multipurpose Tree Improvement team will strive to infuse improved germplasm into complex agroforestry systems. We will focus on:

- \* key species of fruit trees with excellent prospects as timber, fodder, and fuelwood producers. Examples of such species include jackfruit (*Artocarpus heterophyllus*) and durian (*Durio zibethinus*), and *Gnetum gnemom*.
- \* key species of timber trees that are cultivated in mixed agroforestry systems by small-scale farmers for their fruits of industrial importance. Examples include damar (*Shorea javanica*) and illipe nuts (*Shorea macrophylla*, *S. stenoptera* and others). The damar agroforests of Sumatra provide a regular income from resin tapping in addition to quality timber. Illipe nuts provide an important internationally-traded oil.

**Systems Hypothesis 2.** The rehabilitation of imperata grasslands through small-scale agroforestry systems will be superior to plantation reforestation in terms of production, equitability, and participation objectives.

The *Imperata cylindrica* grasslands of southeastern Asia represent a vast underutilized natural resource, covering an aerial extent of 20 to 50 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 maintained through the frequent occurrence of fire. Plantation forestry, particularly the many projects sponsored by forest departments, have had a singularly disappointing history. There is increasing interest in focusing on land use alternatives for these grasslands that feature the active participation of local people. The World Bank (1989) has estimated that 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.

Little systematic knowledge exists concerning the rehabilitation of degraded grasslands. The presence of imperata grasslands is symptomatic of a complex interaction of human and environmental factors. 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.

There are important examples of farmer rehabilitation of imperata grasslands. Agroforestry systems have been notably effective in rehabilitating imperata grasslands in eastern Indonesia.

But the fundamental land tenure requirements for rehabilitation across the range of imperata ecosystems must receive particular emphasis.

### Agroforestation

Timber prices are increasing rapidly in Southeast Asia. This incentive is inducing small-scale farmers to grow trees for sale (van den Beldt *et al.* 1994). Hundreds of farmers in the southern Philippines are widely planting such species as *Gmelina arborea*, *Peraserianthes falcata* and *Acacia mangium*. They are intercropping the trees in contour lines with their annual field crops often in lieu of practicing a grass fallow-rotation (Garrity and Mercado 1994). Unfortunately, the genetic quality of the seed they used is poor, and the lack of diversity in the species planted is alarming.

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

- 1) 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,
- 2) the cropped alleyways between trees provide fire breaks that drastically reduce wildfire damage, and
- 3) small farmers' more intensive field management better insures that the trees will make it to harvestable age.

The premise is that small-scale farmers may be effective agents for reforestation in the future, by integrating trees into their farming systems. Strategically designed tests of this hypothesis will provide a basis for further action. ICRAF proposes to attack this issue most promising by selection and propagation of improved germplasm of the most promising MPTs with research on improved production systems.

In collaboration with several other institutions we are conducting a systems analysis of the imperata ecosystems in Indonesia to classify the grasslands into a limited number of contrasting ecosystems, appraise the current knowledge base on practical agroforestry systems to rehabilitate grasslands differing in ecology, and develop a framework for a long-term research effort in this area (Garrity 1994). This work is through a collaborative research project funded by ACIAR. It currently involves ICRAF and CIFOR scientists, Australian and Indonesian scientists.

We have also begun developing a model of annual-perennial interactions that will guide the process of designing the geometry and management systems for various types of agroforestry systems. All agroforestry is based on the premise that the advantages of combining agricultural and forest enterprises exceeds the value of either in isolation. This assertion needs better empirical analysis leading to efficient predictions of when the



agroforestry advantages are positive, and how systems should optimally be designed.

This issue is made more complex because the mix of trees and crops usually varies in a time-dependent manner. For example, the tree canopy cover is not constant but varies, usually increasing with time. This time dependency in the evolution of agroforestry systems is crucial to evaluating their role for small-scale farms, where the imperative of family staple food supply must be balanced against the opportunities for perennial cash crop production.

We have initiated component interactions research to develop a capacity for process-oriented understanding and modeling of tree-crop interactions. Our three initial experimental approaches in this direction will be to:

- \* Quantify the terms of the ICRAF 'tree-crop interaction equation' for a number of contrasting situations where the overall effect is known to be positive or negative.
- \* Develop and test model descriptions for the equation's interaction terms which are based on tree, soil and crop parameters that are either 'constants' for a given species, or can be easily estimated.
- \* Develop and test a method for predicting tree root length and distribution from easily observable roots close to the main stem.

We anticipate that the practical outputs of our work will guide the efforts of governments and development banks (World Bank and Asian Development Bank) in designing programs that support the efforts of small-scale farmers to produce trees for market and hillslope sustainability.

**Systems Hypothesis 3.** On hillslope farmlands there are several pathways to sustainable small-scale farming. Among these, contour hedgerow systems initiated through natural vegetative strips (NVS) provide distinct advantages as a superior, least cost foundation upon which to build agroforestry-based conservation farming.

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 (Sajjapongse 1992, Garrity 1993). If urgent efforts to stabilize these soil resources are not successful, the resulting land degradation and wasted farms will further exacerbate settlement pressure on the forest margins.

Sloping agricultural land technology based on contour hedgerows of pruned leguminous trees has been promoted for over a decade in most

countries as a solution to the problem. 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 labor 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 alleycropping model is now being widely promoted. But ICRAF researchers recognize that it has some serious limitations.

New directions are urgently required. Research with farmers during the past 7 years has identified alternative pathways to exploit the benefits of the contour hedgerow concept. A few innovative farmers use contour strips of natural vegetation (natural vegetative strips). Recent data indicates that they provide excellent erosion control, with negligible installation and maintenance costs, or competition with the associated annual crops (Ramiamanana 1993). As the strips capture sediment and develop into terraces they also provide a foundation for agroforestry (Garrity 1993). Income-generating cash perennials are planted on the risers along with fodder or green manure species. We hypothesize that the strips are a convenient way to evolve toward more sustainable annual cropping, with a gradually increasing farm area in perennials.

Substantial farmer experience with natural vegetative strips in two municipalities in the Philippines suggests that the concept deserves wider evaluation. Research at Claveria, Mindanao, has provided important data on the management of these systems. But important technical issues require attention: how can soil fertility be maintained in the upper alleyways as terraces form, and how does incorporation of cash perennials 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. These options have yet to be scientifically explored.

ICRAF seeks to develop collaborative research with other institutions to fully explore the strategic implications of natural vegetative strips as a foundation for agroforestry-based conservation farming on hillslope farms. We also want to address the issue of how and where to extrapolate the natural strip concept.

### **Eco-Geographical Focus**

The three systems hypotheses are each strongly related to a particular ecosystem. Each hypothesis also has geographic implications: Where the issue is prominent, and where the appropriate location(s) for its investigation (Table 1).

Table 1: Research Strategy:  
A Test of Three Systems Hypotheses

ECOSYSTEM	Forest Margins	Grasslands	Hillslope Farmlands
HYPOTHESIS	Agroforests superior to foodcrops or monoculture estate crops	Reforestation through Agroforestry	Natural strips as a foundation for agroforestry
RESEARCH LOCATION	Indigenous communities Pioneer communities	Pioneer communities	Permanent farms
ECO GEOGRAPHIC TARGET			
<i>Equatorial</i>	Indonesia	Indonesia	
<i>Midlatitude</i>		Philippines	Philippines
<i>Mainland</i>		Thailand	Thailand

As one proceeds north from the equator in southeast Asia the upland climate generally becomes progressively harsher with longer, more arid dry seasons, cooler winters, and a greater threat of tropical storms. Northward along this gradient are also ecological conditions that are associated with slower establishment of vegetation, lower primary productivity, and a greater tendency for upland soils to lack ground cover for substantial portions of the year. The respective eco-regions along the gradient may be recognized as:

- Equatorial tropics (–5 to 5 degrees lat.)      Indonesia, Malaysia
- Mid-latitude wet-dry tropics (5 to 15 degrees lat)      Philippines, Southern Thailand and Southern Vietnam.
- Northern tropics (15 to 25 degrees lat.)      Northern Thailand, Vietnam, Myanmar, Laos and Southern China

The equatorial tropics is where the major remaining forests exist. These are particularly concentrated on the islands of Sumatra, Borneo, and New Guinea. Research to protect natural forestland by addressing the intensification of agroforestry systems on the forest margins will be targeted predominantly to the equatorial tropics. The strategic research sites tentatively identified is the Hari river watershed in central Sumatra, and in Lampung. The full ICRAF scientific team in Indonesia will be involved in research on hypothesis 1.

The northern tropics encompasses the huge east-west belt of hillylands in the interior of mainland Southeast Asia, reaching from Assam to Vietnam and southern China. The climate is strongly monsoonal with long dry winters that are slightly cooler. The problems in this zone contrasts sharply

with that of the equatorial tropics. Major land degradation in the upland watershed areas has resulted from agricultural intensification on steep terrain. The global Alternatives to Slash and Burn Project has selected northern Thailand as a future key research site. It is in a central location vis-a-vis the uplands of four neighboring countries, and has the most favorable scientific infrastructure to support strategic research and training. Systems hypotheses 2 and 3 are particularly relevant for ICRAFs focus in the ASB research consortium based there.

The mid-latitude tropics is a transitional zone. Research work in the Philippines builds upon the support of ICRAFs strong relationship with the Upland Ecosystem Program of International Rice Research Institute (IRRI) and the Sustainable Agriculture and Natural Resources Management Collaborative Support Program (SANREM CRSP), a long-term initiative of USAID. The work is conducted with these partners in the Manupali watershed in northern Mindanao.

Thus, our plan with respect to research sites focusses on two dominant locations: The equatorial tropics (Sumatra, Indonesia) and the northern tropical hill country (northern Thailand), with a subsidiary site in the mid-latitude tropics (Mindanao).

The humid tropics of Southeast Asia is a huge geographical area. Some attention needs to be given to how ICRAF shall address the needs of countries and institutions outside the key ASB locations. For example, immense possibilities would seem to exist for impact in Indochina, Southern China, and in northeastern south Asia. Our proposal is to handle our engagement outside of our strategic research locations primarily through the strength of the ASB research consortia.

The consortium should provide useful linkages and support to agroforestry research related to ASB objectives in Southern China (e.g., Kunming), Myanmar (viz. Shan uplands) and Vietnam. In this model, ICRAFs support for agroforestry research in these countries would be handled through the ASB consortium. The collaborating countries, would send researchers for training at the key sites. They may also be encouraged to develop national research projects on ASB with bilateral funding. Any further direct involvement of ICRAF scientists would be limited, and assessed critically as to potential dilution effects on our efforts at the key research locations.

The Asian Multipurpose Tree Species (MPTS) Network was founded through the support of USAID as part of the Forestry/Fuelwood Research and Development Project (F/FRED). The network has made substantive progress in understanding the comparative performance of important exotic species of fast-growing hardwoods across the humid/subhumid zone of Southeast Asia. Proposed ICRAF collaboration with the network will build upon the network's knowledge base of popular fast-growing

species performance. We will now work to identify species that may further diversify the alternatives for small-scale farmers. Emphasis will be placed on species that are adapted to the fire-prone and nutrient-poor grassland environments, forest margins, environments, and sloping infertile farmlands.

The choice of species for improvement may in future be focussed more on a regional basis within countries, a somewhat different model than reliance on a few species with presumed wide inter-country extrapolation. Such a shift in emphasis may allow tree improvement to better cope with the diversity of ecological conditions and market realities across Asia. We shall also see a shift toward more emphasis on clonal selection and propagation as a rapid means of identifying and sharing improved tree germplasm.

We anticipate that the practical outputs of the work will guide the efforts of governments and development banks in designing programmes that better support the efforts of small-scale farmers to produce trees for market demand, family consumption, and marginal land sustainability. In Asia, the small-scale farmer may in future be recognized as the most effective forester, producing much of the regions timber and other tree products through profitable and adaptable agroforestry systems. But realizing this eventuality will require an enormous amount of further technical and social innovation.

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