THE COSTS AND BENEFITS OF AGROFORESTRY TO FARMERS

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Deforestation, growing scarcity of tree products, and environmental degradation have created serious problems for rural land use in many developing countries. Agroforestry, a system in which woody perennials are grown on the same land as agricultural crops or livestock, has been increasingly enlisted in the campaign to meet these threats to the rural economy.

Case studies of twenty-one agroforestry projects in six Central American and two Caribbean countries formed the empirical basis for the study described in this article. A focal point of analysis was the profitability of agroforestry for farmers as a crucial incentive to adoption.

The findings indicate that many agroforestry practices are profitable under a broad range of conditions and are therefore likely to be widely applicable. Successful projects have worked with local communities, responding to local needs and preferences and offering farmers a broad basket of species and systems from which to choose. Demonstration plots and the use of paratechnicians have been low-cost and effective means of technology transfer, and applied research has been important in identifying techniques and practices suited to the region. Other findings have identified government regulation of tree harvesting and insecurity of tenure—though not lack of title in itself—as disincentives to adoption.

Deforestation in Central America and the Caribbean has meant increasing scarcity of trees, a principal source of fuel and construction materials in rural areas, and contributes to environmental degradation of fragile agricultural lands. In the eight countries where the empirical part of our work was done, the forest cover declined between 10 and 24 percent during the 1980s (table 1). In the two countries with the highest population density (El Salvador and Haiti), only 6.2 and 1.3 percent of forest cover remained by 1990.
Table 1. Case Study Countries: Key Indicators

<table>
<thead>
<tr>
<th>Country and region</th>
<th>Population density (pop/km²)</th>
<th>Rate of population growth (percent)</th>
<th>GNP per capita (1992 U.S. dollars)</th>
<th>Forest cover in 1990 (percentage)</th>
<th>Forest cover per capita (hectares)</th>
<th>Change in forest cover 1981–90 (percentage)</th>
<th>Rate of deforestation 1981–90 (percent)</th>
<th>Reeforestation as percentage of area deforested per year¹</th>
</tr>
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<tbody>
<tr>
<td>Costa Rica</td>
<td>62.7</td>
<td>2.8</td>
<td>1,960</td>
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<td>2.9</td>
<td>7.5</td>
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<td>Dominican Republic</td>
<td>149.0</td>
<td>2.1</td>
<td>1,050</td>
<td>22.5</td>
<td>0.2</td>
<td>-24.2</td>
<td>2.8</td>
<td>1.1</td>
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<td>El Salvador</td>
<td>257.1</td>
<td>1.4</td>
<td>1,170</td>
<td>6.2</td>
<td>0.0b</td>
<td>-16.8</td>
<td>2.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Guatemala</td>
<td>89.0</td>
<td>2.9</td>
<td>980</td>
<td>39.3</td>
<td>0.5</td>
<td>-15.6</td>
<td>1.7</td>
<td>3.1</td>
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<tr>
<td>Haiti</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.3</td>
<td>0.0b</td>
<td>-10.3</td>
<td>4.8</td>
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<td>Honduras</td>
<td>48.2</td>
<td>3.3</td>
<td>580</td>
<td>41.2</td>
<td>0.9</td>
<td>-19.4</td>
<td>2.1</td>
<td>0.4</td>
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<td>30.0</td>
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<td>340</td>
<td>50.8</td>
<td>1.6</td>
<td>-16.8</td>
<td>1.9</td>
<td>1.5</td>
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<tr>
<td>Panama</td>
<td>32.5</td>
<td>2.1</td>
<td>2,420</td>
<td>41.1</td>
<td>1.3</td>
<td>-17.0</td>
<td>1.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Total</td>
<td>77.3</td>
<td>—</td>
<td>—</td>
<td>36.9</td>
<td>—</td>
<td>-18.1</td>
<td>—</td>
<td>2.3</td>
</tr>
<tr>
<td>Latin America and the</td>
<td>24.2</td>
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<td>2,180</td>
<td>56.2</td>
<td>2.3</td>
<td>-7.1</td>
<td>0.8</td>
<td>5.0</td>
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<tr>
<td>Caribbean (total)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

¹ Not available.

a. Deforestation is defined as change of land use from forest to other use or depletion of forest crown cover to less than 10 percent.
b. Extremely small values.

One response of governments, backed by nongovernmental organizations (NGOs) and international donors, has been to encourage agroforestry: a land use system in which trees, shrubs, palms, and bamboos are cultivated on the same land as agricultural crops or livestock for economic reasons but also for environmental ones, to replenish wood stocks while upgrading land through diminishing erosion, water loss, and other natural phenomena. The system includes managing natural regrowth; seeding, planting, and maintaining trees as border plantings; interplanting in agricultural crops; woodlots; and home gardens (see the glossary in box 1). Agroforestry complements and reinforces traditional reforestation efforts by reducing the pressure on remaining natural forests and providing environmental services.

Traditional agroforestry practices already play an important role in many farming systems—fruit trees are planted in home gardens, pastures, fields, and among permanent tree crops; live shrubs and bushes are used for fencing; coffee and cocoa plants are cultivated in the shaded areas under existing trees; and fallow (shifting cultivation) systems are maintained that sequentially rotate trees with crops.

Recently introduced agroforestry systems include woodlots, taungya, and managed woody fallows for forest tree production. For farm areas devoted to perennial crops, systems include deliberate perennial intercrops and home gardens. The main systems introduced for annual cropland are trees planted in lines on boundaries or on terrace risers, alley cropping of annual crops between tree rows, barrier hedges along the contours of fields, and windbreaks.

Although agroforestry activities have attracted solid support and are likely to receive further substantial investment from public agencies, NGOs, and international donors, they have generally been poorly documented. Monitoring of projects, where it exists, has been weak or focused narrowly on operational concerns (Scherr and Muller 1991; Current, Rivas, and Gómez 1994). Most research and analysis of agroforestry systems have dealt with the physical and biological aspects, neglecting systematic analysis of agroforestry’s economic contributions at the farm level (Swinkels and Scherr 1991), even though the absence of a profit motive may have been a root cause of project failures (Tschinkel 1987; Murray 1991). Nor has there been much comparison of different extension approaches and of their influence on farmer adoption of agroforestry (Vergara and MacDicken 1990).

Thus, important questions remain about which strategies to pursue for agroforestry development. Which agroforestry practices, under different environmental and economic conditions, are profitable for the farmers? Under what conditions are farmers willing to invest in agroforestry systems oriented to environmental rehabilitation? Do certain conditions justify subsidies and nonmarket incentives? What level and type of field extension assistance are needed to disseminate new agroforestry species and information and encourage adoption? What are the principal constraints on farmers that discourage further adoption of agroforestry? What kinds of policy action would encourage adoption?
To find answers to these questions, this study analyzed the experiences of twenty-one projects in eight countries of Central America and the Caribbean (see figure 1) and drew together the lessons to guide the design and execution of future efforts. Consultants from the region and staff at the Tropical Research Center for Research and Education (CATIE) in Costa Rica carried out eight country studies on the basis of an earlier pilot study (Current and Lutz 1992) under the overall direction of the World Bank, with methodological support from the International Food Policy Research Institute (IFPRI). Each study included a country overview and case studies of two or three selected agroforestry projects, analyzing in detail the technical interventions and adoption in each project, the

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**Box 1. Glossary**

**Agroforestry**: The deliberate use of woody perennials (trees, shrubs, palms, bamboos) on the same land management unit as agricultural crops, pastures, and animals. This may consist of a mixed spatial arrangement in the same place at the same time or a sequence over time.

**Alley cropping**: Cultivation of annual crops between rows of trees or hedgerows. Sometimes called hedgerow intercropping.

**Boundary planting**: Lines of multipurpose trees or shrubs planted along borderlines and boundaries dividing properties or land uses.

**Contour planting**: Rows of trees or shrubs planted along the contour of the field.

**Home garden**: A complex collection of woody and herbaceous plants deliberately grown in small plots in or near home compounds, often associated with the production of small domestic animals.

**Live fenceposts**: Use of living trees, rather than dead posts, as fenceposts. In Central America, these are usually used to support barbed wire fencing. The fenceposts may also be managed for fuelwood or poles.

**Multipurpose trees or shrubs**: A woody perennial grown to provide more than one product or service.

**Taungya**: A system in which new forest plantations are established together with food and cash crops, which continue to be intercropped until shaded out by the maturing plantation.

**Trees intercropped with annual crops**: Closely spaced trees planted or maintained in crop-land for their products or their positive effects on associated crop production (for example, nitrogen-fixation or microclimate improvement).

**Trees intercropped with perennial crops**: Closely spaced trees planted or maintained in perennial crops for their products, or their positive effect on associated crop production (for example, shade or nitrogen-fixation).

**Windbreak**: Strips of trees or shrubs planted to protect fields, homes, canals, or other areas from wind and blowing soil or sand.

**Woodlot**: Stands of trees planted and managed to produce various tree products, associated plants or services.

**Woody fallow**: Fallow is land resting from cropping, which may be grazed or left unused; it is often colonized by natural vegetation. For woody fallows, the fallow is left uncultivated for sufficient time for woody plants to become predominant; farmers may enrich, manage, or harvest from this woody fallow.

*Note:* This glossary is based on Rocheleau, Weber, and Field-Juma 1988.
project's economic performance at the farm level, its approach to extension, and policies that influenced the implementation of the project and its adoption by farmers. National workshops and a regional workshop to review preliminary findings were held for farmers, extension agents, project managers, and decisionmakers, with representatives from farmer organizations, NGOs, national agencies, and international donors. To our knowledge, this effort was the first large-scale study of farm-level profitability of agroforestry in the tropics.

The specific objectives of the study were to:

* document earlier agroforestry efforts and their lessons for tree planting on farms;
* determine costs and benefits of agroforestry systems from the farmers' perspective;
* determine the relative advantages and disadvantages for farmers of different types of agroforestry systems under different site and resource conditions; and
identify the effects of institutional factors and government policies on the adoption of agroforestry systems.

This article summarizes the principal findings of the country studies, comparing them, where possible, with the experience of other regions. Beginning with a brief background history of agroforestry in the region, the article goes on to describe the investigative methods used, to outline the characteristics of the projects reviewed, and then to discuss the findings on household benefits, the pros and cons of different extension approaches, and the effects of different policies.

Evolution of Agroforestry in Central America and the Caribbean

Numerous projects have been established in the past two decades throughout Central America and the Caribbean to promote communal and individual tree plantings and agroforestry systems. Agroforestry development in the region generally reflected—and in some cases led—international trends in thinking and action about agroforestry. In the late 1970s and early 1980s, when the emphasis in forestry was on fuelwood production, agroforestry systems were used to plant trees on farms for fuelwood (Eckholm 1975; King 1979). Fuelwood projects were implemented worldwide (U.S. Comptroller General 1982; USAID/ROCAP 1979), and research was undertaken on fuelwood species (National Academy of Sciences 1980). But the response to fuelwood projects in rural communities was discouraging: farmers were unenthusiastic about contributing the sizable investment in labor—for planting, felling, sectioning, and splitting—needed to produce a good with a relatively low market value. Furthermore, fuelwood has traditionally been collected as a free good (even on private lands), which lessened its attraction as a product for farmers. In El Salvador, with its high population density and low forest cover, a recent national study showed that only 33 percent of the rural population considered the acquisition of fuelwood a problem (Current and Juarez 1992).

Subsequently, the emphasis shifted from fuelwood production to the concept of multipurpose tree species in agroforestry systems. Establishing multipurpose trees on farmland can provide a wide range of benefits. For farm families, they may help meet household consumption needs, provide a source of income, or improve land husbandry to ensure future production. In addition to fuelwood, multipurpose tree species supply green manure, wood for construction, fence posts, and raw materials for local or industrial processing, and cash income and savings from any of these. Conflicts do arise between cultivating trees and raising agricultural crops, but many agroforestry systems allow farmers to integrate trees into their farming systems, with only small drawbacks for crop production; in some cases the trees increase overall farm productivity (Gregersen, Draper, and Elz 1989; Raintree 1991).
Social benefits from establishing trees on farms can be significant and are often cited to justify tree-planting projects supported by national governments and donors. Trees can provide protection from soil erosion generated by water and wind (Lutz, Pagiola, and Reiche 1994), thereby protecting future productive potential and preserving important watersheds that feed hydroelectric projects and supply water for population centers. Trees provide wood products for the farm, thus relieving the pressure on natural forest areas (Current and Lutz 1992); they provide raw materials for rural industries that generate employment for rural communities (Arriola and Herrera 1991; Campos, Rodríguez, and Ugalde 1991); and they also provide environmental and social benefits, such as wildlife habitats, water retention capacity, or shade for dwellings.

Regionally, the most important applied research initiative has been the Tree Crop Production (Madeleña 3) Project, financed by the U.S. Agency for International Development (USAID) Regional Office for Central American Programs (ROCAP) and executed by CATIE (Belaunde and Rivas 1993). Other internationally important research programs included those of the Forestry Fuelwood Research and Development (FFRED) Project in Asia (French and van den Beldt 1994), the International Center for Research in Agroforestry (ICRAF) (Steppler and Nair 1987), and the Nitrogen Fixing Tree Association operating around the world (NFTA 1993). Numerous national and international NGOs have also undertaken applied research and extension activities (Cook and Grut 1989; Nair 1990).

The shift in emphasis toward multipurpose tree species was accompanied by a corresponding realization that a project is more likely to succeed if project planners consult local communities about their own perceived needs and then design projects to meet those needs instead of imposing schemes that the communities may not consider a priority. In line with this thinking, research was focused on traditional agroforestry systems (Budowski 1987; Reiche 1992), and many forestry agencies have been changing their emphasis from “guarding” the forest to helping communities produce tree plantings which, in turn, may help protect the remaining forest. The stronger community role in project and technology design has parallels in Africa and Asia (Kerkhof 1990; Budd and others 1990; French and van den Beldt 1994; Raintree 1991).

Methods of the Study

The study compared the economic and technical performance of the most prevalent agroforestry systems used in the twenty-one selected projects.

Analysis of Household Benefits

The analysis identified the role—both intended and actual—of the trees in the household’s livelihood strategy—for household use, to generate cash income or
savings, or as insurance. It then assessed the actual effects of the agroforestry practice on labor, land, and other household resources (including household risks) and used cost-benefit and related analyses to assess the profitability of the agroforestry practice relative to farmers' alternative systems, using sensitivity analysis to determine the range of conditions (such as input or output prices and productivity levels) under which an agroforestry technology was likely to be profitable (Scherr, forthcoming).

The data on inputs, outputs, costs, and prices required to develop the multiyear agroforestry enterprise budgets were generated in various ways, among them recall data and plot measures from single-visit farm surveys and multivisit studies of farms in the case studies, and results of on-farm research trials in the project area. Costs and benefits were valued at the prices that these farmers actually face, with no attempt to adjust for economic distortions. Farmers were interviewed about the means and the opportunity costs of using land, labor, and capital resources in agroforestry. They also provided qualitative assessments and anecdotal information on social and environmental costs and benefits; quantitative information was generally not available.

The study deliberately emphasized household benefits; because farmers make their decisions on land use in light of their own objectives, production possibilities, and constraints, understanding their incentives is essential to understanding patterns of resource use and to formulating appropriate responses to problems. Ultimately the success of any agroforestry system depends not on the project planners' perception, but on the farmers' perception of its costs and benefits. Furthermore, the farm-level approach focuses sharply on effects on farm productivity, which are particularly important in this region. (This is not to minimize the importance, in some situations, of off-farm effects.)

Analysis of Technology Adoption

Researchers collected information on indigenous agroforestry practices, farming systems, land use problems, and the farmers' criteria for selecting agroforestry interventions. Characteristics of technology adoption (the systems selected, the extent, durability, and determinants of adoption) were assessed through informal farmer surveys. Formal and informal surveys of farmers, focus groups, and investigations by project staff identified specific problems, and researchers assessed experience of the project so far with selection of tree species, tree-crop interactions, and methods of establishing trees.

Policy Assessment

The study identified policy influences on agroforestry adoption, project implementation, and the profitability of agroforestry from several sources. Country
overviews drew on public documents, key informants, and unpublished literature. Project case studies relied on interviews with farmers and project staff as well as project reports for policy insights and documented constraints caused by specific legal, institutional, and policy problems. The national and regional workshops provided forums for project executives and policymakers to develop specific recommendations for policy action.

Characteristics of Projects Reviewed

The twenty-one projects analyzed were selected on the basis of the age of the project (older projects being preferred); the availability of economic data; the willingness of project staff to cooperate in the study; and the size of the farms. The focus was on smallholders: average farm size was under twenty hectares in most projects, under five hectares in five projects. Together, the projects cost approximately US$150 million and represent more than 50,000 farm households; they cover a variety of agroforestry systems and site and socioeconomic conditions (table 2).

Table 3 summarizes key elements of the extension strategies used by the projects. Such strategies can generally be divided into four broad categories: using existing forestry or agricultural extension networks; training and providing logistical support to extension agents hired specifically for the project; integrating project extension agents with national extension agencies; and supporting extension staff organized and managed by NGOs. The projects studied represented all four of these categories. The most common methods used to provide information and training to the farmers were visits by extension agents or paratechnicians, field trips and training courses, and demonstration plots. Six projects provided marketing assistance. Most projects used material incentives (free seedlings or other inputs), and many others used cash incentives, credit, or food-for-work incentives. (Food for work has been used for communal and privately owned nurseries, as well as for tree planting on both communal and private lands. Plant survival rates have been much higher for private nurseries and private tree plantings.)

Incentives and Deterrents for Adopting Agroforestry

The study assessed the profitability of agroforestry at the household level in light of financial benefits and costs, risk management, and the nature and accessibility of markets for agroforestry products.

The success or failure of the effort to promote agroforestry depends ultimately on how many farmers take up the system and persevere with it. Perceived profitability for the household is a critical influence on a farmer’s initial decision to include agroforestry in the farm’s activities. The systems adopted
Table 2. Farming and Agroforestry Systems in the Case Study Project

<table>
<thead>
<tr>
<th>Project and country</th>
<th>Agroforestry systems promoted</th>
<th>Principal tree species utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community Agricultural Center—Hojancha Costa Rica</td>
<td>A, E, H</td>
<td>5, 21, 31</td>
</tr>
<tr>
<td>PRODAF Forestry/Agroforestry Development Project Costa Rica</td>
<td>A, E, H, I</td>
<td>5, 11, 17</td>
</tr>
<tr>
<td>COOPELDOS—Windbreaks for coffee and dairy products Costa Rica</td>
<td>F</td>
<td>9, 14, 15, 19</td>
</tr>
<tr>
<td>Traditional Agroforestry Systems of the Humid Tropics Costa Rica</td>
<td>A, C, L</td>
<td>13, 17, 20</td>
</tr>
<tr>
<td>Agroforestry Support to Low-Income Rural Communities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community and Family Nursery Program El Salvador</td>
<td>D, E, G, H, I</td>
<td>18, 20, 24, 31</td>
</tr>
<tr>
<td>Agroforestry Program of DIGEFO/CARE/Peace Corps Guatemala</td>
<td>C, E, H</td>
<td>8, 18, 31</td>
</tr>
<tr>
<td>and DGEFO/CATIE/Madeleña 3 Guatemala</td>
<td>A, C, D, G, L</td>
<td>3, 9, 17, 18, 20, 22, 25</td>
</tr>
<tr>
<td>La Máquina Settlement Guatemala</td>
<td>E, G, H</td>
<td>6, 18</td>
</tr>
<tr>
<td>Development of the Broadleaved Forest (BLFDP) Honduras</td>
<td>A, C, E, G</td>
<td>20, 23, 29</td>
</tr>
<tr>
<td>CONASA Rural Development Honduras</td>
<td>B, E, H</td>
<td>20, 24</td>
</tr>
<tr>
<td>Sierra de Omoa Management Unit Honduras</td>
<td>A, I</td>
<td>13, 20</td>
</tr>
<tr>
<td>Land Use Planning (LUPE) Honduras</td>
<td>C, D, E, H</td>
<td>13, 20</td>
</tr>
<tr>
<td>Control of Erosion in the West and Reforestation Nicaragua</td>
<td>F</td>
<td>18, 24, 30</td>
</tr>
<tr>
<td>Support to Farm Forestry and Rehabilitation of Windbreaks Nicaragua</td>
<td>E, F, G, H</td>
<td>18, 20, 24, 30</td>
</tr>
<tr>
<td>Demonstration Farm “La Esperanza” Nicaragua</td>
<td>C, E, L</td>
<td>7, 8, 16, 20, 27</td>
</tr>
<tr>
<td>Agroforestry for Community Development (INRENARE/CARE) Panama</td>
<td>B, E, F, G, H</td>
<td>2, 18, 24, 26</td>
</tr>
<tr>
<td>Food Production and Community Development—Aquaculture (MIDAS/WFP) Panama</td>
<td>B, E, F, G, H</td>
<td>2, 18, 24, 26</td>
</tr>
<tr>
<td>ENDA—Caribe: Desarrollo Rural Integrado de Zambrana Dominican Rep.</td>
<td>C, G</td>
<td>2, 7</td>
</tr>
<tr>
<td>Fondo Rotanmo Agroforestä y Comercia (FORESTA)</td>
<td>C, E, H</td>
<td>2, 17, 18, 20</td>
</tr>
<tr>
<td>Agroforestry Outreach Project—Pan American Development Foundation Haiti</td>
<td>D, E, H</td>
<td>4, 8, 10, 18, 24</td>
</tr>
<tr>
<td>Maissade Watershed Management Project—Save the Children Haiti</td>
<td>E</td>
<td>1, 8, 12, 28</td>
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<tr>
<th>Code</th>
<th>Agroforestry systems</th>
<th>Principal tree species</th>
<th>Common name</th>
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<tbody>
<tr>
<td>1</td>
<td>Acacia auriculiformis Japanese acacia</td>
<td>Leucaena leucocephala</td>
<td>Leucaena</td>
</tr>
<tr>
<td>2</td>
<td>Acacia mangium</td>
<td>Mangium</td>
<td>Melia azedarach</td>
</tr>
<tr>
<td>3</td>
<td>Alnus viridis</td>
<td>Alder</td>
<td>Pinus caribaea</td>
</tr>
<tr>
<td>4</td>
<td>Azadirachta indica Neem</td>
<td>Pileiafemorobium saman</td>
<td>Raintree</td>
</tr>
<tr>
<td>5</td>
<td>Bombax ceiba</td>
<td>Bombax ceiba</td>
<td>Samara glauca</td>
</tr>
<tr>
<td>6</td>
<td>Casuarina truncata</td>
<td>Casuarina</td>
<td>Swietenia macrophylla</td>
</tr>
<tr>
<td>7</td>
<td>Calliandra calothyrsus Calliandra</td>
<td>Tecoma stans</td>
<td>Yellow trumpet flower</td>
</tr>
<tr>
<td>8</td>
<td>Cassia siamea Yellow cassia</td>
<td>Teague grandis</td>
<td>Teak</td>
</tr>
</tbody>
</table>

### Table 3. Project Extension Approaches

<table>
<thead>
<tr>
<th>Country</th>
<th>Project</th>
<th>Number of communities</th>
<th>Number of families participating</th>
<th>Number of paid technical staff</th>
<th>Extension visits</th>
<th>Food for work</th>
<th>Marketing, processing, or demonstration plots</th>
<th>Radio</th>
<th>Local promoters</th>
<th>Field trips and training courses</th>
<th>Material inputs</th>
<th>Cash incentive, credit</th>
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<tbody>
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<td>Costa Rica</td>
<td>Traditional</td>
<td>3</td>
<td>280</td>
<td>None</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Community agricultural center</td>
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<tr>
<td></td>
<td>PRODAF</td>
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<td>144</td>
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<td>✓</td>
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</tr>
<tr>
<td></td>
<td>COPELDO</td>
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<td>119</td>
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<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>ENDA-Caribe</td>
<td>66</td>
<td>800</td>
<td>5</td>
<td>✓</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Dominican Republic</td>
<td>FORESTA</td>
<td>n.a.</td>
<td>89</td>
<td>5</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Salvador</td>
<td>Agroforestry support</td>
<td>100</td>
<td>3,302</td>
<td>20</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Nursery program</td>
<td>n.a.</td>
<td>22,470</td>
<td>n.a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Guatemala</td>
<td>La Máquina</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DIGEBON/CART</td>
<td>350</td>
<td>10,000</td>
<td>86</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Madeleña 3</td>
<td>22</td>
<td>1,309</td>
<td>22</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haiti</td>
<td>Agroforestry outreach</td>
<td>6^</td>
<td>n.a.</td>
<td>200 NGOX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maquisade watershed</td>
<td>6</td>
<td>2,400</td>
<td>12-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honduras</td>
<td>Broadleaf forest</td>
<td>10</td>
<td>656</td>
<td>32</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>COHASA</td>
<td>6</td>
<td>1,500</td>
<td>5 (n.a.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LUPE</td>
<td>44</td>
<td>5,427</td>
<td>193 (45)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sierra de Omoa</td>
<td>7</td>
<td>109</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nicaragua</td>
<td>Erosion</td>
<td>n.a.</td>
<td>3,000</td>
<td>30 + 600^</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Windbreaks</td>
<td>16</td>
<td>500</td>
<td>20</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>La Esperanza</td>
<td>11</td>
<td>765</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panama</td>
<td>INRENARE/CARE</td>
<td>15 (10)</td>
<td>157 (80)</td>
<td>(10)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIDA/WFP</td>
<td>11 districts</td>
<td>4,380 (600)</td>
<td>(57)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Numbers in parentheses represent the first phases of the projects. Numbers outside the parentheses represent the totals to 1992.

a. Associations.
b. Workers were hired only in the establishment phase.

and the scale and pace of adoption will then be determined by practical matters, such as resources available to the farmer and the specific constraints the farmer encounters. All of these have important implications for the way projects should design their extension efforts.

Financial Results

Financial analyses were undertaken for the major agroforestry systems used in the region—trees intercropped with agricultural crops, alley cropping, contour plantings, perennial crops with interplanted trees, home gardens, taungya, and woodlots (for detailed results, see Current, Lutz, and Scherr, forthcoming). Table 4 shows averages of the financial indicators calculated for these systems, and net present values for each technology—that is, all costs and benefits at the plot level estimated at 10 and 20 percent real discount rates and compared with the net present values for one or more alternative practices. This approach was adopted to allow direct comparison between systems that were very different in components and design. The net present values were found to be positive at a 20 percent discount rate in all but one (woodlots) of the seven systems analyzed.

Local scarcities of timber, fuelwood, and poles—which differ not only from country to country, but from region to region within countries—are critical to the economics and adoption of agroforestry. The higher prices that often accompany scarcity, and correspondingly higher profits, can be an important in-

<table>
<thead>
<tr>
<th>Agroforestry system</th>
<th>Number of systems studied</th>
<th>Net present value 10 percent (U.S. dollars)</th>
<th>Net present value 20 percent (U.S. dollars)</th>
<th>Cost-benefit ratio</th>
<th>Return to labor</th>
<th>Payback period</th>
<th>Average person-days per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees with agricultural crops</td>
<td>5</td>
<td>2,863</td>
<td>1,300</td>
<td>1.8</td>
<td>5.03</td>
<td>3.4</td>
<td>165</td>
</tr>
<tr>
<td>Alley cropping</td>
<td>9</td>
<td>1,335</td>
<td>847</td>
<td>2.1</td>
<td>6.98</td>
<td>1.9</td>
<td>56</td>
</tr>
<tr>
<td>Contour planting</td>
<td>4</td>
<td>1,426</td>
<td>761</td>
<td>1.6</td>
<td>3.75</td>
<td>2.0</td>
<td>116</td>
</tr>
<tr>
<td>Perennial with trees</td>
<td>4</td>
<td>2,867</td>
<td>1,405</td>
<td>1.8</td>
<td>4.19</td>
<td>4.0</td>
<td>139</td>
</tr>
<tr>
<td>Home garden</td>
<td>4</td>
<td>n.a.</td>
<td>372</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Taungya</td>
<td>8</td>
<td>6,797</td>
<td>2,868</td>
<td>2.5</td>
<td>15.98</td>
<td>4.9</td>
<td>53</td>
</tr>
<tr>
<td>Woodlot</td>
<td>10</td>
<td>764</td>
<td>−33</td>
<td>1.0</td>
<td>3.41</td>
<td>9.2</td>
<td>12</td>
</tr>
</tbody>
</table>

Note: This table should be used for general comparison only. The systems analyzed represent only a small sample of each system and cannot be considered a random representative sample. Net present values and return to labor are influenced by localized market conditions and do not fairly represent differences between planting systems. The payback periods and average person-days required per year can more reliably be compared. (See Current, Lutz, and Scherr, forthcoming, where this information is presented by each individual system analyzed.)


centive for farmers to turn to agroforestry. This finding is consistent with those from qualitative assessments and empirical case studies from other parts of the world. Summarizing results for South Asia and Eastern Africa, Arnold (1995: 272-73) concludes that "with most situations experiencing reductions in access to off-farm supplies, growing demand, declining site productivity and increased exposure to risk, it should not be surprising that tree-planting activity does increase as agriculture and land use become more intensive. Though it would be incorrect to assume that this always happens, there is a general progression towards more planted trees as agriculture and pressures on land intensify, and existing tree stocks diminish, within most systems."

A system's financial value may derive from the value of the tree products it provides (woodlots, taungya, and timber species interplanted in coffee and cacao); the protection and subsequent increase in agricultural production it affords (windbreaks and shade trees in perennial crops); its contribution to soil improvement through nitrogen fixation, organic matter, and improved soil structures; or a combination of these. The outputs most commonly produced in the eight countries and seven systems analyzed were fuelwood, charcoal, and roundwood products for local markets and household use. In Costa Rica and the Dominican Republic, sawlogs were major products.

Prices for tree products vary greatly across the region and within each country. Fuelwood prices provide an example of this variability and the effect it may have on a system's profitability: according to our estimates, fuelwood prices range from US$2 per cubic meter in Panama to almost US$6 in Guatemala. In Guatemala City, fuelwood prices are more than twice the price of the same fuelwood in other parts of the country. In contrast, despite a relatively low forest cover around León, Nicaragua, the price for a cubic meter of fuelwood is only US$2.14, one of the lowest prices in the region. This apparent contradiction can probably best be explained by differences in the employment situation, the amount of fuelwood marketing, and relative access to the tree resource. One of the social benefits of windbreaks is that they have served as a source of fuelwood, providing gainful (although illegal) employment opportunities for the surrounding communities and creating a competitive market that maintains prices at a low level.

Financial analyses for six of the seven practices studied show average net present values of more than US$300 per hectare (the exception was woodlots). Findings on profitable returns from taungya and from intercropping of multipurpose tree species in perennial crops confirm findings of earlier case studies of the same region. (For studies on perennial intercropping: Alvarez-Brylla, Lazos-Chavero, and García-Barrios 1989; Glover 1981; Lagemann and Heuveldop 1983; and Estrada, Seré, and Luzuriaga 1988; on taungya: Reiche 1987; Aguirre 1983). The on-farm profitability of agroforestry in Central America appears to be consistently high, under a wide range of conditions and for different systems. Perhaps the reason for this high profitability is that farmers modify systems to ensure profitability under their own farm and local conditions.

Dean Current, Ernst Lutz, and Sara J. Scherr
Returns for perennial intercrops of coffee and black pepper are high in almost every one of the countries studied; low prices for plantain and cacao reduced returns to those systems in Costa Rica. On cropland, net present values for alley cropping and trees planted on contours were high except in Nicaragua. Analysis of the alley-cropping systems used conservative assumptions about the medium- and long-term effects on yield of green manuring and nitrogen-fixation; high returns were often attributable to the added value of the wood product. Except in Costa Rica, windbreaks brought low returns because they were costly to establish and they suppressed yields in adjacent crops; in the case of the government-sponsored windbreaks in Nicaragua, they were valued only for their fuelwood—although more valuable products had been harvested from them—and this valuation underestimated the value of the windbreak. In Costa Rica, increased yields of coffee and milk production alone made the establishment of windbreaks profitable in three years. (Windbreaks protect pasture grass from desiccation and reduce the stress on cows.)

Cost-benefit ratios were above 1.6 for six of the seven agroforestry systems, with woodlots once more the exception. Payback periods were quite long for the woodlot systems, averaging nine years, compared with two to five years for the other systems. Thus, the long gestation period commonly assumed for tree-based systems does not seem to be a problem for most of the agroforestry practices used in this region.

Of course, absolute profitability is less important to a farmer’s decisionmaking than the profitability relative to the available alternatives. Comparing the financial returns for agroforestry with those for alternative farming practices, the case studies found that agroforestry systems produced significantly higher returns per hectare—at least 25 percent—in approximately 40 percent of the cases and at least 10 percent greater returns in more than half of the cases. In more than 75 percent of the cases, the returns to labor were higher for systems including agroforestry than the local agricultural wage.

Financial results were generally most sensitive to yields and product prices, followed in importance by labor; the results were least sensitive to the prices of purchased inputs such as seedlings, agricultural seed, and agrochemicals. Including trees in agricultural systems makes tree, crop, and livestock systems less sensitive to changes in yields and prices and improves overall profitability.

**Risk Management**

Adopting agroforestry systems can both reduce and increase risks to the security of a household’s livelihood. Income diversification is a strongly positive benefit, reducing risk for both annual and perennial cropping systems and for livestock farming. But there are risks associated with cultivating trees, as with any other crop. Unusual drought conditions or poor planting materials could mean failure to establish the trees. Uncertain market prospects—most projects were weak in developing or improving farmer’s access to tree product mar-
kets—increase risk. Badly managed trees or overly competitive tree species can suppress the growth of associated crops. And, where permit procedures and government regulations are restrictive, there is a risk of not being able to harvest trees—a major obstacle to initial adoption. These risks, and perceptions of risk, reduce rates of adoption and expansion, even where average financial returns are good.

Typically the benefits received from the trees offset reported losses in agricultural production, but data on the effects of trees on agricultural crops are scarce. Positive effects were reported for agroforestry systems that produced organic mulch and green manure or wind protection. This was true of trees (*Alnus*) planted on contours in Guatemala, *Leucaena* intercropped with corn in Honduras, and windbreaks in Costa Rica. In Honduras the financial analyses reflect a decline in agricultural production in the alternative systems without trees.

**Markets**

Most farmers in the study initially adopted agroforestry systems to meet household subsistence needs, a result consistent with the findings of household surveys in six countries in Asia in 1991 (French and van den Beldt 1994). In twelve of the projects, a significant part of total output continued to be reserved for use on the farm. Once subsistence needs were satisfied, farmers became interested in market opportunities; in seven projects, local markets were important, and for twelve projects, considerable output was directed to regional or urban markets (usually through middlemen who purchased locally).

The market for farm-grown tree products varies within the region. In El Salvador and on the Pacific coast of Guatemala, markets have developed for rural construction; poles and roundwood have also found a market in Guatemala for tobacco-drying racks. In La Máquina, Guatemala, when the market for roundwood for construction became saturated, the market for tobacco racks picked up the slack. But farmers in Costa Rica, who had been led to believe they would be able to sell products from thinnings (wood three to five years old), have encountered a limited market that has quickly become saturated, leaving many farmers without an outlet. The market for sawlogs is strong in Costa Rica but requires wood that is eleven to fifteen years old. Similar problems with saturation in certain markets have also arisen in Asia.

Local organizations are working to develop new local, national, and international markets—notably in Guanacaste, Costa Rica, where tree farmers have formed a regional association of local organizations and cooperatives, which is studying markets for a regional forest industry based on the members' new and existing plantations. On the Pacific coast of Guatemala, tree farmers recently formed a similar organization to explore markets for their tree products.

In Hojancha, Costa Rica, early work to improve nursery practices for some of the most commonly planted species engendered a nursery industry that now supplies plants for individual and industrial tree planting throughout the coun-
try and provides a source of employment and income for Hojancha. The market has had to adapt to the normal vicissitudes of supply and demand; as new nurseries have developed outside Hojancha, the demand and prices for certain species have declined, so some nurseries have had to sell plants at a loss, while others have specialized their product to suit industrial growers with special requirements.

Studies by Cook and Grut (1989) and Warner (1993) for Africa, and the collection edited by Raintree and Francisco (1994) for Asia, and Arnold and Dewees (1995) for Africa and Asia show the importance of local markets in providing incentives for agroforestry, but these studies still conclude that household use is the driving force for most adoption. Arnold (1995: 278) further argues that distinctions between the two are blurred:

In most of the situations studied, self-sufficiency, in particular tree products, proved to be the primary objective. However, with the growing dependence of farm households on income to meet at least part of their needs, as forest products such as fuelwood, fodder and fruits become progressively commoditized, and the market-place provides opportunities to substitute purchased inputs such as fertilizer for inputs previously supplied by growing trees, the distinction between production for subsistence or sale has progressively less meaning. Not only will producers sell what is surplus to their subsistence needs, but they will sell a commodity needed in the household if the opportunity cost of doing so is advantageous.

The role that local and regional fuelwood markets play in inducing farmers to adopt agroforestry practices, although not a major incentive, appears to be much more important in Central America than it is in Africa, possibly because farming systems in Central America and the Caribbean are more highly commercialized than in much of Africa, and the region is more integrated economically. Thus farmers may be more inclined to specialize in particular tree species and tree products; the multiproduct feature of agroforestry, which appears to be so highly valued in Africa and Asia (Raintree and Francisco 1994), is generally less valued in Central America.

Adoption Patterns

Potential profitability may be a key incentive in farmers' decisions to adopt agroforestry, but the viability of a system for a particular household or area will be determined by the resources available to them and the constraints they face.

Management Factors

Land, labor, and capital resources were as influential as profit considerations in farmers' decisions about agroforestry (Dewees 1993; Scherr 1992). The re-
sources available to the typical farm family limit the type of agroforestry system it can adopt because different systems require different resources. Home gardens and alley cropping, for instance, may be very labor intensive; on the contrary, timber trees or woodlots require little labor but more land.

An advantage of agroforestry is that tree management operations can often be scheduled for slack periods of labor demand; indeed the case studies suggest that this is a significant incentive for adoption. In El Salvador fuelwood prices follow the agricultural calendar: during slack agricultural periods, farmers dedicate more time to extracting and processing fuelwood, and the increase in supply is reflected in a seasonal decline in fuelwood prices (Current and Juárez 1992). One constraint on adoption of alley cropping was its need for labor for pruning, which frequently conflicted with major agricultural operations. Intensive agroforestry systems, such as alley cropping, are less attractive to farmers who have land available for fallowing.

Management of agroforestry ranged in scope and sophistication from simply gathering of products from naturally growing trees to actively managing naturally growing resources, domesticating and establishing trees in selected sites, expanding the scale of tree planting, and finally, intensive managing (Scherr 1992). The level of intensity that is economic for farmers depends upon factors such as scarcity of forest resources; level and composition of demand; returns to alternative uses of land, labor, and capital resources; and the costs of production relative to costs of available substitutes for tree products and services, such as bricks for building poles and kerosene for fuelwood. The Panama project demonstrated that a woody fallow system, for recuperating soils and for extracting forest products, is a very profitable traditional alternative where land is available for that type of management. The study found the highest intensity of agroforestry management—for example, trimming branches to limit shading of agricultural crops—in areas of greatest land shortage, such as El Salvador and the Guatemalan highlands.

Agroforestry Practices and Tree Species

The most prevalent agroforestry systems found on farms were taungya or woodlots, followed by trees in some kind of linear arrangement (border plantings, contour plantings, live fences). Evidence of recent adoption was mixed for alley cropping, home gardens, windbreaks, green manuring, and trees-in-pasture systems. The choice of a particular tree species for use in agroforestry technologies was dictated by considerations such as familiarity to farmers, growth performance, market value, ease of propagation and management, multiple use options, interaction with crops (see table 5), availability, project recommendations, and environmental effects. The study identified thirty-two different forest tree species promoted by at least one project, along with a large number of well-known or exotic fruit trees. The most frequently used species were Eucalyptus camaldulensis, Gliricida spp., and
Table 5. Interaction of Agroforestry Systems with Other Crops

<table>
<thead>
<tr>
<th>Agroforestry system</th>
<th>Positive tree-crop interactionsa</th>
<th>Negative tree-crop interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial crop with trees</td>
<td>Complementaryb</td>
<td>Competitive for water and nutrients. Shade</td>
</tr>
<tr>
<td>Trees intercropped with agricultural crops</td>
<td>Complementary</td>
<td>Competitive for water and nutrients. Shade</td>
</tr>
<tr>
<td>Alley cropping</td>
<td>Complementary</td>
<td>Competitive for water and nutrients. Shade</td>
</tr>
<tr>
<td>Contour planting</td>
<td>Increased production through protection from soil and organic material contribution</td>
<td>Competitive for space, water, and nutrients</td>
</tr>
<tr>
<td>Windbreak</td>
<td>Increased production through protection from winds</td>
<td>Competitive for space, water, and nutrients</td>
</tr>
<tr>
<td>Taungya</td>
<td>Crop production helps cover cost of plantation establishment.</td>
<td>Shade and competition eliminate crop production in 3-4 years.</td>
</tr>
<tr>
<td>Woodlot</td>
<td>Isolates trees from crops, avoiding potential negative tree-crop interactions.</td>
<td>Competitive for crop production area. Poor matching of species to site and poor management have led to soil erosion problems.</td>
</tr>
<tr>
<td>Home garden</td>
<td>Generally does not compete for crop production area. Provides for tree product and fruit production on the same area.</td>
<td>There is no tree-crop interface, little or no interaction.</td>
</tr>
</tbody>
</table>

a. Choice of species and management may determine whether interaction is positive or negative and may limit or enhance the magnitude of impact.
b. Complementary: trees shade crop, agricultural inputs improve tree growth, and trees provide organic material and nutrients to crop.
c. Competitive: agricultural production decreases because of competition for sunlight, water, and nutrients; tree harvesting may damage perennials.

Source: Authors' data.

Leucaena leucocephala. Tectonis grandis (teak), Acacia mangium, and Cassia sp. were also mentioned by at least four projects (see table 2 for common names). Projects had tended in the past to promote only introduced species; more recently, there was a shift in the opposite direction, with some projects offering only native species. A mix of species appeared to be desirable, from the farmers’ point of view.

Scale and Pace of Adoption

Most empirical studies have found that farmers tend to adopt agroforestry gradually, starting with a few trees and expanding after they have gained expe-
perience and have realized the benefits. Thus in the projects studied here, signifi-
cant adoption commonly required five to ten years. This would seem an espe-
cially wise course of action for smallholders on resource-poor farms, given their
need to ensure food security and reduce risks. Continuous, small-scale establish-
ment of trees seems a more appropriate objective than crash-planting programs
for smallholder agroforestry programs. Studies documenting cases of rapid adop-
tion (for example, of eucalyptus in India) have found poorer economic returns.
Several theoretical cost-benefit modeling exercises also show that enterprises
are more profitable when costs and risks of establishing trees are spread over
several years, obtaining early benefits from multiproduct systems and a more
regular flow of final products over time (Swinkels and Scherr 1991; selected
cases).

Farm size clearly influences the pace and scale of adoption: even within the
limited range of resource-poor farms targeted by the projects studied. Research-
ers found that adoption was greater on larger farms. Farmers selected and adapted
agroforestry practices and management to suit their differing labor, land, and
capital resources. Female participation was significant in several projects. Informa-
tion from four projects in El Salvador and Guatemala indicates that, for small
and medium-size farms the average number of trees planted ranged from 440 on
farms with an average size of 2.2 hectares (or 200 trees per hectare) to 1,160 on
farms with an average of 10.4 hectares (or 112 trees per hectare). Although the
farmers with more land planted more trees in total, farmers with less land tended
to plant more trees per hectare.

Effects of Land Tenure and Land Use Regulation

Harvesting laws and regulations, created to protect forests, are a significant
barrier to the adoption of agroforestry in many places. In several countries farmers
are reluctant to plant trees because they fear possible expropriation of the land
or inability to obtain the permits needed to harvest trees. Most projects have
developed mechanisms to overcome these concerns, such as contracts and writ-
ten agreements giving the farmer explicit rights to harvest trees, but such agree-
ments are often not applicable nationally. Farmers without clear land rights—
renters, squatters, or residents of land that is de jure under forest reserve or
protection—face substantial obstacles to agroforestry.

Lack of formal land tenure has not generally been found to be a binding
constraint to adoption (Cook and Grut 1989), except in certain situations in
Africa, where constraints to women on tree planting or difficulties in protecting
trees established in fields used by pastoralists during the fallow period may be
deterrent. Tree ownership and disposal rights by contrast, particularly the re-
strictions and insecurities created by state claims of control over harvesting,
have been particularly problematic in dry areas in West Africa (Shepherd 1992),
as well as in Central America. Terms of sharecropping arrangements appear
also to be a constraint in parts of Asia (Arnold 1995: 276).
Implications for Extension

The forces that influence the spread of agroforestry and the patterns of adoption that have emerged should be a central concern in designing or modifying projects, particularly the amount of extension assistance offered and the form it should take. Sometimes tree planting on farms has been promoted irrespective of the particular profitability of the agroforestry system or how it fitted into the household and farm resource management. Extension and supply-driven innovation can, of course, act as a catalyst by promulgating new species or agroforestry systems, for instance, through demonstration plots or farms. But extension and technical assistance need to be highly responsive to farmers' concerns, and extension agents should provide a range of options and outline their pros and cons, rather than “push” tree planting as something that is intrinsically good.

Information on Available Options

Findings suggest that farmers would be better served if projects provided information on resource requirements and performance of a variety of agroforestry designs and species, rather than standard designs. To do that, promotion programs would have to broaden this “basket of choice” of species and systems to provide detailed information and performance under different types of management. Farmers could then select those that best met household needs and resources and would have the information needed to modify the basic design to suit their own preferences.

Demonstration, Technical Assistance, and Training

Agroforestry development in parts of the region is clearly occurring as a natural response to economic incentives and subsistence needs. Qualitative information from farmers, project staff, and informed observers suggests that the demonstrated benefits of fast-growing tree species and systems has often been a strong impetus to the expansion of agroforestry activities (see box 2 on the La Máquina project). Nonetheless, even where agroforestry systems are demonstrably profitable, some technical assistance appears to be needed to facilitate adoption and to provide information about tree management for unfamiliar species and configurations. The diffusion process is slow, in part because evaluating perennial systems takes farmers a long time and because they are frequently unfamiliar with product markets. Technical assistance can accelerate diffusion. The assistance can be phased out after the technology transfer has taken place, although, as the La Máquina example indicates, continued applied research to produce the best tree species and to discover which conditions and management suit them best remains very important, even where public extension on agroforestry has been phased out.

Training and employing local people as paratechnicians was judged to be a successful, low-cost means of promoting technology in nine of the projects.
Box 2. The La Máquina Project in Guatemala: A Case of Participatory Field Research With Demand-Driven Diffusion of Technology

La Máquina is a farming area of approximately 345 square kilometers on the Pacific Coastal Plain of Guatemala. Activities were initiated there in 1983 under the Lena Project, a regional project with core professional staff located at CATIE in Costa Rica, operating in the participating countries through a national coordinator who worked with a counterpart from the forestry agency. Under their direction, two or three professionals assisted with the activities, along with support and field personnel provided by the forestry agency.

The principal activity was to establish silvicultural experiments to evaluate species performance in different systems. Rather than restricting research plots to experimental fields, they were established on farmers' lands by agreement with the owners, and the local population was involved in the research effort. In 1987 the work was expanded to include plots on demonstration farms managed by the farmers under various agroforestry systems. Detailed information was collected on the inputs and returns for both agricultural and forestry-agroforestry plots.

A nursery was also established in the area, managed by two resident technicians who also provided technical assistance to farmers interested in planting or managing multipurpose tree species. Between 1986 and 1991 about 238,000 seedlings of multipurpose tree species were provided to 550 farmers.

Due in part to the success of the La Máquina plantings, two new projects have been introduced on the Pacific Coast based on the same technology and species. La Máquina's success is principally attributable to three aspects of the project: the demonstration effect, the quality of the product, and the evolution of incentives.

- The demonstration effect meant that dissemination was initially demand driven; directed extension activities to support the effort came later.
- As the product of a research project, planting stock is reliable, and technical assistance in planting and management have helped guarantee quality.
- Incentives have been modified as the project developed. To launch tree planting, free seedlings were given to farmers and were often also delivered to the farm. Once the community became interested, farmers came to the nursery to request seedlings and received technical assistance from the staff. Later, seedlings were provided in exchange for an equivalent number of plastic bags (which were used at the nursery as containers to produce seedlings). Most recently, the project and a new effort in an adjacent community have been promoting family nurseries. Thus the project has gradually shifted the costs and responsibilities for tree production to the farmers.

Paratechnicians could generally turn to professional staff for technical expertise. Use of paratechnicians develops local human resources, which develops continuity of agroforestry efforts beyond the project period.

Providing Planting Materials

Of the variety of project strategies for providing germplasm—direct seeding of native and introduced species, family nurseries, community nurseries, and specialized, centralized nurseries producing containerized seedlings in "root train-
ers” for easier transport—community and family nurseries proved superior to centralized nurseries, when backstopped by good technical assistance and logistical support. Farmers in many projects indicated willingness to purchase seedlings at market prices.

Financial and Material Incentives

The case studies suggest that financial incentives and subsidies may not, in fact, be needed for adoption, at least not in the quantity and duration that were available during the project. The important objective for extension is to put forward agroforestry technologies that will be profitable for the farmer without subsidies. An argument may be made for time-limited financial incentives for early adopters of unfamiliar technologies, to be reduced and eventually eliminated once farmers are aware of the benefits.

Small, in-kind, material inputs (seedlings, watering cans, planting bags, and fertilizer), generally provided with extension services, proved widely effective in persuading farmers to try out agroforestry. The advantage of these incentives was not so much that they had an effect on profitability, albeit quite modest, but that they reduced perceived risks of new planting and the need for “out-of-pocket” cash expenditures. Food-for-work incentives, by contrast, were very problematic, commonly leading to dependency, failure to maintain systems once they were established and incentives were no longer given, and reluctance to undertake subsequent agroforestry efforts without payment.

Credit for Agroforestry

Evidence from the study suggests that formal lines of credit may not be suitable for promoting smallholder agroforestry. Poor farmers seldom use formal production credit, because of the risks involved, and when they do, may reserve it for other priorities. Credit is needed mainly to cover costs of hired labor for planting relatively large acreages—an activity not relevant for smallholders. Where credit is made available, integrated or nontargeted systems (rather than separate lines of credit for specific crops or trees) would benefit farmers most.

Social and Environmental Benefits

Quantitative data on the social (as distinguished from private) benefits provided by agroforestry systems are sparse. But some information and anecdotal evidence indicate that these projects are making social and environmental contributions that could justify further promotion for that purpose. Agroforestry systems are replacing less-stable systems in watersheds, protecting the remaining forest resource by providing an alternative supply of tree products, protecting cities from the effects of airborne dust, and providing sources of employ-
ment and income generation for rural communities, thus helping to slow out-
migration. These benefits, of course, generally do not accrue to the farmer and
therefore tend not to figure prominently in adoption decisions. As in Central
America, Cook and Grut (1989) found for Africa that environmental benefits,
while appreciated by farmers, are not sufficient to spur adoption, except for
those providing indirect productive benefits (such as soil conservation in areas
of intensive production where yields are declining).

Some specific examples of environmental and social benefits noted in Central
America:

- Cacao plantings with tree shade introduced in fragile watersheds in Choloma,
  Honduras, are replacing shifting agricultural systems with perennial tree crops
  that protect and build soil. In Choluteca, Honduras, communal and individual
  tree plantings combined with soil conservation measures are providing a similar
  benefit. In addition, in most areas where projects have been operating, the amount
  of burning of agricultural fields and pastures has declined.

- In Honduras, El Salvador, and Guatemala, tree planting is providing an
  alternative source of tree products and thereby reducing the higher social costs—
  such as loss of biodiversity and increased downstream flooding—entailed in
  "mining" a natural forest, as data from three projects studied demonstrated. In
  Honduras farmers who once depended on the natural forest for up to 100 per-
  cent of their tree products are now meeting the bulk of that demand from their
  tree plantings. In El Salvador a community close to the capital city, which used
  to produce charcoal for sale from natural vegetation, is now using its tree plantings
  for that purpose. In Guatemala the expanding tobacco industry is using as posts
  the tree plantings on the Pacific Coast instead of using the remaining mangrove
  forest, which would have been the most probable alternative source of that ma-
  terial.

- In Costa Rica the Monteverde Conservation League has for several years pro-
  moted the establishment of windbreaks, which have improved the productivity of
dairy and coffee for participating farmers. Preliminary results of a recent study by
researchers from Duke University have demonstrated that those windbreaks are
acting as biological corridors connecting remnant forest patches. In addition, be-
cause farmers have increased their productivity through their participation with the
league, they are more receptive to protecting and improving their natural forest and
expanding the width of the windbreaks to serve environmental purposes.

- In León, Nicaragua, extensive windbreaks were established to protect León
  from dust carried into the city by winds. Reportedly, the windbreaks have suc-
sessfully reduced the dust and with it the health costs for the population.

- Finally, as this study demonstrates, these projects are improving rural wel-
lfare by providing needed tree products and generating income and employment.
A documented example is the effort of the Centro Agrícola Cantonal in Hojancha,
Costa Rica. According to a report prepared in 1990, the commercial nurseries in
Hojancha that developed from the reforestation efforts generated 30,000 per-
son-days of employment in 1989, and seed collection from plantations provided

Dean Current, Ernst Lutz, and Sara J. Scherr

173
an additional 4,900 person-days. The increased employment opportunity is an advantage for Hojancha, because out-migration in the region adds people to already overburdened urban areas. Furthermore, agroforestry activities are often undertaken at times when the labor demand is low. Recent efforts to process small diameter logs from new plantings and explore markets for the tree resource will provide further possibilities for employment and income generation.

To get a better empirical handle on social and environmental impacts, much more data would have to be collected than is currently available. More monitoring of projects is needed in general, and that monitoring should include data collection to allow hypotheses about social and environmental effects to be tested.

Conclusions

The attitude of the individual farmer to agroforestry is crucial to the success of agroforestry projects. Farmers' perception of the role the system will play in their farm's production system, as well as its costs, benefits, and profitability, will determine the extent and durability of adoption and should guide project strategies on extension services and institutional and policy issues.

Agroforestry's Profitability, and Its Role in the Farming System

Agroforestry, in many ways, is comparable to other parts of the farming system. Its special characteristics are that it includes a large number of species, configurations, and management intensities; that it has a longer gestation than most agricultural crops; and that its components have multiple uses.

In addition to the estimated financial return, farmers attach considerable importance to the way an agroforestry system fits into the overall farm production system and the existing land, labor, and capital constraints. Even more important for a farmer's decision than the absolute profitability of agroforestry systems may be the returns relative to alternative options. The most profitable agroforestry systems sometimes entail the most market risks. Some marginally profitable systems are widely used to meet specific household subsistence needs. Once those are met, there is an interest in market opportunities. The existence or development of markets is crucial for expansion (see similar findings for Mexico in Alvarez-Brylla, Lazos-Chavero, and García-Barrios 1989; for Ecuador in Mussak and Laarman 1989; and for Asia in French and van der Beldt 1994).

Our study found that many agroforestry systems are profitable to farmers under a considerable range of economic conditions, and various types of (low-intensity) traditional agroforestry are indeed practiced in many areas; the tentative economic analyses indicated that many agroforestry systems are profitable at real discount rates of 20 percent or higher. Intercropping, if managed prop-
erly, tended to be superior to woodlots. Soil-improving interventions could be profitable even with conservative assumptions of environmental effects. In all but one case, the profitability of windbreaks tended to be poor, perhaps because of poor design and, in one case, because of the lack of local participation (in a government-mandated program). Perennial intercrops diversified income, added value per unit of land, improved cash flow, and caused only limited loss of the main product.

Agroforestry Adoption

Local scarcity of wood products is, as might be expected, a key motivator in adopting nontraditional agroforestry systems. When deciding where to locate an agroforestry effort, projects must begin by assessing the scarcity of wood, as well as the existence of local markets for products.

Taungya, perennial intercrops, trees on contours, woodlots, and tree lines have proved to be the easiest systems to introduce. Results are mixed for alley cropping, home gardens, windbreaks, green manuring, dispersed trees in cropland, and tree-pasture systems. Farmers are willing to invest in rehabilitating their land where systems also produce products or income, and they prefer less-intensive systems.

Even when agroforestry is profitable, smallholders will and should adopt agroforestry incrementally and gradually because of management and resource constraints. Poorer farmers, in particular, are often hampered by limited land, labor, and capital resources and their need to ensure food security and reduce risks. Programs to promote rapid, large-scale adoption of agroforestry may put smallholders at risk or bias adoption and benefits heavily toward higher-income farmers; continuous, small-scale adoption is a more appropriate objective for smallholder programs. Preferred agroforestry systems offer short-term and intermittent benefits that permit farmers to finance investments themselves.

Adoption patterns differ between small and large farms. Fallow and extensive grazing are still important for medium-size and large farms, and intensive agroforestry systems may not yet be economic. For smallholders, in contrast, intensive systems may be more interesting, but food security and risk issues are more critical.

Extension Strategies

The demonstration effect of fast-growing tree species on farms and of benefits on demonstration plots has helped expand agroforestry activities, reducing the costs of extension and increasing its effectiveness.

Rather than offering standard designs, programs would serve farmers best if they offered a broad selection of species and systems, allowing farmers to choose those most suitable to their household’s needs and resources. Technical assis-
tance is needed to facilitate adoption and to provide information about managing unfamiliar species and configurations. An endogenous process of agroforestry is clearly developing in parts of the region in response to economic incentives and subsistence needs. But this process is slow; its acceleration would require access to limited, but continuous, farm- or group-level technical assistance. Where new markets for products are being opened or developed, extension services may also provide critical information and assistance in marketing.

Involving local people as paratechnicians is often a successful, low-cost approach to promoting technology. Their participation makes projects more sustainable by developing local human resources that can carry forward agroforestry efforts beyond the project period.

Financial incentives and subsidies should be kept to a minimum, with the possible exception of time-limited financial incentives for early adopters of unfamiliar technologies. Agroforestry technologies promoted by extension should be financially profitable—and thus adoptable—for the farmer without subsidies. In-kind, material inputs have effectively encouraged farmers to experiment with and adopt agroforestry, but the experiences with food-for-work incentives have generally been unpromising.

Institutional and Policy Implications

There has recently been considerable debate, both regional (Alfaro and others 1994) and international (FAO 1993; Oram and Scherr 1993), about the types of policy reforms necessary to promote agroforestry as well as forestry. In general, the issues raised, such as macro- and intersectoral policy linkages, trade policies, institutional development, and conservation policy, are also relevant to agroforestry promotion in Central America and the Caribbean. The findings of this study suggest that particular attention should be paid to improving the institutional structure for tree product markets (information, monitoring, grading, and standards); modifying regulations that restrict markets for farm-produced products; public support services for decentralized NGO extension and paraextension efforts; and incorporation of agroforestry into planning efforts.

Institutional responsibilities for agroforestry extension and support need to be defined. Because agroforestry falls between the ministries of forestry and agriculture, the institutional “home” for agroforestry activities has been uncertain. Nongovernmental organizations have taken a leading role in providing information and support, but have sometimes undertaken isolated and uncoordinated efforts. Semi-autonomous projects coordinated closely with host government agencies have been effective.

Even though lack of land title was not a variable that was systematically analyzed in our study, some observations indicate that it does not of itself appear to be a significant constraint to agroforestry adoption in most areas. The important point is how secure farmers feel in their property rights with or without an official title. De facto property rights generally provide farmers with
enough security. On rented land, however, generally no tree planting is taking place.

**Future Research**

The value of the study's findings for project planners, policymakers, and practitioners would be enhanced by more precise assessment of the effects of specific policies and extension approaches. For that purpose empirical studies would be needed on a large number of farms, with specific agroforestry practices sampled across a range of environments, farm size, and market access. Monitoring of on-farm environmental effects would also be particularly interesting, given the dearth of information in that area.

**Notes**

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1. Note that, although many trees have multiple potential uses, some types of tree management for one use preclude other uses. One cannot produce high-quality wood in alley-cropping systems. Fodder banks and living fences generally do not produce timber.

2. Financial profitability was determined by a cost-benefit analysis of the agroforestry systems reviewed in their entirety, and not on the incremental net benefit of the agroforestry system over an alternative land use system. The profitability of the systems was compared to an alternative.

**References**

The word "processed" describes informally reproduced works that may not be commonly available through library systems.


Alfaro, Marielos, Ronnie de Camino, Maria Ileana Mora, and Peter Oram, eds. 1994. *Taller Regional: Necesidades y Prioridades de Investigación en Políticas Forestales y*


Dean Current, Ernst Lutz, and Sara J. Scherr


