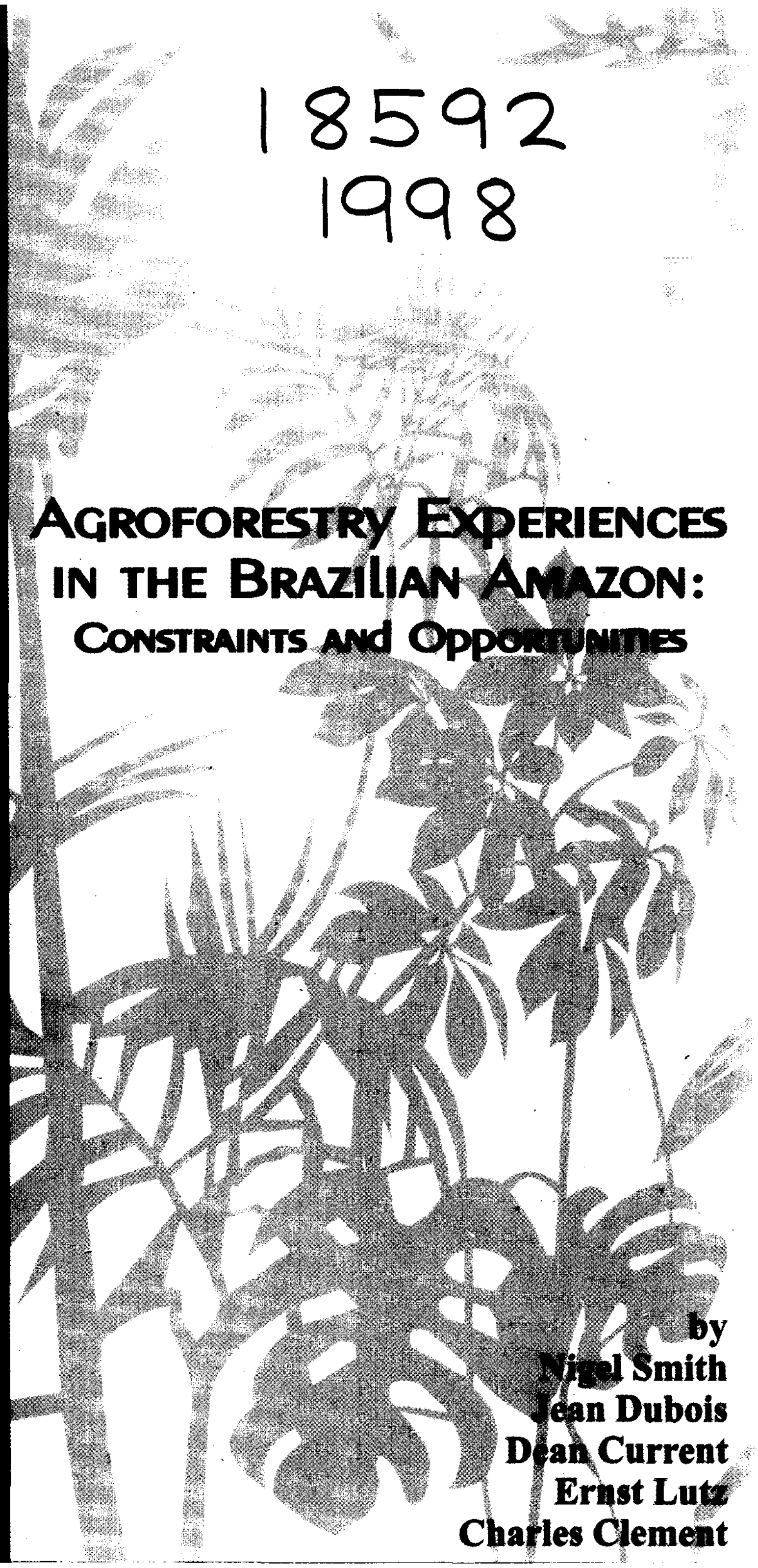
*onservation and Development*
*f Brazil's Tropical Forest Regions*

18592
1998



# Agroforestry Experiences in the Brazilian Amazon:
## Constraints and Opportunities


by
Nigel Smith
Jean Dubois
Dean Current
Ernst Lutz
Charles Clement



PILOT PROGRAM
TO CONSERVE
THE BRAZILIAN
RAIN FOREST

**The Pilot Program to Conserve the Brazilian Rain Forest**

**It's time for Brazil**

**Federal Government of Brazil**

*President of the Republic*
Fernando Henrique Cardoso

*Minister of the Environment, Water Resources and the Legal Amazon*
Gustavo Krause Gonçalves Sobrinho

*Executive Secretary*
Sérgio Moreira

*Secretary for the Coordination of Amazon Affairs*
José Seixas Lourenço

**World Bank**

*Rain Forest Unit*
SCN Quadra 01 Lote A
Ed. Corporate Financial Center, Conj. 303/304
70.712-900 Brasília D.F., Brasil
Telefone (55-61) 329-1000; Fax (55-61) 329-1012

1818 H Street, N.W.
Washington, D.C. 20433, USA
Telephone (202) 473-0596; Fax (202) 522-2105

*Conservation and Development of Brazil's Tropical Forest Regions*

*Conservation and Development of Brazil's Tropical Forest Regions*

# Agroforestry Experiences in the Brazilian Amazon: Constraints and Opportunities

by

Nigel Smith, Jean Dubois, Dean Current, Ernst Lutz, & Charles Clement

The Pilot Program to Conserve the Brazilian Rain Forest
1998

Smith, N., J. Dubois, D. Current, E. Lutz, & C. Clement. 1998. *Agroforestry Experiences in the Brazilian Amazon: Constraints and Opportunities.* The Pilot Program to Conserve the Brazilian Rain Forest, Brasília, Brazil.

Nigel Smith is a Professor in the Department of Geography, University of Florida, Gainesville, Florida, USA. Jean Dubois is Director of the Brazilian Agroforestry Network (REFBRAF), Rio de Janeiro, Brazil. Dean Current is a forest economist at the Center for Research and Training in Tropical Agriculture (CATIE), Turrialba, Costa Rica. Ernst Lutz is a Senior Resource Economist at the World Bank, Washington, D.C., USA. Charles Clement is a Senior Researcher in the Department of Agronomy, National Institute of Amazonian Research (INPA), Manaus, Brazil.

## Table of Contents

## *Executive Summary*

Agroforestry has potential to slow tropical deforestation for three main reasons. First, it can extend the period of agricultural production in already cleared areas, thus reducing the need to clear more forest. Second, evidence is accumulating that agroforestry - especially modern, market-oriented systems - improves living standards, thus enabling farmers to channel less time and resources toward extensive slash-and-burn agriculture for subsistence. Third, farmers who successfully plant trees as part of their farming systems are more likely to perceive the importance of conserving forest resources.

A great deal of farmer experimentation is underway with agroforestry systems across the Brazilian Amazon, and farmers are deploying hundreds of different combinations involving both native and introduced crop species. Such experiences are a valuable reservoir of knowledge that can be tapped for further agroforestry development in the region. Overall, however, agroforestry represents a small portion of land uses in Amazonia. Cattle pasture, often degraded, and secondary growth still dominate most cultural landscapes in the region. Slash-and-burn fields that are cultivated for a few years with cereal or root crops account for much of the remaining farmland.

The purpose of this study is to analyze the constraints holding back a fuller deployment of agroforestry systems in the Brazilian Amazon, and to identify opportunities for overcoming those constraints. By examining specific cases throughout the region, the study identifies important lessons that, if applied more widely, could help promote agroforestry and achieve a better balance of land use systems in the region.

Socioeconomic factors are the primary constraints to further development of agroforestry in the Brazilian Amazon. Commercial interest rates in Brazil are too high for either farmers or entrepreneurs interested in processing agricultural products, and few government-subsidized credit programs effectively target agroforestry. In an increasingly global marketplace, Amazonia is at a distinct disadvantage due its inadequate infrastructure (particularly energy supplies, roads, and port facilities), lack of agroindustry, incipient farmer organizations, and insufficiently funded and staffed R&D system. Because of these constraints, most of the growing and processing of tropical fruits, including those native to Amazonia, takes place in Brazil's Northeast and in the state of São Paulo, where infrastructure and yields are better.

In general, neither the region's public sector research system nor extension by government agencies or non-government organizations (NGOs) are meeting the needs of farmers involved in agroforestry. Reasons for this mismatch include:

- Drastically reduced budgets and lack of client orientation undermine the effectiveness of many governmental research and extension agencies in the region; likewise, NGOs generally lack research capacity and are too often production oriented, rather than market oriented.
- Because it falls between the cracks of traditional commodity research and forestry, agroforestry still receives limited attention from the agricultural research and

extension programs of the region.

- Most agroforestry research in the public sector still involves a top-down approach, in which crop configurations are conceived by scientists with little or no input or participation by local farmers.
- Inadequate attention is paid to existing and potential markets when planning research and extension programs, in part because of the paucity of economists and marketing specialists on the staff of research institutes.
- Both public agencies and NGOs have been unable to provide reliable seed stock and seedling supply sources, and although the private sector is increasingly supplying planting material used in commercial agroforestry systems, demand far outstrips supply - which is of highly variabie quality.
- While natural forest ecosystems represent an important source of genetic resources for improving existing and potential agroforestry crops, the linkages between forest conservation and agroforestry development are generally not recognized nor clearly understood.

Notable exceptions to the situation outlined above can be found and they have important implications for agroforestry development. An examination of selected case studies reveals that the more successful efforts to promote agroforestry are characterized by:

- a flexible agroforestry design that can respond to changing conditions;
- a focus on processing and marketing issues from the start;
- solid technical support to assure high quality germplasm and appropriate plantation management;
- access to markets and sufficient infrastructure; and
- minimal - or at least short-term - reliance on external sources of funding.

Some of the existing constraints to agroforestry in Amazonia could be removed through policy and institutional reform. Promising areas for reform include:

- *Information on costs and prices.* Throughout the Brazilian Amazon, there is a notable lack of information on local and regional prices for agroforestry products, and on the costs of producing, processing, and marketing those products. This information vacuum inhibits regional and state banks from providing credit for agroforestry, thus further undermining the adoption of this land use by farmers. Collaboration between extension services and business assistance agencies such as SEBRAE could make information on agroforestry product costs and prices more widely available in the region.
- *Processing.* Unreliable sources of electricity and poor quality control undermine regionally based agroindustries and act as major constraints to agroforestry in the Amazon region. One promising yet little explored solution is asceptic packaging, which eliminates the need for refrigerated storage, helps maintain high product quality, and can literally bring the factory to the forest. Another option is to explore markets for byproducts that are generally ignored or discarded. Although

its inadequate infrastructure will continue to draw crop production to other regions, Amazonia's diverse array of under exploited crops provides potential opportunities for local producers and agroindustries alike.

- *New crop development.* With an estimated 200 known timber and non-timber species of economic value, Amazonia's comparative advantage over other regions lies in its potential for providing the germplasm and information needed to generate new crops and products. Yet the Amazon region's agricultural R&D system is poorly organized to assume this strategic role. Existing and new funding for agricultural R&D should be targeted to support development of promising crops, product processing, and markets, carried out by research teams representing diverse disciplines and institutions.
- *Extension.* Local governments, NGOs, and agribusinesses are playing an increasing role in agroforestry extension throughout the Amazon region, and each brings its own strengths and limitations. Yet partnerships between these institutions are rare. Public extension agencies could lead the way in forging such partnerships and assuring that key research findings on promising crops, product processing, and markets are effectively disseminated to farmers. Given the region's immense geography, poor accessibility, and limited financial resources, extension needs to be increasingly strategic, focusing field visits on priority locales, using appropriate media such as radio to reach wider areas, and building strong farmer organizations through training in critical areas such as administration, accounting, conflict resolution, and marketing.
- *Credit.* Due to lack of economic information and high transaction costs, credit for agroforestry is not offered by commercial banks and, even when subsidized, tends to be poorly managed by public banks in the Brazilian Amazon. New sources of credit provided by international development agencies and locally based agribusinesses offer an opportunity to test strategies for overcoming these constraints. Successful strategies could then point the way for regional banks to play a more active and effective role in promoting agroforestry.

## *Preface*

In recent years, agroforestry systems have emerged as one of the most promising land use alternatives for the Amazon basin. By combining trees with annual crops or pastures, these systems hold the potential of minimizing soil degradation, diversifying income sources and diminishing pressures on remaining forested areas. Despite its promise, however, agroforestry currently occupies a relatively small area compared to more extensive land uses such as logging, shifting cultivation and cattle pastures. The spread of these latter land uses, in turn, is generating increased rates of deforestation and forest degradation - as indicated by recent data from the Brazilian Amazon.

Implementing agroforestry on a larger scale will require overcoming a wide array of socioeconomic, political and technical constraints that operate in the region. This study provides an overview of those constraints and suggests strategies for overcoming them. Carried out by a team of specialists with in-depth experience in agroforestry-related issues throughout Latin America, this study shows that the constraints to agroforestry in the Brazilian Amazon are formidable and complex, and that overcoming them will require long-term investment by both the public and private sectors. In this context, the region's governmental research and extension agencies, in conjunction with new business enterprises and non-governmental organizations (NGOs), can play a crucial role in developing, testing, and disseminating new crops and configurations for agroforestry. To be successful, however, these efforts will require the close collaboration of the farmers themselves - who generally have been treated as passive recipients rather than active partners.

This study was supported by the Pilot Program to Conserve the Brazilian Rain Forest. Funded by the G-7 countries, the European Union, and the Brazilian government, the Pilot Program is implemented by numerous governmental agencies and NGOs, under the coordination of the Secretariat for the Legal Amazon in Brazil's Ministry of Environment and the World Bank. With approximately US$250 million in grant funds, this program represents the largest multilateral donation to promote environmental conservation in a single country. Its 12 core projects cover a wide array of initiatives in Brazil's Amazon and Atlantic forest regions, including increased protection of protected areas, extractive reserves, and indigenous reserves; innovative approaches to management of forests and flood plains; environmentally sound development initiatives carried out by local communities; strategic research and strengthening of key research centers; and improved surveillance and enforcement of environmental policies.

Agroforestry crosscuts many of these projects, and the Pilot Program can promote its development - especially in the Brazilian Amazon. In the ongoing Extractive Reserves, Directed Research, and Demonstration projects, agroforestry is already a major activity, and it is likely to be an important component of future projects such as Forest Resources Management, Flood Plain Resources Management, and Deforestation and Fire Control. As a result, understanding agroforestry's constraints and opportunities can contribute to the success of these projects, as well as of the Pilot Program as a whole.

This study provides critical insight concerning those constraints and opportunities. Its bottom-line message is that agroforestry is no panacea. But with increased commitment by both public and private sectors, agroforestry can begin to play an important role in curbing deforestation and improving livelihoods in the Brazilian Amazon.

José Seixas Lourenço
Secretary for the Coordination of Amazon Affairs
Ministry of Environment, Water Resources and the Legal Amazon
Brasília - D.F.
Brazil

## Acronyms

| | |
|---|---|
| AMAFRUTAS | Amazon Frutas |
| APA | Associação de Produtores Alternativas |
| ASPRUVE | Associação dos Produtores Rurais Vencedores |
| BASA | Banco da Amazônia, S.A. |
| BEA | Banco do Estado do Amazonas |
| BERON | Banco do Estado do Rondônia |
| BNDES | Banco Nacional de Desenvolvimento Econômico e Social |
| BONAL | Borracha Natural |
| CAEX | Cooperativa Agro-Extrativista de Xapuri |
| CAMTA | Cooperativa Agropecuária Mixta de Tomé-Açu |
| CCCF | Comité Catholique contre la Faim et pour le Développement |
| CEPLAC | Comissão Executiva do Plano da Lavoura Cacaueira |
| CIRAD | Centre de Cooperation Internationale en Recherche Agronomique pour le Développement |
| CONTAG | Confederação dos Trabalhadores da Agricultura |
| CPAA | Centro de Pesquisa Agroflorestal da Amazônia Occidental |
| CPAF | Centro de Pesquisa Agroflorestal |
| CPATU | Centro de Pesquisa Agroflorestal da Amazônia Oriental |
| EC | European Community |
| EMATER | Empresa de Assistência Técnica e Extensão Rural |
| EMBRAPA | Empresa Brasileira de Pesquisa Agropecuária |
| FCAP | Faculdade de Ciências Agrárias do Pará |
| FNO | Fundo Constitucional de Financiamento do Norte |
| FUNAI | Fundação Nacional do Índio |
| FUNTAC | Fundação de Tecnologia do Estado do Acre |
| GATT | General Agreement on Tariffs and Trade |
| IBAMA | Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis |
| IDAM | Instituto de Desenvolvimento do Amazonas |
| IFC | International Finance Corporation |
| IMAZON | Instituto do Homem e Meio Ambiente da Amazônia |
| INCRA | Instituto Nacional de Colonização e Reforma Agrária |
| INPA | Instituto Nacional de Pesquisas da Amazônia |
| LAET | Laboratório Agroecológico da Transamazônica |
| MLAL | Movimento Laico para América Latina |
| MPST | Movimento pela Sobrevivência na Transamazônica |
| ORSTOM | Office de la Recherche Scientifique Outre-Mer |
| PAI | Programa Amazônia Integrada |

| | |
|---|---|
| PESACRE | Grupo de Pesquisa e Extensão Agroflorestal do Acre |
| PLANAFLORO | Plano Agropecuário e Florestal de Rondônia |
| POEMA | Pobreza e Meio Ambiente na Amazônia |
| PROBOR | Programa de Incentivo à Produção de Borracha Natural |
| PROCERA | Programa de Crédito Especial de Reforma Agrária |
| REBRAF | Instituto Rede Brasileira Agroflorestal |
| RECA | Projeto de Reflorestamento Consorciado e Adensado |
| SEBRAE | Serviço Brasileiro de Apoio às Micro e Pequenas Empresas |
| SENAR | Serviço Nacional de Aprendizagem Rural |
| SUDAM | Superintendência do Desenvolvimento da Amazônia |

## Acknowledgments

Many individuals and organizations kindly discussed ideas and provided information that proved helpful in the preparation of this study. In addition to hundreds of farmers who gave generously of their time and provided many useful insights, we would like to thank the following individuals for generously sharing their observations on agroforestry and agricultural policy in Amazonia: Samuel Alexandre (EMATER, Porto Velho); Mary Allegretti (Secretária de Meio Ambiente, Macapá); José Arimateia (EMATER, Ji-Paraná); Abrelino Alves (ASPRUVE, Extrema); Hélcio Amaral (Assesor, Prefeitura de Santarém); Abib Araújo (PESACRE, Rio Branco); Eugenio Arima (IMAZON); Imar Cesar de Araújo (SUFRAMA, Manaus); Mauro J. Arruda (BASA, Manaus); Osvaldino Ataide (EMATER, Santo Antonio de Tauá, Pará); Pedro Beber (PLANAFLORO, Porto Velho); Arnoldo Berkenbrock (RECA, Nova Califórnia); Arnaldo Biangetti (EMBRAPA/UNDP, Porto Velho); Antonio Bomfim (EMATER, Ji-Paraná); Marcelo Bonnett (CTAA-EMBRAPA, Rio de Janeiro); João Capiberibe (Governor of Amapá); Cledemar Carneiro (EMATER, Porto Velho); Francisco Cartaxo (PESACRE, Rio Branco); Gário Carvalho (REBRAF, Macapá); Olegario Carvalho (CPATU-EMBRAPA, Belém); Soraya Carvalho (LAET, Altamira); Carlos Castilla (ICRAF, Porto Velho); Josué Cavalcante (EMATER, Altamira); Luis Ciarini (EMATER, Santo Antonio de Tauá, Pará); Ruy Corrêa (Mayor of Santarém); Nilton Cosson (PESACRE, Rio Branco); Valdeci Costa (EMATER, Ouro Preto); Gladys DeSouza (CPAA-EMBRAPA, Manaus); Adriano Dias (CPI, Rio Branco); Jean Dupui (Fink & Cia, Manaus); Amancio Estevão (EMATER, Ouro Preto, Rondônia); Italo Falesi (CPATU-EMBRAPA, Belém); Samuel Fernandes (EMBRAPA, Ouro Preto, Rondônia); João Ferraz (INPA, Manaus); Maria Ferreira (CPATU-EMBRAPA, Belém); Edson Figueiredo (Agromazon, Porto Velho); Ozório Fonseca (INPA, Manaus); Dilson Frazão (CPATU-EMBRAPA, Belém); Claudenor Freitas (POEMA, Jenipa-úba); Kelton Freitas (REBRAF, Amapá); Renato Gavazzi (CPI, Rio Branco); Carlos Gomez (Ji-Paraná); Belchior Gonçalves (ANCA, Ouro Preto, Rondônia); Abelardo Guimarães (CPAF-Acre, Rio Branco); Flaviano Guimarães (Amazônia Ind. & Com. de Guaraná, S.A., Manaus); Francisco Herrera (Industrial manager, DICACAU, Altamira); Alfredo Homma (CPATU-EMBRAPA, Belém); Walmir Jesus (APA, Ji-Paraná); Milton Kanashiro (CPATU-EMBRAPA, Belém); Noemi Leão (CPATU-EMBRAPA, Belém); Johannes van Leeuwen (INPA, Manaus); Ailton Lima (POEMA, Belém); Elizen Lima (EMATER, Acrilandia, Acre); Fernando Lima (Rancher, Xingu River); Jorge Lima (EMBRAPA, Macapá); Maria Luisa (EMATER, Altamira); David McGrath (Projeto Várzea, Santarém); Pedro Marques (SENAR, Santarém); Luciano Marques (CPATU-EMBRAPA, Santarém); João Matos (CPAA-EMBRAPA, Manaus); Albert Mayer (Agromazon, Porto Velho); Márcio Miranda (EMBRAPA, Brasília); Nilson Medeiros (Rural Health Service, Terra Caída, Rondônia); Wolfgang Meier (Projeto IARA, Santarém); Paulo Meireles (EMBRAPA, Macapá); José Mendes (EMATER, Ji-Paraná); Luis Menezes (UFAC-PZ, Rio Branco); Ronei Menezes (PESACRE, Rio Branco); Manuel Miranda (EMATER, Santo Antonio de Tauá, Pará); Thomas Mitschein (POEMA, Belém); Bernd Mitlewiski (Projeto IARA, Santarém); John Moon (Universidade Federal do Pará, Belém); Francisco

Moreida (POEMA, Belém); Mário Neumann (EMATER, Porto Velho); Oswaldo Nogueira (Managing Director, Guaraná Xingu, Altamira); Dorremi Oliveira (CPAA-EMBRAPA, Manaus); James Oliveira (Coordinator, Agroforestry Pole Project, Rio Branco); Samuel Oliveira (EMBRAPA, Porto Velho); Sinval Paiva (POEMA, Belém); Paulo Paladini (FRUIT-RON, Ji-Paraná); Ernesto de Paula (Ministry of Science and Technology, Brasília); José Pedro (EMATER, Porto Velho); Lecir Peixoto (LAET, Altamira); Gabriel Pereira (AMAFRUTAS, Belém); Rogário Perin (CPAA-EMBRAPA, Manaus); Flávio Pimentel (CPAF-Acre, Rio Branco); Otavio Pires (CITROPAR, S.A., Belém); Darcisio Quantz (CPATU-EMBRAPA, Uruará); Ivaldo Regalado (EMATER, Ji-Paraná); Fatima Ribeiro (CPATU-EMBRAPA, Belém); Edward Richardson (CPAF-Acre, Rio Branco); Delano Riker (Rancher, Santarém); Carla Rocha (LAET, Altamira); Toni Rocha (Macapá); Claudenor Sá (CPAF-Acre, Rio Branco); Álvaro Santos (CPAA-EMBRAPA, Manaus); Cirinaldo Santos (PLANAFLORO, Porto Velho); Manuel Santos (EMATER, Porto Velho); Vicky Schneider (POEMA, Belém); João Segovia (EMBRAPA, Macapá); Cristovam Senna (EMATER, Santarém); Adilson Serrão (CPATU-EMBRAPA, Belém); Carlos Silva (PACA, Cacoal, Rondônia); Fernando Silva (BEA-Manaus); Luiz Silva (ANCA, Ouro Preto, Rondônia); Abraão Silvestre (CIRAD, Altamira); Victor Souza (EMBRAPA, Porto Velho); Mario Tanaka (EMATER, Santarém); Ricardo Tarifa (World Bank, Brasília); José Tasiso (EMATER, Ji-Paraná); Cacique Tataré (Cinta Larga Indians, Cacoal, Rondônia); Emerson Teixeira (SEPLAN, Porto Velho); Evaristo Terezo (SUDAM, Belém); Ismar Trevisan (Cerealista Trevisan, Medicilândia); José Trinidad (BASA, Belém); Judson Valentim (CPAF-Acre, Rio Branco); Kelson Vaz (REBRAF, Macapá); Jonas Veiga (CPATU-EMBRAPA, Belém); Giorgini Venturieri (Universidade Federal do Pará, Belém); Adalberto Veríssimo (IMAZON, Belém); Konrad Vielhauer (SHIFT-CPATU, Belém); Jurandir Vieira (EMATER, Porto Velho); Noel Vieira (DICACAU, km 140 Altamira-Itaituba); Pedro Vilson (EMBRAPA, Porto Velho); Marcos Vinicius (CPAF-Acre, Rio Branco); Francesco Vita (World Bank, Cuiabá); Jorge Yared (CPATU-EMBRAPA, Belém); Stephen Vosti (IFPRI, Washington, D.C.); Alexandre Wanghon (Secretária de Planejamento, Prefeitura de Santarém).

Jason Clay (Rights and Resources) and Jeff Moats (Kapok International) generously put their thoughts about agroforestry constraints and potential in Amazonia on paper for the authors to consider. Their business experience with tropical fruits and other non-timber forest products provided a wealth of insights. Jason Clay also provided helpful commentary on this study when it was presented at a seminar series hosted by the Environment Department of the World Bank on 26 September 1996. Paulo Alvim (CEPLAC, Itabuna), Hans Gregersen (University of Minnesota, St. Paul), Scott Josiah (Center for Integrated Natural Resource and Agricultural Management, St. Paul), and Sebastião Kengen (IBAMA/FAO) also provided helpful comments on the study.

Cirinaldo Santos (PLANAFLORO, Porto Velho), Pedro Souza (REBRAF, Macapá), Mario Tanaka (EMATER, Santarém), and José Tosisio (EMATER, Ji-Paraná) kindly collaborated by applying questionnaires for this study.

We are grateful to the following reviewers of drafts of this study: Jason Clay (Rights and Resources); John Browder (Virginia Tech); Jean Dupui (Fink & Cia, Manaus); João Ferraz (INPA); Ozório Fonseca (INPA, Manaus); Anthony Hall (London School of Economics); Johannes van Leeuwen (INPA, Manaus); Thomas Mitschein (POEMA, Belém); Jeff Moats (Kapok International); Adilson Serrão (CPATU, Belém); Avrum Shriar (University of Florida, Gainesville); Vanessa Slinger (Department of Geography, University of Florida, Gainesville); and Susan Swales (University of Florida, Gainesville). Mark McLean (University of Florida, Gainesville) drew the map (Figure 1).

Finally, the authors are grateful for the enthusiasm, ideas, and encouragement of Phil Hazelton, task manager for this study. Likewise, Robert Schneider, manager of the Pilot Program to Conserve the Brazilian Rain Forest, and Ricardo Tarifa, also of the Pilot Program, helped sharpen some of the thinking on how to tackle the issues covered in this study. Anthony Anderson, editor of the series in which this study appears, patiently revised entire sections and helped steer it to publication.

# I. Introduction

### *A. Deforestation and Agroforestry*

Deforestation in the Amazon basin has been hotly debated regionally and worldwide for over a decade now. After slowing somewhat in the early 1990s, forest clearing sharply increased in 1994, and with widespread burning reported by the press in 1995, the question of how to slow down deforestation in the region has re-emerged with new urgency.

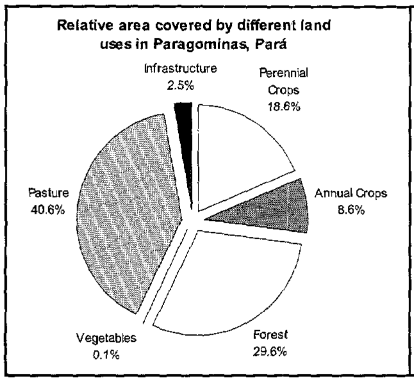
Agroforestry is often perceived as a way to help slow deforestation by breaking the predominate slash-and-burn cycle practiced by most farmers in the region. Shifting agriculture is thought to account for about one-third of the deforestation in Amazonia, while cattle ranching is responsible for at least half of the forest retreat in recent years (Serrão et al., 1996). Rural populations in many parts of eastern Amazonia are now so dense that fallow periods between cultivation cycles are too short to allow soils to recuperate (Toniolo and Uhl, 1995). Although some observers are skeptical that agroforestry will have much impact on alleviating poverty or slowing deforestation in the region (Fearnside, 1995), it can certainly help wean farmers from production systems that are in an ecological tailspin.

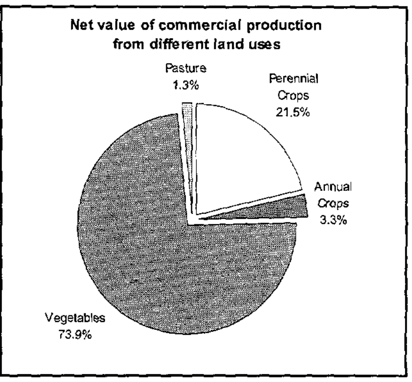
Yet the notion that agroforestry can "break" the destructive pattern of slash-and-burn farming is true only up to a point. Agroforestry may occupy some areas that would otherwise be in secondary growth, but farmers who engage in this practice will continue clearing forest to grow their basic staples because of declining soil fertility, build-up of weeds and pests, or other factors. How much is cleared would appear to depend on the profitability of commercial agroforestry systems: presumably, with more income generated, farmer families will buy more of their basic staples. Agroforestry may not be a panacea, but it can be an option to help slow deforestation and generate significant income from relatively small areas compared to other land use systems, especially cattle ranching and shifting agriculture (Box 1).

Agroforestry is often promoted as one of the most "environmentally-friendly" ways to develop rural areas of the humid tropics. In addition to its perceived local environmental benefits, the global community is also beginning to recognize forest conservation and tree planting in the tropics as a carbon sink (Myers, 1992). One mechanism by which the global community could support forest conservation and tree planting in the tropics would be through "carbon offsets," in which industrialized countries could "offset" required targets for carbon emissions by supporting appropriate land uses in developing countries.[1] Although the impact of tree planting in agroforestry systems on any purported global warming is likely to be small, such mechanisms could eventually provide incentives to cover some of the incremental costs of promoting agroforestry in developing countries.

**Box 1. Land use intensity, income and employment generation: An example from Paragominas, Pará.**

In order to take pressure off the remaining forest, one option is to intensify land use on already cleared areas. By generating more income and employment from intensively managed cropping systems, farmers will have less need to clear more land or migrate to urban areas in search of a livelihood.




Data Source: Toniolo and Uhl, 1996.

In a farming community near Paragominas (see Figure 1), intensive land uses such as vegetable and perennial crop production generate much more income and employment per unit area than extensive land uses such as shifting cultivation and cattle ranching. Vegetable production occupies only 0.1% of the land area but accounts for nearly three quarters of the net value of agricultural production, and it generates over 20 times as much employment per hectare and over three times as much net income as the next most intensive land use - perennial crops. Perennial crops cover 19% of the area but generate 21% of agricultural earnings. Shifting cultivation occupies 38% of the land area, when fallow vegetation is included, but contributes only 3% of the value of total agricultural production. In the case of cattle ranching, the respective figures are 41% and 1%.

This example graphically illustrates the value of perennial crops and the potential value of agroforestry systems in taking pressure off the remaining forest area for agricultural production. Where markets are available, perennial crop agroforestry systems can provide an option for farm families to maintain a good standard of living on a much smaller area than would be required by more extensive production systems.

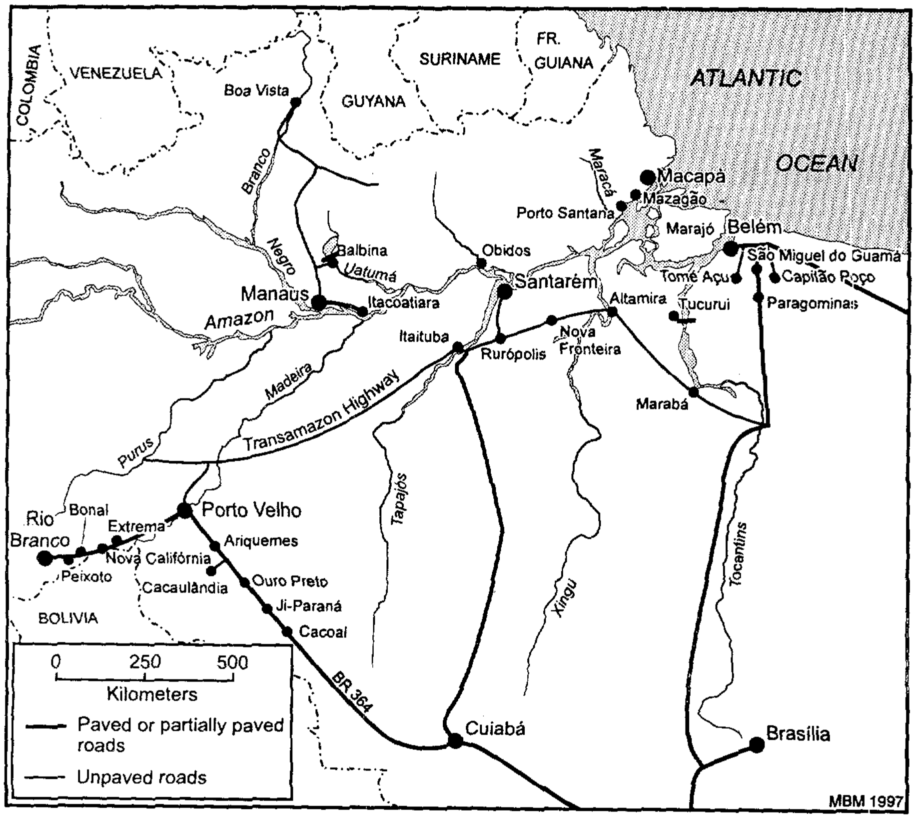



Figure 1. Partial map of the Brazilian Amazon showing locales visited as part of this study.

Agroforestry is particularly appropriate for rehabilitating degraded areas because it has the potential to check soil erosion, improve soil structure, and protect watersheds of managed areas (Sanchez, 1995; Pimentel et al., 1992). In severely degraded areas, agroforestry can increase soil moisture by alleviating compaction and allowing better infiltration of rainwater.

In addition to addressing some of the concerns associated with environmental conservation, agroforestry is particularly well suited to small farms and has the potential to help raise living standards for many rural inhabitants. It can be seen as a risk avoidance strategy that diversifies sources of income for farmers (Nair, 1990). Furthermore, agroforestry systems can be tailored to a wide range of ecological and socioeconomic conditions (Nair, 1990, 1991).

The purpose of this report is not to document the many perceived virtues of agroforestry, nor to describe in detail the many different configurations that are being tested by farmers throughout the Amazon basin. The literature is replete with examples of how agroforestry has helped improve the livelihoods of farmers and conserve natural resources compared to other prevailing land uses (e.g., Nair, 1991; Walker et al., 1994a,b). Rather, the main focus is to ascertain the constraints operating on agroforestry in the Brazilian Amazon, and to identify opportunities for overcoming them.

***B. A Typology of Agroforestry Systems in Amazonia***

Agroforestry involves the growing together of perennial crops with annual crops and/or animals. In some definitions, an annual food crop is a "required" component in order for the land use system to be classified as agroforestry (Bandy, 1994). Although annual food crops are generally not an important component of commercial agroforestry systems in the Brazilian Amazon, they play a significant role in launching such systems. When rice, maize, or manioc is planted or nearing maturity, growers will sometimes interplant such perennials as orange, cupuaçu,[2] or peach palm. In such cases, swidden agriculture is transformed into agroforestry, and annual food crops thus help underwrite the cost of establishing perennial cropping systems. All agroforestry systems in the Amazon are highly dynamic, especially in the early years of their establishment when species turnover is relatively rapid (Smith et al. 1996), which makes agroforestry classification more difficult still.

Attempts at classifying the broad range of agroforestry practices sometimes fail to capture nuances because they represent "freeze-frames." Various agroforestry typologies have been proposed, some fine-grained with numerous sub-systems, others relatively simple but with a somewhat awkward terminology for non-specialists (Johnson and Nair, 1985; Nair, 1990; Nair and Dagar, 1985). Three main types of agroforestry systems are generally recognized in the specialist literature: agrosilvicultural, agrosilvopastoral, and silvopastoral (Nair, 1991). Agrosilvicultural systems include planted trees with seasonal crops, silvopastoral systems typically involve pasture with tree crops, and agrosilvopastoral configurations encompass perennial and annual crops associated with animal production (Bandy, 1994).

While each classification system has its merits and flaws, a different typology is used here: traditional agroforestry and commercial agroforestry. Both of these types are actually part of a continuum. Traditional agroforestry is characterized by relatively low labor and material inputs, high species and genetic diversity, reliance on natural forest regeneration, and a high proportion of products used for subsistence purposes. In contrast, high labor and material inputs, low species and genetic diversity, minimal incorporation of natural forest regeneration, and a high proportion of products that are sold in markets characterize commercial agroforestry. Although many cases can be cited that combine characteristics of both types, the historic development of agroforestry in the Amazon region appears to be moving gradually from a traditional to a commercial basis. A brief description of each type is provided below:

*Traditional Agroforestry*

Agroforestry is an ancient practice in Amazonia. Many indigenous peoples plant a mixture of tree and annual crops in their fields, and traditional, small-scale farmers (sometimes referred to as *ribeirinhos* or *caboclos*) usually maintain a rich assortment of tree, bush, and herbaceous plants in their home gardens. In some definitions, swidden fallows - that highly variable period between the end of one cropping cycle and the clearing of secondary forest for the next cycle in slash-and-burn farming - are considered a form of agroforestry, even if the regrowth is entirely spontaneous (REBRAF, 1996). While there is merit to this definition because trees are frequently utilized in late fallow stages, it is not adopted here. The main reason is that agroforestry is often touted as an "answer" to swidden systems that are no longer holding up in the face of population pressure, as is the case in several areas of eastern Amazonia such as the Bragantina zone east of Belém (Toniolo and Uhl, 1996).

Traditional agroforestry encompasses three main land uses: forest enrichment, managed fallows between periods of cultivation with short-cycle crops, and home gardens. *Forest enrichment* is often seen as the most "desirable" form of traditional agroforestry because, in theory, forest disturbance is minimal. Under this system, crops, usually perennials, are introduced in light gaps in the forest. The gaps can be either natural (i.e., caused by tree falls) or human-induced, and enrichment planting generally works better in secondary growth where light is more generous. In practice, few contemporary examples of forest enrichment can be identified in the Amazon. Although Brazil nut-enriched forests may occupy up to six million hectares in the Amazon basin (Balée, 1989), enriching forests with Brazil nut is rarely practiced today. Some indigenous groups have enriched the forest around their villages and camps with useful trees, especially those producing fruits and nuts (Balée, 1989; Balée and Gély, 1989; Smith, 1995). In some cases, "enriched" forests exploited by rural folk in the

Amazon today are in fact "managed" fallows: i.e. areas that have been completely deforested, farmed, and then reconstituted using perennial species of subsistence and commercial value. Regardless of their origin, enriched forests provide highly variable economic returns: documented cases range from US$ 23 to US$ 6,660 per hectare per year (Peters et al., 1989). In certain areas of the Amazon basin, harvesting from enriched forests apparently cannot compete with other land uses.[4] In other areas, however, it still persists as an economically viable land use.[5]

*Managed fallows* can be found in various parts of the Amazon basin, including Peru, where umarí and Brazil nut are often important components of such systems in their mature stages (Denevan and Padoch, 1987; Padoch and de Jong, 1995), and in Colombia (Hammond et al., 1995). Both small producers and indigenous groups often manage fallows, but such systems are generally not linked strongly to markets. One exception are flood plain forests in the Amazon estuary, where seeding and enrichment planting following slash-and-burn farming generate high densities of the economically important açaí palm adjacent to human settlements. While this system has many of the attributes of traditional agroforestry (i.e. low labor and material inputs and high incorporation of natural forest regeneration), it is also strongly oriented to local markets. Furthermore, it provides a major source of income for flood plain inhabitants near the major port of Belém (Anderson, 1988, 1990; Anderson and Ioris, 1992; Peters et al., 1989). In the Peruvian Amazon near Iquitos, similar transitional systems involving fallow management generate a wide variety of fruits, nuts, and other products, and they also provide significant sources of income for flood plain residents (Denevan and Padoch, 1987; Hiraoka, 1989; Padoch, 1988; Padoch et al. 1985).

*Home gardens* are another traditional form of agroforestry. Rural people throughout the Amazon, both in upland and flood plain areas, typically cultivate a wide assortment of perennial and herbaceous plants around their houses (Leeuwen and Gomes, 1995). Home gardens are often impressive reservoirs of agrobiodiversity - that portion of biodiversity used in agricultural production - but their potential is still largely untapped. Some home gardens contain dozens of trees or shrub species, and an equal number of cultivated herbs and grasses. Even in urban areas they can be quite complex, providing significant sources of subsistence and income. Home gardens are an underutilized source of promising new plants for commercial production because farmers often test exotic plants in their home gardens before risking a larger investment by planting them in fields (Dubois, 1996; Saragoussi et al., 1990; Smith, 1996). Furthermore, home gardens are active arenas of plant domestication. Men and women recruit wild plants from nearby forests to grow them near their houses for a wide variety of purposes, ranging from fish baits to livestock feed. Future options for farmers in Amazonia are thus intricately linked to the maintenance of forest ecosystems.

*Commercial Agroforestry*

Commercial agroforestry in plots away from home gardens is the main focus of this study because it can play an especially important role in slowing deforestation and improving rural livelihoods. While highly variable, most commercial polycultural plots contain from two to six tree or shrub species (Figure 2a-b). Species diversity is usually lower than home gardens, as market forces streamline the number of commercially viable candidates with which the farmer can work. Agroforestry plots generally range from 0.5 to 10 hectares, with a typical size of one to three hectares. In contrast to traditional agroforestry, commercially oriented systems generally require considerable inputs of labor and materials, and incorporation of natural regeneration is much less common.

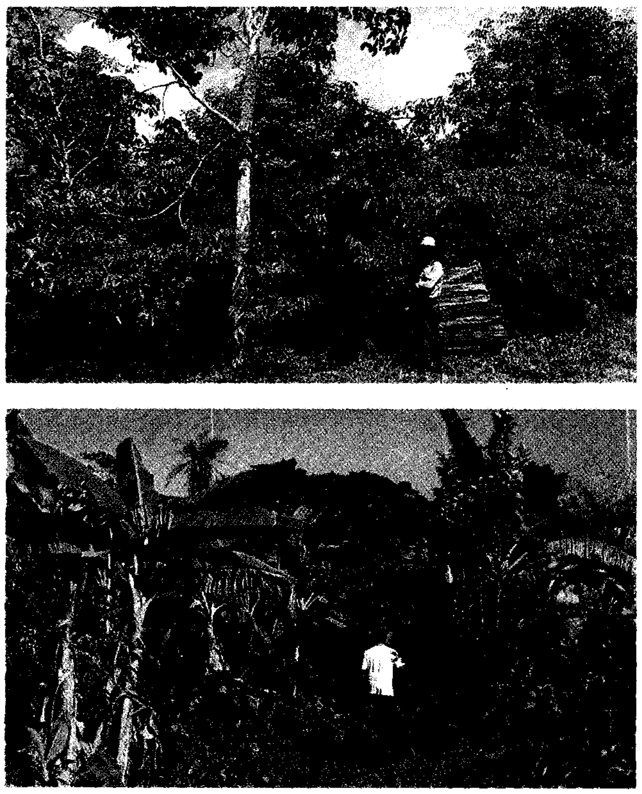


Figure 2. Commercial agroforestry systems in the Brazilian Amazon. A: Spontaneous timber trees (freijó) growing in robusta coffee plantation near Nova Londrina, Rondônia. B: A 2-hectare agroforestry field containing plantations of banana, orange, Barbados cherry, papaya, sweetsop, cashew, and yellow mombim, in Aninduba, Pará. Photographs by N. J. H. Smith.

Within the last two decades or so, commercial polycultural systems have emerged in various parts of the Amazon. Tomé-Açu in Pará, settled by Japanese immigrants in the late 1920s and early 1930s, became an innovative pole for agroforestry systems geared to markets starting in the 1970s. Agroforestry is the most recent manifestation of a history of evolving land uses at Tomé-Açu. Japanese settlers first tried upland rice farming, but with limited success. Large-scale vegetable production, a specialty of Japanese immigrants and their descendants in Brazil, was not feasible because of access problems to the main market in Belém. In the 1950s, farmers at Tomé-Açu began experimenting with black pepper, which found ready markets in Brazil and internationally. Cultivated as a monocrop, black pepper became a bonanza, but eventually it succumbed to Fusarium wilt. The ravages of this disease forced the Japanese-Brazilian farmers to diversify their farming operations toward agroforestry, with a wide assortment of fruit and timber trees, including cacao, cupuaçu, passion fruit, rubber, African oil palm, citrus, cedar, freijó, and paricá (Subler and Uhl, 1990).

The experience of agroforestry farmers at Tomé-Açu reflects how farmers change crop configurations in accordance with shifting market conditions (Figure 3). Black pepper once accounted for virtually all of the value of crop production, but by 1992 the crop accounted for only about one fifth of the total value of agricultural production in the Tomé-Açu area. Papaya came on the scene as a commercial option in the late 1970s, but within a few years its importance had plummeted, the victim of disease build-up, particularly from ringspot virus, and competition from other producers, especially in the Northeast of Brazil. Whereas in the past farmers in the vicinity of Tomé-Açu relied on monocropping for the bulk of their income, now many of them grow a greater mix of crops in agroforestry systems.

It might be argued that the experience of farmers at Tomé-Açu is unique and cannot be replicated. The legacy of black pepper generated significant wealth, enabling farmers to experiment with alternative crops when the need arose. In addition to capital generated by Japanese-Brazilians traveling to Japan for short-term employment, the government of Japan has subsidized the cooperative at Tomé-Açu. Furthermore, the distinctive cultural background of the colony made it unusually cohesive, and the educational level of the Japanese-Brazilian population is higher than the regional average for rural areas. Yet field excursions in the vicinity of Tomé-Açu reveal that farmers of non-Japanese descent have also adopted a diverse array of agroforestry systems in plots planted with black pepper. The incomes of the latter do not appear to be as high as the Japanese-Brazilian farms, possibly due to less efficient organization for marketing, but the trend toward diversification is similar. A preliminary conclusion based on the Tomé-Açu experience is that it is critical to find at least one crop in a system that generates significant income to sustain experimentation with various configurations and tide the farmer over until other, longer-maturing crops start to produce.

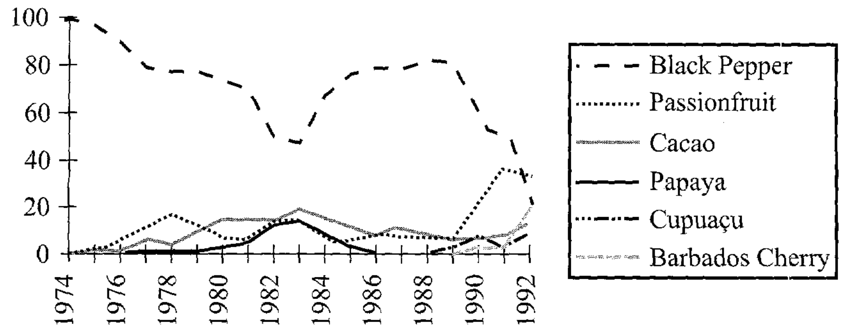



Figure 3. Changes in the importance of crops as a function of their contribution to the total value of agricultural production of CAMTA - the Mixed Agricultural Cooperative of Tomé-Açu. Data source: Homma et al., 1994.

Although the experience at Tomé-Açu is in many ways unique, farmers in both upland and flood plain areas of the Amazon are experimenting with a rich array of perennial crops and crop combinations, mostly on their own initiative. A total of 111 different agroforestry configurations were noted in a survey of 142 polycultural fields in the Brazilian Amazon, mostly in the 1 to 10 hectare range (Smith et al., 1995a). These findings reveal some promising avenues for the further development of agroforestry in Amazonia. And they also reveal that the Amazon is a patchwork of ecological systems and economic opportunities. A "typical" farm does not exist; it is an artifact. The task is to recognize patterns, understand their inter-relationships, and identify elements that are generalizable across an array of experiences.

***C. Agroforestry in a Land Use Perspective***

Despite its purported environmental and socioeconomic advantages, agroforestry accounts for a minuscule proportion of the land use in the Brazilian Amazon. Cattle pastures and secondary growth account for most of the cleared areas in the region (Fearnside, 1990). Many of the cattle pastures are degraded by weed invasion; in the case of Rondônia state, for example, degraded pastures cover about 5.4 million hectares, whereas the area devoted to coffee and cacao production does not exceed 133,000 hectares and 36,000 hectares, respectively (PLANAFLORO, 1995). Since the late 1980s, coffee and cacao have been losing ground to cattle pasture in Rondônia and other parts of the Brazilian Amazon.

At present, agroforestry is virtually absent on ranches, even as living fences, mainly because of the frequent use of fire to keep weeds in check and to encourage grass growth. However, new generation pasture grasses, such as brachiarão, are apparently more susceptible to damage by fire than "first cycle" grasses, such as guinea grass, and some ranchers are reducing or eliminating the use of fire to control weeds. Furthermore, cattle prices are at an especially low ebb in the Brazilian Amazon, with "farmgate" prices in 1996 ranging from US$0.60 to 0.75/kg liveweight, down from US$1.30/kg in 1993.[6] As a result, now might be a propitious time to explore ways of encouraging ranchers to diversify their operations by planting tree crops.

At present, however, innovative combinations of pasture and tree crops are largely confined to smallholders rather than large-scale ranchers. One farmer in the community of Murumuru in the Municipality of Santarém, for example, has planted yellow mombim trees to support a fence around his small pasture that contains five cattle. Yellow mombim, known locally as taperebá and as cajá in other parts of tropical Brazil, sprouts readily from cuttings and produces a much-appreciated fruit. In Rondônia and near Tomé-Açu, some farmers graze livestock in rubber plots. And in other parts of Pará, smallholders have fenced off pasture and allowed fruit trees to become established before allowing cattle to graze again.[7] Opportunities to promote agroforestry on small-scale ranches thus appear to be improving.

Yet agroforestry still accounts for a small fraction of the cultivated land in the region. Cultivation of traditional food crops such as manioc, rice, maize, and beans - together with the forest fallows on which such cropping systems depend - occupy a far greater area than either monocropping with perennials or agroforestry.[8] This reflects the fact that a large proportion of farmers still rely primarily on slash-and-burn agriculture for subsistence and income generation. Agroforestry and intensive vegetable production, the latter concentrated mostly near sizable urban centers, occupy last place in terms of the planted area in the region (see Box 1).

In short, agroforestry is still only a minor component of the varied tapestry of land uses in Amazonia. A clearer understanding of the constraints to agroforestry adoption and how those constraints can and have been overcome might help achieve a better balance of land use systems in both pioneer zones and older settlements. This understanding can then provide a basis for proposing policy changes aimed at promoting agroforestry.

After outlining the objectives, conceptual framework, and methodology, this study presents an analysis of the major constraints to wider adoption of agroforestry in the Brazilian Amazon. Based on this analysis, the study explores options for a better balance of land use systems in the Amazon. Progress in agricultural development in the region will come from a better integration of land uses involving a mosaic of managed and protected habitats, rather than homogenous cultural landscapes.

### *D. Objectives and Conceptual Framework*

The purpose of this study is to identify the constraints holding back a fuller deployment of agroforestry systems in Amazonia, and to identify opportunities for overcoming them. By highlighting specific case studies throughout the region, the study reveals important lessons learned that, if applied more generally, can help overcome some of the constraints to agroforestry and achieve a better balance of land use systems in both upland and flood plain areas.

No attempt is made here to produce a blueprint of agroforestry configurations to be applied across the Amazon. Given the highly heterogeneous nature of cultural experiences, soils, climatic conditions, and distances to markets, such an approach would certainly fail. Farmers are adept at designing a wide variety of configurations to suit their particular needs. Nor does this study attempt to identify "winners" in the crop sweepstakes that characterizes agroforestry in Amazonia and many other regions. Today's "hot" crop can be tomorrow's disappointment. Conversely, a "minor" crop today can rapidly emerge as a major income earner for thousands of farmers.

The experience of Tomé-Açu and other parts of Amazonia underlines the importance of maintaining a flexible approach to promoting agroforestry. Farmers should be free to pick from a range of crops to suit their particular needs (Leeuwen, 1994). Such an approach is more likely to succeed than a complete "package" devised by scientists and then handed over to extension agents for delivery to farmers.

## II. Methodological Approach

Three main groups of farmers were sampled for this study: farmers who have adopted agroforestry practices as a result of a formal, externally instigated project; farmers who have adopted agroforestry spontaneously; and non-adopters. Cases where farmers who have established commercial agroforestry on their own initiative are particularly interesting because these experiences may point to low-cost options for successful extension. The main focus is on small farmers both in relatively recent colonization zones as well as areas that have been farmed for decades or even a century or more. As cattle ranching is a major driving force for deforestation in the region, some medium and large-scale cattle ranchers were canvassed for their views on the potential for combining livestock production with agroforestry.

This study synthesizes information obtained from three main sources: field surveys conducted during May-July 1996; previous field experiences of two of the authors (Dubois and Smith) in the Amazon; and a review of the literature. Major emphasis is placed on field surveys because of the paucity of reliable data. Field surveys entailed visits to farmers' lots and interviews with individuals and organizations involved in agricultural development and extension. Information on the adoption or non-adoption of agroforestry was obtained in the field through the use of a questionnaire and open-ended interviews.

### *A. Field Survey Sites*

The farming areas surveyed for this study encompass both upland and flood plain environments at diverse locations in Amapá, Pará, Amazonas, Rondônia, and Acre (see

Figure 1). A wide range of sites were visited, with variations in soil quality, time of settlement, and access to markets.

***B. Data Gathering***

A questionnaire was applied to 53 farmers visited in 10 communities in Acre, Rondônia, Pará and Amapá. The questionnaire was designed to help tease out the technical, social, and financial constraints on agroforestry adoption as well as identify those factors that promote the interplanting of tree crops in fields and home gardens. In addition, open-ended interviews were conducted with approximately 200 farmers.

## III. Constraints to Agroforestry

If agroforestry is deemed a "desirable" land use system for Amazonia, policy makers need to understand the principal constraints to its wider adoption and be aware of opportunities to overcome those constraints. For organizational convenience, constraints and opportunities are grouped into two main categories: socioeconomic and political aspects, and technical considerations related to research capacity and technology delivery systems. It is recognized, however, that these are not hard-and-fast groupings, and that issues often overlap.

Overall, socioeconomic factors are the main constraints to the diffusion of commercial agroforestry systems in the region. Inadequate market information, weak farmers' associations, and poor agroindustrial infrastructure are major "brakes" holding back the further development of agroforestry. No magic wand is available to suddenly change the picture. For example, credit to set up agroindustrial plants alone will not provide a lasting solution to farmers involved with perennial crops. As with any other type of agricultural development, a variety of supporting factors - from the right fiscal environment to an agile research system geared to work on emerging problems - is needed to promote agroforestry. It is not an easy task to get all the pieces working together harmoniously; if one element is out of sync, it can undercut progress in other areas (Table 1). For example, some farmers in agroforestry projects are obtaining impressive harvests, but facilities are inadequate or non-existent for processing the fruits. In other cases, processing plants are operational, but unreliable supplies, variable fruit quality, and equipment maintenance problems inhibit their full potential.

***A. Socioeconomic and Political Constraints***

A wide array of socioeconomic factors constrain agroforestry production in Amazonia. The key factors identified in this study are:

- markets,
- agroindustrial development,
- community organization at the local level,
- credit,

• the regulatory and fiscal environment, and
• land tenure.

Table 1. Inter-connected steps for successful agroforestry development.

| Step | Needs |
|---|---|
| Land preparation and planting | Good quality planting material<br>Technical assistance<br>Agile and timely credit |
| Crop management | Technical assistance<br>Pest control technologies<br>Soil improvements/corrections |
| Harvest | Adequate labor supply<br>Post-harvest technologies |
| Processing | Processing facilities to add value<br>Reliable energy<br>Technical assistance<br>Managerial skills<br>Credit to establish/update processing facilities |
| Marketing | Good transport<br>Access to information on market conditions<br>Promotion and advertising |

*Markets*

*Market Information.* When and how market information is transmitted to farmers affects decisions on the mix of crops that they deploy. Farmers obtain market information mostly through the private sector rather than via state-run agricultural extension services. Over 80 perennial species are cultivated in agroforestry systems across the Amazon basin (Smith et al., 1995a, 1996; see Figure 4 a-d); products from several dozen of these find their way periodically into local or regional markets, but only a handful reach national or international markets. This picture is likely to change, however, as some of the timber trees present in agroforestry systems mature and are harvested. Close to two dozen timber species are currently encountered in agroforestry systems in the Brazilian Amazon, with cedar, freijó, ipê, itaúba, and mahogany among the most valuable for long-term investments. Farmers are fortunate to have a generous basket of crops to chose from when designing agroforestry configurations.

While genetic resources are diverse, market information is frequently scarce for present or potential agroforestry practitioners in Amazonia. The issue is not what will grow well, but who is willing to buy the product at a price and in sufficient quantities to make it a worthwhile proposition. In Amazonia, local projects and growers' associations generally do not have experience marketing processed products except through intermediaries. The RECA project in eastern Acre illustrates some of the problems

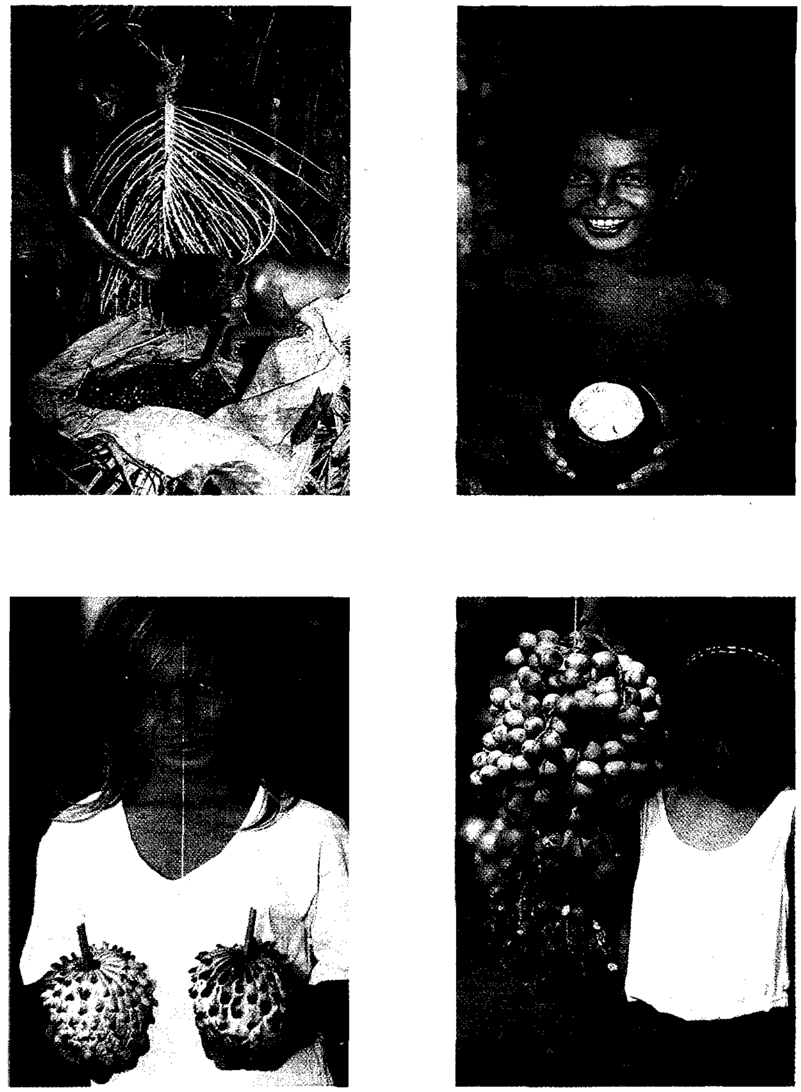


Figure 4. A sampling of fruits harvested from agroforestry systems in the Brazilian Amazon. A (top left): açaí palm fruits harvested near Santarém, Pará; B (top right): boy with cupuaçu fruit, near Rurópolis, Pará; C (bottom left): girl with biribá fruit, near Macapá, Amapá; and D (bottom right): girl with peach palm fruits near Macapá, Amapá. Photographs by N. J. H. Smith.

generated by lack of information on markets for agroforestry products in Amazonia (Box 2).

The rural extension agency (EMATER) in Rondônia has started a program of price monitoring on a weekly basis. Local agencies in the state collect information on the prices paid to farmers for their produce and also the prices farmers pay for agricultural inputs. In addition to price monitoring, EMATER's commercial division is linked to the commodities market in São Paulo, which allows it to offer commodities for sale on that market. Unfortunately, extension agents in some EMATER offices have dutifully sent in data on agricultural prices to headquarters but received no collated information in return. This relatively new effort could assist agroforestry development in Rondônia if the information were disseminated more efficiently to extension agents and farmers.

Some "green" markets may help alleviate marketing problems for growers adopting agroforestry systems in Amazonia. A Belém-based NGO, POEMA (Poverty and Environment in Amazonia), has been able to sell headrest cushions made from coconut fiber and rubber to the Daimler-Benz company of Germany, which uses them in automobile production. Although these types of markets may be limited, they provide income generating opportunities.

In many cases projects, organized groups, and government agencies promoting new agroforestry systems simply assume there will be a market for whatever they produce and are disappointed when that market does not materialize. This is not a problem specific to the Brazilian Amazon and is characteristic of many development efforts around the world. More emphasis needs to be put on ensuring that markets will be available for agroforestry products, at prices that are attractive to farmers.

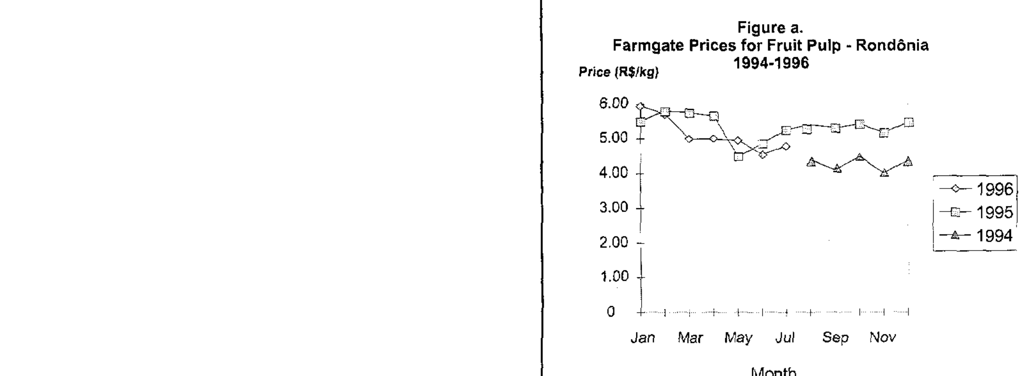
*Production, Prices, and Market Trends.* Perennial agroforestry crops tend to have relatively long gestation periods, so farmers are less able to calibrate production to sudden changes in the marketplace than with annual crops. Significant "overshooting" can thus occur, thereby triggering substantial losses to late adopters and high cost producers. Passionfruit and Barbados cherry are examples of "overshooting" in the Amazon. Frozen passionfruit juice prices declined dramatically in the mid-1990s, thereby imperiling AMAFRUTAS, a large agroindustrial plant near Belém that had worked exclusively with passionfruit since the early 1980s. Barbados cherry production rose steeply in the Brazilian Amazon during the early 1990s, especially in the vicinity of Tomé-Açu (Figure 3). By the mid-1990s, however, markets in Amazonia had become saturated with the fruit, and prices have fallen accordingly. Although some farmers are still making money with Barbados cherry, planting rates have slackened. Cupuaçu appeared to be following the route of passionfruit and Barbados cherry. In 1990, frozen cupuaçu pulp was being imported to the United States at US$9.90/kg FOB, but by 1995 the FOB price had dipped to US$2.20-3.30/kg.[9] Yet cupuaçu production in the Brazilian Amazon continues to increase, mainly because new national

## Box 2. Marketing cupuaçu pulp in Rondônia and Acre: The case of RECA

The RECA project near the border between Acre and Rondônia illustrates some of the problems and opportunities when marketing perishable products from agroforestry systems. While the production of fruits from agroforestry systems offers opportunities to generate income for farmers, processing, storage, and marketing are often major constraints. The RECA project promoted the cultivation of cupuaçu in the late 1980s and has served as the impetus for increased production of this fruit in Acre. Cupuaçu is presently used widely in the Brazilian Amazon for fruit juice, preserves, and ice cream flavoring. RECA's cupuaçu plantings came into production in the mid-1990s, and in order to deal with the problem of perishability the project processes the fruit into a pulp that is frozen for storage and eventual sale.

After the harvest season of 1996 (roughly March through May), RECA had to store 62 tons of pulp in Rio Branco and Porto Velho, for which the cooperative paid US$3,000 every 2 weeks, because no buyers were located. The increase in the price of cupuaçu pulp in the off-season would likely be enough to offset storage costs (Figure a). At the same time, the price of cupuaçu in supermarkets in Porto Velho is roughly twice that of other fruit pulps (Figure b), suggesting appreciable demand for the pulp but possibly a poor link between the market and the RECA project.

RECA stored the fruit pulp out of necessity rather than as a marketing strategy, and it runs the risk of losing the pulp if power goes out in the government warehouse. Part of the problem and a major constraint to sales has been a delay in obtaining registration with the Ministries of Health and Agriculture, which is required to sell food products to supermarkets.



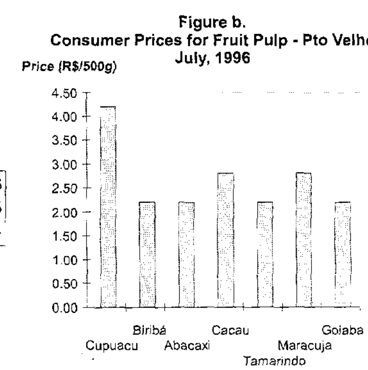




Fig. a: Monthly prices paid to producers in Rondônia; Fig. b: Cost of purchasing frozen cupuaçu pulp in supermarkets in Porto Velho. Source: EMATER.

markets are constantly emerging for this popular product, particularly in central and southern Brazil, and thus far no other region has emerged as a major producer. While local overshoots may occur, the Brazil's fast-growing urban population seems likely to "pull" cupuaçu production.

Domestic and international markets are so strong for logs, sawnwood, and furniture, that "overshooting" with new timber species is unlikely to be a problem. Markets for logs, sawnwood, and furniture thus tend to be more stable than for fruits, frozen pulp, and nuts. According to World Bank commodity forecasts, timber prices are expected to increase significantly more than other commodities during the next ten years. This market trend augurs favorably for farmers who have timber species as components of their agroforestry systems. Also, restrictions on destructive logging of forests might favor producers who plant timber trees, particularly if logging bans and other regulations are enforced more effectively.

Timber extraction has emerged as a major economic activity in Amazonia during the last two decades, particularly since pioneer highways sliced across extensive tracts of forest. Numerous sawmills are operating in the region, and farmers have little difficulty in selling timber from forests on their lots. As the forest retreats, or is increasingly "creamed" of high-value timber, the value of such species planted in agroforestry systems is sure to increase. The fact that the Federal government limited the export of mahogany for a two-year period starting in 1996 has alerted growers that the time is coming when plantations may be the only way to legally exploit this valuable timber species. Attack by the shoot borer, *Hypsipyla grandella* - a ubiquitous moth larva that tunnels into apical shoots - has effectively prevented establishment of monocultures of mahogany in the Amazon. In a collaborative agroforestry project involving EMBRAPA's center in Manaus (CPAA) and Cornell University (see section III-B below), scientists found that mahogany surrounded by paricá and ingá develops commercial length boles (>7 m) with little or no attack, suggesting that some agroforestry combinations may permit commercial production of mahogany in Amazonia.[10]

Our survey revealed that a substantial proportion of farmers are incorporating timber species in their agroforestry systems.[11] Timber species are increasingly found in such systems either because they are deliberately planted or because spontaneous seedlings are spared while weeding. This trend is widespread but is particularly noticeable among cacao and coffee growers in Rondônia and along the Transamazon Highway between Altamira and Rurópolis in Pará. Flood plain farmers are also increasingly aware of the value of spontaneous timber species in their agroforestry fields, such as along the Maracá river in Amapá and near Urucurituba on the middle Amazon flood plain. Farmers are planting or encouraging two types of timber species - quick-growing "softwoods" to be used in plywood, and hardwoods with high market value. In the former category, three species are commonly being planted or protected: paricá, pinho cuiabano, and the kapok tree. Paricá (also known as bandarra) and pinho cuiabano are both planted and allowed to regenerate spontaneously in fields; they can be harvested within about ten to twelve years. Kapok is spontaneous on flood plains and fertile soils of the uplands, particularly alfisols (terra roxa). Precious hardwoods, such as ipê, mahogany, cedar, and freijó, are also being planted or protected if they regenerate spontaneously, but farmers will have to wait thirty to forty years before these species are ready for market.

The increasing demand for tropical hardwoods has exacerbated degradation of tropical forests in some regions, including Amazonia. But it has also created an incentive for forest conservation on smallholdings. A number of farmers interviewed during this study remarked that they are saving tracts of forest on their properties because the forest is a source of seed for spontaneous regeneration of timber species in fields. Also, several farmers in Rondônia remarked that commercial firms are increasingly visiting their farms in search of seeds of timber species. In such cases, farmers have spared trees in their forest tracts from the chain saws of logging crews.

A major issue involving timber production in silvicultural regimes concerns the quality and reliability of the seed stock. Mahogany seeds, for example, are typically harvested by cutting down the tree. Since the biggest trees are highly prized both for their hardwood and their seeds, this practice leads to progressive genetic erosion, which could eventually undermine commercial plantations in the absence of adequate conservation measures (Browder et al. 1996). Indeed, shortages of mahogany seeds have been reported at various locations in Amazonia, probably reflecting both increasing scarcity and growing demand for planting material among farmers and companies.[12]

Regardless of whether they generate timber or non-timber products, perennial crops have a number of strategic advantages over annual food crops. Farmers who plant perennials not only benefit from staggered production but are less susceptible to harvesting bottlenecks and problems with accessibility to drying machines that affect farmers who opt for rice production. An extensive survey of land use activities along the Transamazon and Santarém-Rurópolis highways in Pará found that farmers who had adopted agroforestry were better off financially than those who relied primarily on traditional subsistence crops (Walker et al., 1994a,b).

*Transportation.* Access to markets is a major limiting factor for agricultural production in the Amazon. Road transportation costs are high in most areas of the region, in part because few roads are asphalted, and maintenance of those that have a hard surface is typically sporadic. The cultivation of products that are highly perishable or have a low value per unit weight is thus generally unattractive in the region, unless the growers are close to major urban centers or near rivers. As a result, transportation is a major limiting factor for many of the highly perishable fruits that could potentially be produced in the region.

Difficulties with transportation help explain why citrus, black pepper, and coffee are among the most common components in agroforestry systems. Citrus fruits are relatively tolerant of mild abuse during travel, while black pepper and coffee beans have a high value per unit weight and are not damaged by rough roads. An emerging "hot" agroforestry crop is coconut, which finds a ready market in urban centers where it is sold primarily as a chilled drink. Coconuts can take considerable abuse and delays during transportation without appreciably affecting their quality. Farmers at Terra Caída on the Madeira River near Porto Velho, for example, sell some 80,000 green coconuts a month during the main harvest season; at US$0.40 each, the crop provides an appreciable income for local residents.

Although the Amazon is closer to consumer markets in the United States and Europe, the region is still at a disadvantage for the production of tropical fruit juices and frozen pulp compared to other regions of Brazil. Shipping companies charge US$230/ton to transport frozen fruit pulp from Belém to the United States, about twice the cost of sea freight from Rio de Janeiro, which is several thousand kilometers further away. The much greater frequency of ship departures from Rio probably accounts for the wide discrepancy in freight charges.

In theory, agroforestry farmers along rivers should benefit from cheaper water transportation. In general, however, commercial agroforestry is poorly developed along rivers. In part, this may be explained by the fact that most "development" efforts related to agriculture during the last three decades in the Brazilian Amazon have focused on upland areas where infrastructure and technical assistance is, or at least has been, better developed. Brazil's agency for cacao research (CEPLAC), for example, has virtually ignored the potential of cacao production on the Amazon flood plain, despite the fact that historically most cacao production in the region has come from riverine environments, especially the middle and lower Amazon. Another factor may be the relatively cheap freight rates charged by trucks returning from major Amazonian cities to southern Brazil. Because the trucks often return nearly empty, transport firms are willing to take on cargo at a nominal cost. The Fruit-Ron factory near Ji-Paraná in Rondônia expects to take advantage of this opportunity (known as back hauling) when sending frozen fruit pulp to southern markets.

*Agroindustrial Development*

Although several large and small agroindustries have been established in the Brazilian Amazon to process fruits, a number of constraints have prevented expansion of their activities or have led to plant closings in several cases. Among the most common constraints is unreliable electricity.

Rural electrification is either non-existent or precarious, leading to blackouts and, in some cases, deterioration of pulp in cold storage. Back-up generators, if available, are expensive to operate. Relatively few farmers are connected to any electrical grid and, not surprisingly, electricity was cited as the single-most important item needed to improve life on the farm among 53 farmers sampled with the questionnaire.

In Altamira, a city of some 65,000 inhabitants on the banks of the Xingu River, electricity is usually only available for 18 - and sometimes as little as 12 - hours per day. Blackouts occur on a rotational basis around the clock, and can adversely affect many businesses, such as the bottling plant for Guaraná Xingu and the fruit processing plant operated by DICACAU. Guaraná Xingu has its own diesel-powered generator, but costs rise when it has to be turned on. DICACAU, which maintains up to 500 tons of pulp from a dozen fruits in its two cold storage units in Altamira, also experiences increased costs when it has to operate its back-up generator.

Alternative energy sources may soon become cost-effective, thereby reducing dependence on conventional hydroelectric power and diesel generators. Conventional hydroelectrical power is unlikely to solve Amazonia's energy problems; the hydroelectric dams currently operating have flooded substantial areas of forest while generating relatively little energy. The Balbina dam (Figure 1) does not meet the energy needs of Manaus, and the Curuá-Una dam near Santarém only provides sufficient electricity during the rainy season. The Tucurui dam on the Tocantins River only benefits parts of eastern and southern Pará; the cost of extending power lines to other parts of Pará, such as Altamira, is high, hence the delay in reaching other consumers with power. Submerged turbines, on the other hand, do not require the impounding of water and would be suitable for agroindustries near rivers. Liquid natural gas from the Juruá watershed might also provide a stopgap until photovoltaic systems become more efficient and cost effective in the next century.

In cases where it may not be feasible to develop alternative energy supplies or upgrade the existing electricity grid, asceptic packaging may be an option.[13] This technology permits processing and packaging of many agroforestry products so that they will not require refrigerated storage. Asceptic packaging enables fruits to retain more of their natural color and taste than is possible in conventional cooking and canning operations, and it is more hygienic than uncooked frozen fruit pulps. Small-scale and highly mobile asceptic packaging plants are now available and can be placed on tractor trailers or barges, thus bringing the factory to the forest. This mobility reduces waste and spoilage, and it could potentially establish new links between rural communities and markets throughout Amazonia. At present, however, asceptic packaging has been implemented on a limited scale in the region.

Variable product quality is a key constraint to marketing agroforestry products from the Amazon region. For the most part, standards of cleanliness in fruit-processing plants leave much to be desired, a particularly critical defect for the export market. Few agroindustries can afford to set up in-house laboratories for continual monitoring of product quality. Fruit-Ron in Ji-Paraná, Rondônia, which began operations in September 1996, is an exception. Fruit-Ron is one of the largest fruit pulp processing plants in Amazonia, with an annual capacity of 15,000 tons of pulp; it is currently exporting frozen fruit pulp, mainly of Barbados cherry, to Germany, Puerto Rico, and the United States via the port of Santos in São Paulo. The plant is considering investing in a fruit pulp concentrator in order to tap further the international trade in fruit juices. Because of its sizable investment and impressive facilities, Fruit-Ron is better placed to ensure quality control than most smaller operators in Amazonia.

Product quality applies to preserves as well as frozen pulp or juice. One small manufacturer of cupuaçu compote *(doce de cupuaçu)* in Santarém had to shut down when consumers in Belém complained that the sugary product was covered with mold when they tore off the aluminum foil lid. The manufacturer in question has been forced to lay off most of the workers until the problem is corrected. Because the operation is so small, the three owners of the plant cannot afford to hire the services of a food technician to trouble-shoot the problem. Management is hoping to receive free, or highly subsidized, services from the local campus of the Federal University of Pará. The university plans to set up a biochemical laboratory in Santarém, but this may take some time.

Quality control and uniformity are thus important considerations for agroindustrial development. Buyers in national and international markets demand high quality and uniformity. For example, Brazil nut - an increasingly common component of agroforestry systems in the Amazon and part of a huge international market for mixed nuts - is losing ground to other nuts, especially peanuts, in part because of quality considerations.[14] A now-defunct Manaus-based company, CHOCAM (Chocolate of Amazonas), which produced a powdered chocolate mix (or "cupulate") from cupuaçu beans, reportedly had a similar problem related to product uniformity. Because farmers did not always take care to ferment the beans properly, batches of cupuaçu powder varied noticeably in taste, ultimately undermining the acceptance of the new product in the marketplace.

One lesson to be drawn from the interplay between agroindustry and agroforestry is that most farmers are better off not relying solely on fruit crops that need refrigeration. A mixture of agroforestry products, both perishable and durable, offers the best chance of avoiding complete harvest loss. Another option is to explore markets for byproducts that are generally ignored or discarded. Such byproducts could include soft stem cores below palm hearts, trimmings from sawmills, shells from Brazil nuts, seeds from açaí and peach palm fruits, and fermented cupuaçu seeds.[15] Several international buyers, for example, have expressed interest in purchasing cupulate from fermented cupuaçu beans. In Belém, scientists at EMBRAPA are experimenting with a powdered cupuaçu pulp to make reconstituted juice and for use by bakeries; the product is promising, but processing machinery is expensive. In Manaus, a local food company (CIALI) recently started producing açaí, camu-camu, and cupuaçu powders with spray-dry technology. Flavor loss is significant for cupuaçu, less so for camu-camu, and acceptable for açaí, while hygiene is excellent.

Inadequate infrastructure for agroindustry and marketing is a major reason why Amazonia is losing out to other regions of Brazil in agricultural production. Additionally, the Amazon's exuberant biodiversity includes an abundance of pests, diseases, and weeds, all of which are better adapted to the region's poor soils and rainfall regime than are most of the crops that farmers plant, including the native species. The flight of Amazonian crops probably started with tobacco, pineapple, peanuts, and rubber. More recently it includes annatto, peach palm, and guaraná. Growers in the drier parts of northeastern Brazil are competing successfully with Amazonian producers to supply southern markets with Barbados cherry, and the Northeast has recently emerged as a significant exporter of fresh fruit to the United States (Caviedes and Muller, 1994).

Camu-camu, a fruit that is native to certain flood plain areas of central and western Amazonia, seems destined for the same fate. Camu-camu is one of the up-and-coming fruits of Amazonia since it makes an enticing juice and is exceptionally rich in vitamin C, much higher than the juice of orange or Barbados cherry. Fink, a Manaus-based company, established a nursery for camu-camu at km 100 of the Manaus-Itacoatiara highway that contained a million seedlings in 1996. The company has contracted with about 30 nearby farmers to grow the crop. But most of the camu-camu seedlings are being dispatched in plastic bags by overnight mail to a commercial farm in São Paulo where a 500-hectare plantation of the crop is being established. Fink has chosen São Paulo as the mainstay of the camu-camu operation because yields are expected to be much higher there on better soils using drip irrigation. Furthermore, bank loans are much easier to obtain in São Paulo than in Manaus, and São Paulo has a huge urban market with a growing demand for "natural" vitamin C pills.

In short, lack of agroindustrial development acts as a major constraint to agroforestry in the Brazilian Amazon. Unreliable sources of electricity and poor quality control undermine regionally based agroindustries. Given these limitations, regional farmers would be encouraged to provide a mix of agroforestry products - both perishable and durable, and with a variety of potential applications. One promising yet little explored solution is asceptic packaging, which eliminates the need for refrigerated storage, helps maintain high product quality, and can literally bring the factory to the forest. Another option is to explore markets for byproducts that are generally ignored or discarded. Although its inadequate infrastructure will continue to draw crop production to other regions, Amazonia's diverse array of underexploited crops provides potential opportunities for local producers and agroindustries alike.

*Community Organization at the Local Level*
Appropriate local-level organization is as crucial for the success of agroforestry projects as adequate policies and infrastructure. This does not mean that farmers have to belong to a cooperative or association in order to prosper. Rather, agroforestry development has a greater chance of success if farmers are sufficiently organized to articulate their needs, lobby for support, and gain access to markets.

A number of key questions related to local-level organization should therefore be applied to on-going or future projects involving agroforestry development (Box 3). The major issues here are whether farmers are active participants in the design and delivery of technology, whether mechanisms are in place for conflict resolution, and whether the project is paternalistic rather than empowering.

In theory, farmers' organizations that are free of political, ideological, or religious agendas would seem the best platform for promoting agroforestry, particularly on a commercial scale. In practice, few well-grounded growers' associations or cooperatives have thus far emerged in Amazonia. It may take the private sector to catalyze this process.

*Credit*
Credit can provide a critical incentive for farmers interested in agroforestry and for entrepreneurs who wish to establish or expand agroindustrial operations. The bias of fiscal incentives toward cattle production that prevailed in the Brazilian Amazon during 1960s, 1970s, and to a more limited extent in the 1980s, has been largely removed (Smith et al., 1995b). Yet with interest rates far above inflation,[16] commercial sources of credit are out of reach for farmers and agroindustries alike, and funds from subsidized credit programs are limited and competition for them is keen. This section examines both official and alternative sources of credit for agroindustrial and agroforestry development in the Brazilian Amazon.

*Official Sources of Credit.* In theory, the National Bank for Economic and Social Development (BNDES) would be an ideal source of relatively low-cost loans for entrepreneurs interested in developing agroindustries in Amazonia, particularly for export. BNDES apparently has resources in the order of US$2 billion for fostering industrial development, with a special line of credit destined for Amazonia: the Integrated Amazonia Program (PAI). In practice, however, individuals interviewed in the business community in the Brazilian Amazon report that it is virtually impossible to obtain such funding. One problem is that BNDES does not make loans directly; the funds are funneled to other banks which act as intermediaries. When dealing with such intermediaries, loan applicants are legally required to furnish guarantees that they are credit worthy and do not owe back taxes.[17] These and other bureaucratic formalities discourage smaller and middle-scale operators.

**Box 3. Key questions related to local-level organization for agroforestry development.**

*Active Participation or Passive Bystander?*

- How much influence do farmers have on the design and implementation of the project? To what extent were "target" farmers canvassed beforehand about their needs, aspirations, and constraints?
- Are farmers allowed to use their own knowledge and experience when choosing agroforestry configurations, or are such systems delivered as a *fait accompli* by outsiders such as NGOs, church groups, foreign donors, agricultural research centers, and state extension services? In general, successful agroforestry schemes will involve a blend of indigenous knowledge and modern science.
- To what extent has farmer participation evolved from passive forms, such as cost sharing and consultation, to more proactive interventions, particularly during the design and implementation of the project? Such questions indicate the capacity of farmers' organizations to withstand potential abuse by outside groups.
- To what extent has the project built up constructive alliances with outside groups? To the degree that farmers' organizations focus on commercial and technical issues vital to their economic livelihood, the greater the chances of building durable support from such groups.
- What is the institutional relationship between "project managers" and the target farmers and their organizations? Is the relationship largely paternalistic?

*Socio-Political Organization*

- Is there a socio-political basis for collective discussion and decision-making to generate group commitment and agreement on project aims?
- Are existing arrangements for organization and decision-making adequate or acceptable to the community?
- Given that little or no tradition of group action exists in rural areas of the Amazon, what provisions are being made to work out fundamental organizational arrangements that require a modicum of group action and commitment?

*Financial Dependence*

- To what extent does the project encourage farmers to depend on their own resources? Is the project creating chronic dependence on external financial support?
- Many donors like to be seen as playing a "catalytic" role in jump-starting agroforestry development. Yet are any of the supported projects able to make it essentially on their own, in terms of external financial aid, after a few years? Has the donor agency explored options to generate greater financial sustainability among the project beneficiaries?

The Bank of Amazonia (BASA) administers three subsidized credit programs derived from the FNO and aimed at farmers and small agribusinesses: PROCERA, PRORURAL, and FNO-Especial. All of these programs provide loans at three main rates: ranging from 4% yearly interest plus 50% of the cost-of-living increase for small producers to 8% annual interest and full cost-of-living increases for larger operators. Intermediary rates prevail for medium-scale farmers and agribusinesses. Under FNO guidelines, small-scale farmers may apply for a loan of up to US$12,000, which should be sufficient to help farmers adopt or expand agroforestry.

PROCERA is designed specifically for small-scale farmers in INCRA settlements, while PRORURAL is designed for small-scale farmers in associations or cooperatives outside of INCRA settlements. In mid-1996, credit could be obtained through PROCERA and PRORURAL at an interest rate approximating Brazil's inflation - far below the prevailing rates of interest charged by commercial banks. Neither of these programs specifically targets agroforestry.

Disbursements in both PROCERA and PRORURAL are typically behind schedule, a seemingly perennial problem with subsidized credit for small-scale farmers in the Amazon (Smith, 1982:87). Disbursement delays result in missed opportunities to clear, plant, or weed at the proper time. Countless days are lost on trips to and from banks in town to try and resolve bureaucratic snags related to the release of loan funds. One reason for the slow pace of processing FNO and PROCERA applications is the long chain of decision-makers and institutions involved. Federal funds are passed to BASA, which then passes them on to state banks if agencies of BASA are not available in the smaller towns. The state extension service, EMATER, prepares the projects with farmers and acts as a critical intermediary between farmers and the state banks. The more institutions involved, the greater the chance that bottlenecks will occur. In May 1996, at the tail end of the planting season, reports surfaced that BASA had terminated FNO financing for farmers;[18] such delays led to a protest by some 300 farmers in front of the BASA agency in Altamira.[19]

A special line of financing from BASA (FNO Especial) became available in 1992 for small-scale farmers to establish agroforestry systems that includes 10 head of cattle. The favored perennial crops for financing have been coconut, cupuaçu, orange, peach palm, and robusta coffee. In practice, however, the FNO Especial has been largely ineffective. Those relatively few farmers who have applied for funding[20] are interested mostly in the cattle, not the agroforestry part of the deal. In some cases, a token plot of coconut and cupuaçu is established and then abandoned. The cattle are supposed to be for dairy purposes, but most of the participating farmers are purchasing beef cattle such as Nelore. Cattle can help sustain a small farm and in theory slow deforestation. But to accomplish this goal, pastures have to be managed and periodically recuperated. The FNO Especial does not support construction of fences or corrals - essential elements in pasture management. As a result, this line of financing does little to promote agroforestry and may in fact encourage deforestation.

In 1997 BASA assumed administrative responsibility for a new line of credit that focuses on harvesting of non-timber forest products but which also includes specific support for agroforestry: PRODEX. This program provides up to R$1,000 for operating expenses and R$7,500 for equipment or perennial plantations (including agroforestry systems) to individual producers who are members of an association, or up to R$375,000 for associations or cooperatives.[21] The loans must be paid in 4 to 12 years at 7.6% annual interest, with 1 to 3 years grace period, depending upon the size and nature of the project. Producers are encouraged to develop agroforestry systems, with technical assistence from the local EMATER. PRODEX can finance costs associated with land preparation, purchase of germplasm, plantation management, harvest, and transport. Support for value-added processing is not specifically mentioned for agroforestry products, although the program appears to be flexible enough to accomodate this upon request.

A major impediment to providing loans for agroforestry is that banks do not know how to evaluate the economic viability of agroforestry projects.[22] Proposals to establish plantations of rubber or African oil palm projects easily obtain funding because proponents can provide detailed information on production, processing, and marketing. Such information is much more difficult to obtain for many of the lesser known crops present in regional agroforestry systems. BASA commissioned the Agronomy Faculty of Pará State (FCAP) to carry out a series of studies on production, processing, and marketing of exotic and native perennial crops (e.g., Anonymous, 1997). With documents like these in hand, BASA analysts can easily evaluate the costs and expected returns for a given project in a given locality and decide whether or not to extend credit. All of the studies prepared to date, however, involve specific, relatively well-known crops. There are, as yet, no general purpose studies of agroforestry systems or of minor or new crops. Although Amazonian state banks work cooperatively with BASA, as of May 1997, the Bank of Amazonas State (BEA) did not have copies of these studies and had great difficulty analyzing proposals for establishing perennial crop plantations, much less agroforestry systems.[23]

Finally, the low profile of agroforestry in credit programs such as PROCERA and PRORURAL underscores a broader issue. Agroforestry often falls between the cracks when policy makers allocate funding priorities. Although it is now part of the research agenda of the national agricultural research system (EMBRAPA), agroforestry has not infiltrated far into the extension and financial arenas. The value of agroforestry will have to be promoted at much higher political levels in the state and federal governments to gain a fair share of attention by agricultural policy makers.

The above review indicates that credit flows to small producers in the Brazilian Amazon could be improved by:

- developing studies on production, processing, and marketing of lesser-known crops and crop combinations that can be used by banks to assist in their analysis of agroforestry;
- earmarking a larger proportion of subsidized credit for small-scale farmers and micro-enterprises;
- creating mechanisms for providing credit to farmers who do not have official title to their land, but who have a demonstrated commitment to staying on their land and possess farming skills;
- streamlining credit procedures so that farmers waste less time and money on trips to banks to obtain funds; and
- speeding disbursements and assuring that they coincide with clearing, planting and weeding activities.

*Alternative Sources of Credit.* The preceding discussion shows that, for a variety of reasons, official credit mechanisms currently operating in the Brazilian Amazon are largely irrelevant to agroindustrial and agroforestry development because of lack of information, excessive bureaucracy, and high interest rates. Transforming this scenario will probably require new and more agile sources of credit. With the opening of Brazil's markets to world trade, international investors may provide such sources.

One example of a new, international source of credit is a biodiversity investment fund for Latin America, called Terra Capital Fund, which has been established by the Banco Axial in São Paulo, with support from a pool of investors, including the International Finance Corportation - a World Bank affiliate that focuses on private sector loans. Depending on the interest or private commercial investors, the fund is expected to raise US$20-50 million by late 1997 and will target sustainable forestry, agriculture (including agroforestry and organic agriculture), aquaculture, non-timber forest products, and ecotourism. To assure that World Bank environmental standards and business plan objectives are met, an associated company, Terra Capital Advisors, will provide technical and marketing assistance to the enterprises supported by the fund. Compared to traditional investments in agriculture, fisheries, and forestry, the US$20-50 million fund is minuscule, but it may nevertheless play an important catalytic role.

Another new source of credit is a venture capital fund known as FAROL (literally, "lighthouse"), backed by the New York-based South-North Development Initiative (SNDI) and Agora, a London-based fair trade consultancy company. After FAROL achieves an initial capitalization of US$10 million, the fund will invest in projects promoted by POEMA in eastern Amazonia and involving renewable energy, agroforestry, and industrial processing of natural products. Capital is being raised from public institutions, such as BASA and BNDES; the business community in Brazil; and international organizations, including foundations, individual investors, multilateral institutions, and bilateral aid agencies. Initially, at least, the success of this venture will hinge on tapping the "green" market, particularly in western Europe and North America, where POEMA has experience and contacts in marketing.

Although they are still in an embryonic stage, these examples illustrate innovative departures from conventional credit mechanisms operating in the Brazilian Amazon. If successful, they could point the way toward new and more agile sources of credit for agroindustrial and agroforestry development in the region.

*The Regulatory and Fiscal Environment*

The successful expansion of agroforestry systems in Amazonia is strongly influenced by both domestic and international policies. This section examines the impact of specific policies on agriculture and forestry in general, and on agroforestry in particular.

*Import Tariffs on Certain Perennial Crops by the European* Union. In an effort to discourage coca planting in Bolivia, Ecuador, and Peru, "alternative" crops from those countries receive preferential treatment by the European Union (EU). The European community allows those coca-producing countries to export tropical fruits and heart-of-palm to western Europe without the burden of an import tax that is applied to similar products from Brazil. While in theory, such measures might encourage farmers to turn to agroforestry in the Amazonian portions of the coca-producing countries, in practice farmers along the Pacific Coast are likely to be the beneficiaries. Peru, for example, has emerged as a significant player in the international tropical fruit trade, and most of the production is in the irrigated valleys of the desert coastal plain.

During the first half of 1996, the EU applied an import tariff of 7% on heart-of-palm from Brazil. As of July 1996, that tariff increased to 10.8%, and further increases are envisaged for 1999. A similar import tariff applies to frozen passionfruit pulp from Brazil, compounding problems facing management of the AMAFRUTAS factory discussed in connection with agroindustries. AMAFRUTAS sends the bulk of its production to Switzerland, but is faced with three major challenges: (a) the EU import tariff; (b) depressed world market prices because of overproduction, particularly in Asia; and (c) Brazil's foreign exchange and macro-economic policies, which make it a relatively high cost producer.

The discriminatory tariff rates imposed by the EU are unlikely to have much impact on coca production, and they create hardships for countries that do not grow coca on a significant scale. On the one hand, most if not all EU countries have expressed an interest in helping check deforestation in the Amazon, particularly in Brazil; on the other, EU trade regulations hinder agroforestry, a land use system that promises to help slow deforestation.

*Restrictions on Log Exports.* For several decades log exports have been banned from Brazil to encourage value-added processing. The ban may also partially relieve logging pressure on remaining forest areas. Yet its overall impacts on timber production and processing in Amazonia are poorly understood. Given Brazil's increased integration in global markets, a detailed analysis of the current log export ban's impacts on timber production and processing in Amazonia would be timely.

Amazon-based companies are increasingly involved in planting tropical timber trees. In Rondônia, nine reforestation companies certified by IBAMA had established plantations of timber trees by 1993 (Matricardi and Abdala, 1993). In Pará, at least nine private wood processing companies are involved in timber planting projects, usually involving forest enrichment or pure stand plantations.[24] Although data are scare, individual farmers also appear to be increasingly involved in planting tropical timber trees. A 1993 survey found that an estimated 1,300 small-scale farmers had planted various timber species (mostly mahogany) in Rondônia (Browder et al., 1996). For these producers, a partial or complete lifting of the ban on log exports would result in a boost in the value of logs - which would tend toward export prices minus transportation costs. This increase would apply to logs destined for export as well as for sawmills and furniture businesses in Brazil.

Any change in Brazil's ban on log exports would probably require complementary measures to promote regional timber production and processing. One measure - encouraged by NGOs and adopted by a growing number of countries - would be to assign a "green" label for timber produced in a sustainable manner. "Green" label products generally fetch higher prices than those for which sustainable growing or harvesting procedures cannot be assured (Kishor and Constantino, 1996). Another measure would be to provide incentives for improving regional processing of timber. At present, high quality furniture using Amazonian timber is usually made in industrial countries and in southern Brazil. Increased training by agencies such as SEBRAE and facilitated access to improved equipment could encourage the establishment of furniture businesses in both rural and urban areas of the region.

*Restrictions on Intercropping.* In the 1970s and 1980s, government agencies either prohibited intercropping with some industrial crops or greatly restricted the choices for intercropping. The now defunct national program for fostering rubber planting (PROBOR), for example, forbade participating farmers to plant any other crop with rubber. The rationale for such restrictions was that farmers might "siphon" away fertilizers and other inputs for other crops. In practice, farmers who received PROBOR incentives for planting small plots of rubber either intercropped on their own initiative, abandoned the plots, or harvested only the seeds from rubber trees to supplement the feed of tambaqui fish in aquaculture ponds. Most of the farmers who participated in the PROBOR program in the 1970s have never tapped their planted rubber trees because of low prices and high incidence of leaf blight.

Now that PROBOR is no longer on the regulatory scene and rubber prices have dropped, farmers have opted for several intercropping configurations. In Rondônia, for example, one farmer near Alto Paraíso grazes cattle on pasture planted under rubber trees, and near Paragominas in Pará, a farmer has intercropped his rubber grove with black pepper. In other parts of Rondônia, farmers have planted robusta coffee in their rubber plots (Souza et al., 1994). In the vicinity of Uruará along the Transamazon Highway in Pará, a farmer is participating in an on-farm trial set up by EMBRAPA's station in Belém (CPATU) that involves interplanting kudzu in a small rubber plantation intercropped with cacao. Cattle browse on the nutritious kudzu, while *Rhizobium* bacteria in the kudzu's roots fix atmospheric nitrogen, thereby enriching the soil.

Beginning in 1976, CEPLAC encouraged smallholders in Amazonia to plant cacao on the better soils in colonization areas, particularly in Rondônia and along the Altamira-Ruropólis stretch of the Transamazon. CEPLAC provided planting material, including seedlings of shade trees. Bananas were chosen as the initial shade tree to help seedlings get established, a wise choice since bananas and plantains provided subsistence as well as some cash income until the young cacao trees started producing about four to five years after planting. But for farmers to be eligible for CEPLAC assistance and credit, their choices for long-term shading were restricted initially to just three species (palheteira, erythrina, and gmelina), with madre del cacao (mother of cacao) becoming available in 1979.

The rationale for choosing palheteira, erythrina, and mother of cacao was that they are nitrogen-fixing trees and would thus fertilize the cacao in addition to providing shade. Few colonists are interested in the shade trees promoted by CEPLAC and many of the "indicated" shade trees have been either felled or ringed so that they perish. In their place, farmers have either allowed an impressive array of timber and fruit species to establish themselves spontaneously, or have planted several high-value timber trees. To CEPLAC's credit, the agency's intercropping policy changed in the early 1980s: cacao growers are now encouraged to interplant with valuable timber species, especially mahogany. Unfortunately, however, CEPLAC's budget has dwindled considerably since the 1970s and early 1980s, and the agency is no longer in a position to be of much assistance to cacao growers in most parts of Amazonia.

The notion that government agencies know the "best" cropping patterns for farmers to follow is fallacious. Even the idea that intercropping diverts nutrients from the crop targeted for incentives carries little weight. Agroforestry systems involving diverse crops would probably lead to more efficient utilization of soil nutrients, water, and light. It is best left up to farmers to decide what crop combinations should be grown.

*Forestry Regulations.* Brazil's environmental protection agency (IBAMA) requires that sawmill operators in the Amazon region plant six trees for every cubic meter of wood they process. Although compliance with this regulation appears to be spotty at best, some farmers in Rondônia have planted timber species in their agroforestry plots at the instigation of local sawmill owners. Other government regulations, however, impede the planting of forest trees destined for non-timber use. IBAMA classifies peach palm, known as pupunha in Brazil, and açai palm as non-timber forest products. Accordingly, marketed products from these widespread palms are supposed to be "backed" by management plans. Several problems arise from this requirement.

Peach palm is a crop and does not occur in a truly wild state. Its wild progenitors grow in the forests of western Amazonia, but peach palm is always cultivated either in home gardens, agroforestry fields, or in plantations. Peach palm may persist for a decade or two around old homesites, but it does not occur in mature forest. This may sound like an academic point, but it complicates the lives of farmers who are growing peach palm for the heart-of-palm trade. Farmers involved in the RECA Project in eastern Acre reported that they are supposed to draw up a "management plan" for peach palm even though it is cultivated. This requirement has no scientific basis and only increases costs for peach palm producers.

Another species of palm, açaí, forms dense stands in the Amazon estuary and lower Amazon flood plain. It is virtually impossible to say which of these stands are "natural" and which have been artificially enriched over decades or even centuries. Evidence suggests that harvesting of palm heart from these stands may be unsustainable. Cans of açaí palm heart purchased in Belém and the United States frequently contain undersized heart-of-palm,[25] and by the mid-1990s the average palm heart from açaí was noticeably smaller than two decades ago. Coupled with the closing of numerous processing plants in the Amazon, this evidence indicates that açaí is not being managed adequately in many areas (Pollak et al., 1995).

While management plans may make sense for areas where large quantities of heart-of-palm and fruits are being extracted, such regulations hinder attempts to establish this crop on upland sites. If watered frequently during early stages of growth, açaí also thrives in plantations on well-drained sites. Small-scale farmers are incorporating the palm in their upland agroforestry plots, such as in the Santarém area, to satisfy local demand for açaí fruits. Unfortunately, IBAMA requires a management plans for these plantations. It makes little sense to require such a plan for açaí grown in upland agroforestry plots, or in areas where açaí is virtually absent or has been largely eradicated, such as in the flood plains along the middle Amazon.

*Land Tenure*

Skewed land ownership patterns are sometimes identified as a key constraint to equitable rural development. In the case of agroforestry, one might expect that secure land ownership would be a prerequisite for commercial agroforestry; why would farmers invest in perennial crops if there was no assurance they would still be on the land to reap the benefits of their labor? In practice, however, many farmers develop agroforestry - albeit on a relatively small scale - without official title to the land.[26] In fact, planting trees is often used as a way to strengthen claims for land tenure in the Amazon region.

Behavior is determined by security of land tenure or property rights, not possession of a document. Along the Amazon flood plain, for example, many smallholders do not have title to the land, but their homesteads are not threatened. In any given area of the flood plain, the owners, both small and large-scale, are generally recognized and their rights respected. On both the flood plains and on upland sites, larger landowners, who usually possess better documentation for their properties, rarely practice agroforestry. A similar situation prevails in Central America, where lack of land titles does not hinder investments in long-gestation crops as long as people feel secure on the land they work (Current et al., 1995a).

Two main processes are underway in upland areas undergoing settlement: concentration of land ownership and subdivision of land parcels among small holders (minifundia). The former process, which occurs more frequently throughout the Brazilian Amazon, usually means transformation of the land to cattle pasture and can seriously hinder agroforestry development. The second process, especially noticeable in twenty year-old colonization zones in the vicinity of the BR 364 highway in Rondônia, leads to more intensive use of the land, typically involving perennials either as monoculture or in polycultural systems. In the vicinity of Alto Paraiso near Ariquemes in Rondônia, for example, some 100 hectare-plots have been subdivided among family members and are planted to a patchwork of perennial cash crops, particularly robusta coffee, subsistence crops, and agroforestry plots with fruit trees.

Rapid urbanization in Amazonia could have an important impact on land tenure and land-use patterns in rural areas. In 1991 more than 57% of the region's inhabitants lived in urban centers of 2,000 or more, up from 37% in 1960 (Browder and Godfrey 1997). The number of urban centers with more than 5,000 inhabitants rose from 22 to 133 during this same period, with most of this growth occurring in newly-accessible upland areas. The rapid urbanization of Brazilian Amazonia has important consequences for rural areas. First, it has increased market demand for local food products, many of which can be produced within agroforestry systems. Second, a growing number of farms and increasing rural areas are coming under the control of urban-based interests. In 1990, an urban household survey in Rondônia revealed that 23% of the population owned rural properties in the state.[27] Urban households are often engaged in a different and wider array of economic activities than their rural counterparts. They have access to more economic information and resources, and not surprisingly, they pursue different (typically more casual) rural land uses than full-time farmers, which could act as a constraint to the adoption of agroforestry. On the other hand, it is likely that urban-based landowners also have easier access to credit from local banks than do their rural counterparts, which could provide an incentive for adopting long-term land-use practices such as agroforestry. As a result, the impact of increased urbanization of rural property ownership on adoption of agroforestry remains unclear.

### *B. Technical Constraints*

*Research*

Technical knowledge is important for the long-term success of efforts to promote agroforestry. The main question asked here is: Does the public sector agricultural R&D system address the needs of farmers engaged in agroforestry? The answer, in short, is no. To understand why, and what can be done about it, a brief history of the agricultural R&D system is warranted.

Agroforestry research began in the Brazilian Amazon in the early 1970s, although little of this research was completed due to severe funding cutbacks in the wake of the 1982 foreign debt crisis that rocked Brazil and much of Latin America. The two major agricultural research institutions (the EMBRAPA network and CEPLAC) and the recently created agricultural department at INPA set up large-scale experiments with a limited number of native and exotic species. Except for CEPLAC's experiments with cacao, the other species used were comparatively little known, which resulted in inadequate spacing and species combinations. CEPLAC's work was designed to identify shade species that combined well with cacao and offered ecological and/or economic benefits to the system. The more ambitious research undertaken by EMBRAPA and INPA aimed to identify agroforestry models that would be economically viable and appropriate for small-scale farmers. The latter two institutions failed to take market information and farmer preferences into account, and as a result adoption of the models was negligible; in INPA's case the farmers even abandoned the experimental plantations established on their properties free of charge (Leeuwen et al., 1997).

In 1992, agroforestry became a dominant activity on the research agenda of EMBRAPA as part of its system-wide strategic plan. All of the EMBRAPA centers in Amazonia were designated agroforestry centers, even though relatively small proportions of their respective staffs were directly involved in agroforestry-related research. As the plan only became operational in 1993, its impacts on agroforestry research and development remain to be seen. About 5% of EMBRAPA's overall research budget is spent on forestry and agroforestry combined.[28] Traditional commodity and livestock programs have a much longer, and better endowed, track record among EMBRAPA centers in the Amazon region.

It is hard to draw the line around "agroforestry" scientists versus others engaged in various aspects of agricultural research. Many perennial crop research programs, such as citrus and rubber, could in theory be considered part of agroforestry programs. It would probably make more sense for institutions to identify loose-knit teams or clusters of expertise in agroforestry that would draw on skills and knowledge from a wide range of disciplines, such as agronomy and forestry, entomology and plant pathology, plant growth and physiology, plant nutrition and soil sciences, as needed. Unfortunately, little coordination currently exists between the main regional research institutions engaged in agroforestry. For example, at a recent workshop in Manaus (March 1996), a survey revealed about 50 regional scientists working on some aspects of peach palm and 30 on cupuaçu (with some working on both), while another 50 fruit species with economic potential were largely neglected.

In general, agroforestry research in the Brazilian Amazon is still a top-down affair that is more oriented toward generating scientific publications than useful information for farmers. Even when the research is conducted "on-farm," farmers are generally not canvassed in advance as to the crops that might interest them, nor are they informed about current or potential market conditions. Agroforestry models are essentially "parachuted" on to farmers' lots in the hope that the technology package will be well received and thus take-off. In some scientific circles in Brazil, including Amazonia, on-farm research is still considered to be extension rather than serious science.

Several examples of such top-down agroforestry projects could be cited, but only two will be mentioned here. We do not wish to imply that top-down agroforestry projects are completely without merit; parts of the systems being tested may well prove useful, and some of the externally-funded agroforestry projects provide resources to train Brazilians. But as an approach, top-down agroforestry models are not adopted widely, either because farmers were not involved in the research design or because viable markets do not exist for the crops tested.

CPATU, EMBRAPA's leading center in Amazonia located in Belém, established two on-farm agroforestry trials along the Cuiabá-Santarém highway, one at km 53 that began in 1978, and a newer one at km 60, started in 1988. The purpose of these trials was to test the growth of the following combination of crops on nutrient-poor soils: manioc, banana, ingá, cupuaçu, Brazil nut, and six native timber species.[29] The manioc provided subsistence and some early income to the farmers. Ingá was included in the configuration to enrich the soil with nitrogen and to provide green manure. The mixture of timber, fruit, and nut trees is growing well on the nutrient-poor oxisol, even without fertilizer. But as dozens or even hundreds of candidate species are available for farmers to choose from, the key challenge for agroforestry research is not to find trees that grow well on the generally poor soils. Instead, the challenge is to tailor species combinations that best fit farmers' circumstances, such as consumer demand, distance to market, availability of processing plants, and household needs. Farmers, for example, are not particularly interested in improving the nitrogen content of the soil because they do not see how that improves their incomes. Thus ingá is not valued, and farmers do not lop off the branches to form green manure because of labor considerations. As is typical in such top-down configurations, farmers either modify the system or abandon it. In the case of the experiment at km 53, the farmer modified the configuration in 1992 to include pineapple. No farmers in the vicinity of the trials have adopted the CPATU model.

A similar situation prevails with a collaborative agroforestry project between the EMBRAPA center in Manaus (CPAA) and Cornell University, implemented along the road to the Balbina Dam in 1991-2. Cupuaçu, peach palm, and ingá are the main components of a relatively simple model, which was based on a diagnostic survey among farmers during the design phase and the perception by EMBRAPA researchers that ingá would prove a valuable tree for green manure. During implementation, however, farmers changed their mind: they wanted to include banana because it was proving to be a valuable cash crop. Farmers are also ignoring the ingá due to labor considerations. Wisely, the project implementers acceded to the wishes of the farmers and "allowed" them to incorporate banana in the crop mixture. By keeping channels open for feedback, the CPAA-Cornell University collaborative project has increased the chances for more widespread adoption of their agroforestry model.

Although many agroforestry research programs are still at an incipient stage, this study revealed a number of critical limitations, some of which may self-correct in time:

- Most agroforestry research in the formal public sector still involves a top-down approach, in which crop configurations are conceived by scientists with little or no input or participation by local farmers.
- Almost no research is being directed toward identifying existing or new market opportunities for farmers.
- Little if any work is being done to understand the socioeconomic constraints and opportunities that affect farmers' land-use decisions.
- Few scientists are looking at agroforestry from a systems perspective; instead, they tend to concentrate on one or two crops, with little work done on interactions in multiple-species assemblages.
- Agroforestry research rarely receives a long-term commitment by either funding agencies or regional research centers.

The lack of research on agroforestry's constraints and opportunities in Amazonia is a reflection of the under-representation of the social sciences and economics at the EMBRAPA and other research centers. Few social scientists in the region are conducting research at the farmer level. At the Goeldi Museum in Belém, natural scientists are knowledgeable about biodiversity of plants and animals, some of which could be important components of future agroforestry systems. The Museum's social scientists, however, are not engaged in agriculturally-oriented research. The National Institute for Amazonian Research (INPA) in Manaus pursues on-farm research in some of its agronomic work but has no social scientists on its staff. While INPA has valuable expertise in native fruits of Amazonia and farming systems research, budgetary constraints hamper efforts to carry out these important lines of research.

The limited socioeconomic work that is being carried out by research institutions in Amazonia has tenuous links to agroforestry research and technology development. CPATU has several highly qualified agricultural economists who periodically conduct farm-level surveys. One such survey recently identified a growing need for fuelwood among small producers in several parts of the Bragantina zone east of Belém, particularly in the vicinity of Ourém and São Miguel do Guamá.[30] Many farmers in the region rely heavily on manioc flour for subsistence and income generation, but most of the original forest in the Bragantina zone has been cut down, and even secondary growth contains few sizable trees because of short fallow cycles. Firewood is needed in large quantities to toast manioc flour and fuelwood species could be easily incorporated in agroforestry systems, as in other tropical regions. Such information should be systematically fed into agroforestry research programs so that the agenda is more demand-driven.

For many years, EMBRAPA employed only a handful of economists in the entire Amazon region, albeit highly competent ones. Two economists have recently been added, one each in Rondônia and Acre, a promising development but still not enough to meet the demand. For example, several farmers canvassed for this study expressed interest in knowing how much profit they could expect to generate from various agroforestry systems compared to other land use options. As few economic models have been generated for agricultural production systems in Amazonia, this is a promising yet neglected area of research. Fortunately, FCAP, under contract with BASA, has started to produce these models for individual perennial crops. As this work expands, a general purpose economic model for agroforestry would be a logical next step.

Another way that the mismatch between research priorities and farmers' needs manifests itself is in the vital area of quality planting stock. Very few farmers are using improved planting stock and many are collecting seed from both timber and perennial crop trees without selecting for desirable characteristics. In the late 1980s, an INPA researcher helped create a cupuaçu network to connect farmers and processors with researchers and extensionists. One of the network's first priorities was to train farmers in stratified mass selection to permit each farmer to identify the best local sources of germplasm. Unfortunately the INPA researcher left Manaus and the network collapsed before this selection could affect local germplasm quality. This plant improvement methodology could be used for almost any crop. In contrast, most of the farmers who have adopted commercial agroforestry are obtaining their planting material, of highly variable quality, from other farmers or from commercial sources.[31]

Public research institutions have an important role to play in backing-up the private sector with basic research, breeding, and field testing of promising material. Such institutions have an especially important role to play in establishing and maintaining germplasm collections that contain a diverse array of plants and varieties. Yet the public sector has pulled back from this vital task, a casualty of reduced funding.

As part of the POLONOROESTE Program in Rondônia, for example, INPA distributed thousands of fruit tree seedlings and the state planning agency distributed some 800,000 seedlings of timber species to small farmers for agroforestry development in the 1980s (PLANAFLORO, 1995). Budgetary problems led to a sharp curtailment of this program after 1990. Nonetheless, some of the fruit and timber crops currently used in agroforestry systems in Rondônia can be traced back to those germplasm distributions. Severe funding restrictions in recent years have also led to the neglect and even abandonment of important field genebanks of perennial species, such as the native fruit collection established by INPA in the mid-1970s, where 65% of the general fruit accessions and 85% of the genetic variability were lost between 1988 and 1995 (Clement, 1996). Field genebanks serve as valuable repositories of promising planting material that can be incorporated in breeding programs or used directly by farmers.

Due to underfunding of the R&D sector, farmers are generally way ahead of the research community with respect to experimentation with agroforestry systems in the Amazon region. EMBRAPA has the resources to focus on only a small number of the crops of interest to agroforestry farmers. Although some of INPA's and the Goeldi Museum's research is relevant to agroforestry and is generally of high quality, linkages to extension are poorly developed if they exist at all. In short, the fruits of research are slow to reach the farmers, an issue common to many parts of the world.

Underfunding for R&D institutions is clearly a critical constraint to agroforestry development in the Brazilian Amazon.[32] While more funding is certainly warranted for agricultural R&D in Amazonia, a broader issue is at stake here: a need to move researchers closer to the "end-users," which implies working with producers as research partners, not passive recipients of improved technologies.

Of course, exceptions to the top-down generalization exist. For example, INPA is doing some innovative agroforestry work in collaboration with farmers. In an attempt to help growers transform their traditional slash-and-burn systems into agroforestry systems in two settlements near Manacapuru, Amazonas, an INPA agronomist and two interns are conducting on-farm trials with various growers (Leeuwen et al., 1994). Final decisions on the composition of agroforestry systems to be tested were made by the farmers. Although the total number of farmers involved in the research was small, the participatory research methodology adopted by INPA scientists is more likely to result in successful diffusion than rigid, top-down approaches.

The overall isolation of agricultural research programs from the needs of growers also applies to companies planting perennial crops. The Equador agroindustrial company near Porto Santana in Amapá, for example, established a 50 hectare guava plantation with its own resources and without any technical assistance. The EMBRAPA center in Amapá has only one specialist in tropical fruits, but guava is not an area of competence at that center. AMAFRUTAS, which processes passionfruit near Belém and is exploring options with other fruits, does not have any collaborative research links with EMBRAPA. And in the case of CITROPAR, a subsidiary of a major construction company (ESTACON) in Belém which owns large orange plantations near Capitão Poço in Pará, the company hires its own agronomists to take care of its nearly one million orange trees. EMBRAPA centers in the Amazon do provide technical assistance for growers of a few perennials, such as oil palm, rubber, robusta coffee, Brazil nut, and cupuaçu, and INPA provides support for peach palm and camu-camu. But for many of the crops of interest to small- and large-scale growers alike, no technical backstopping is available from the public sector. The larger companies are essentially buying their own technical assistance in Amazonia, and land development and agroindustrial enterprises may eventually take over more of the research and extension with small farmers as well.

The knowledge of a small but important segment of Amazonia's population is essentially ignored by the agricultural R&D system: indigenous people. Several reasons account for this neglect. First, few indigenous groups in the Brazilian Amazon are growing crops for markets, and their experiences are therefore thought to have little relevance for "development." Second, access to indigenous groups is often difficult for researchers because of restrictions imposed by the Indian protection agency (FUNAI), designed to minimize exposure to introduced diseases and prevent exploitation of natural resources in indigenous reserves. Third, language barriers discourage many researchers, particularly in the agricultural sciences, from visiting indigenous groups.

More partnerships could nevertheless be encouraged between agricultural research centers, the Goeldi Museum, INPA, various universities, and NGOs to better understand how indigenous people have managed natural resources in the varied environments of Amazonia. And information exchange need not be a one-way affair. Indigenous groups are actively seeking new sources of income and are usually receptive to new crops. For example, the Waimiri-Atroari north of Manaus are especially interested in acquiring orange seedlings to plant around their villages (Miller, 1994). The Wai-Wai from the Nhamundá-Mapuera reserve in northern Amazonia invited technicians from POEMA to assess their basic sanitation and agroforestry needs, and two members of the Wai-Wai have been trained by EMBRAPA in grafting techniques and the care of seedlings (POEMA, 1995).

In short, over two decades of agroforestry research by governmental agencies in Amazonia have been dominated by top-down approaches that have had little impact on agricultural development. Demand-driven, market-oriented R&D in agroforestry remains rare, even though this approach is likely to have the greatest beneficial impact on farmers. As a consequence of the inefficiency of the public research sector, Amazonian extension agents have little useful information to offer producers on appropriate crops and crop combinations for agroforestry systems.

*Extension*

In the past, the public sector's extension services played a significant role in running nurseries and distributing planting material of perennial crops, and introducing conventional agricultural systems (i.e. monocultures) to rural producers in the Brazilian Amazon. In Rondônia, for example, EMATER has distributed seedlings of high-value timber species to farmers in colonization zones. Farmers near km 15 of the Santarém-Rurópolis highway took up agroforestry as a result of EMATER field training courses in grafting of perennial crops in the early 1970s. And CEPLAC has provided appreciable assistance to promote cacao planting as a monocrop in parts of Rondônia and Pará, and some of these cacao groves have been transformed into more diverse agroforestry systems. But as in the case of other public sectors, public extension services in Amazonia suffered drastic budget cuts in the 1980s and early 1990s, and their importance has waned considerably.

The public sector still has a role to play in agricultural extension. The governor of Amazonas recently disbanded EMATER and has created the Institute for Development of Amazonas (IDAM) to fulfill the same function. It remains to be seen if the revamped extension service in Amazonas is just a change in name and leadership, or whether it will work effectively. In parts of Pará, such as near Santarém, the national service for rural training (SENAR) is taking over some of the functions of EMATER. SENAR conducts training courses for farmers on such topics as grafting and management of home gardens and commercial agroforestry plots.

In some cases, public extension agencies are charging the private sector for services rendered. EMATER in Rondônia is evolving into a part public, part private, organization; already close to a third of its budget is derived from contractual services. And in the vicinity of Capitão Poço in Pará, a private orange producer provides gasoline and other logistical support services for EMATER extension agents so that they will have the means to advise smallholders, from whom the producer purchases oranges for processing. Many of the state banks in Amazonia include a line item in project budgets for extension services, so that farmers will be encouraged to demand services from the public sector (and pay for it) or contract private extensionists for assistance.[33]

One approach that has worked well in some other Latin American countries, and might also be successful in the Brazilian Amazon, is the training of farmers to provide technical assistance to their neighbors (Current et al., 1995a,b). It allows the already stretched government agencies that provide extension services to concentrate on a smaller number of individuals, but still have an impact on a larger number of farmers.

This training approach to extension provides a local link to technical assistance providers who can also act as a conduit for demand-driven research. Strengthening the capacity of local communities to carry out extension while encouraging governmental extension agencies to use limited resources strategically may prove to be a more sustainable approach to technology transfer. Nonetheless, this approach also requires a vigorous extension service, rather than the weakened, underfunded remnants found in most of Amazonia today.

In theory, agricultural extension is supposed to work more efficiently when farmers are organized. In practice, many such organizations are extremely weak and largely ineffectual. Many growers' associations in Rondônia and along the Transamazon have been patched together hastily in order to "capture" external funding (Castellanet et al., 1996). One such case is the Association of Cacao Producers of Cacaulândia in Rondônia. In the early 1990s, cacao farmers in this "community" along a side-road of the BR 364 banded together to apply for financing of a small agroindustrial plant to separate and freeze the pulp surrounding cacao seeds. In contrast to the plummeting prices for cacao seed in international markets, the local market for frozen cacao pulp used to make fruit juice was growing. Based on this new market trend, the association was successful in obtaining a loan from Rondônia's state bank (BERON). The cacao pulp plant started operating in 1993 but closed down within a couple of years due to disagreements among farmers on the governing board of the association. The fact that farmers are signing up for growers' associations, then, is no real indication that a true cooperative spirit is emerging, nor that such organizations are robust enough to withstand internal and external pressures.

Some farmers operate "community" nurseries, often associated with externally funded projects administered by NGOs. In some cases, planting stock is purchased from trucks traveling long distances with highly desirable perennial crops, such as sweet orange. The quality of this stock is often dubious, however, as planting stock brought in from São Paulo or elsewhere are left-overs or rejects from plantations in the region of origin. Worse still, some of it comes with diseases, especially viruses.[34] In many parts of Amazonia, especially among native peoples and folk populations in older settled areas, informal "trade" networks have evolved whereby farmers, especially women, actively exchange planting material (Salick et al., 1997). This informal movement of plants and seeds, much of it undertaken without cash being exchanged, is an interesting but little understood dimension to the region's rich genetic resources.

An increasing share of agroforestry extension in the Brazilian Amazon is in private hands. The private sector in this case involves the farmers themselves, urban-based businesses, and entrepreneurs. One of the most important technologies sought by agroforestry farmers is planting material. Some farmers form their own backyard nurseries for seedlings such as cupuaçu; others specialize in nursery production and derive appreciable income from such sales. Miguel das Freiras, at km 16 of the Santarém-Rurópolis highway, is a case in point. Miguel has been selling seedlings and grafted material of numerous perennial crops for several decades, and growers from within a radius of dozens of kilometers come to his farm to purchase planting material.

In addition to entrepreneurs, NGOs are helping to fill the vacuum created by the reduced presence of public extension services in the region. The Agroecological Laboratory of the Transamazon Highway (LAET), based in Altamira, Pará, is an example of an NGO that works closely with farmers to help them solve agricultural production problems through better management of natural resources. Established in 1991 and linked to the Federal University of Pará, LAET is staffed by ten professionals with training in agronomy, livestock production, biology, agroecology, and sociology. LAET provides a promising model because it acts as a network node for various institutions, including CPATU, CEPLAC, and the local campus of the Federal University of Pará. The French program for foreign assistance in agricultural research and development (CIRAD), the French overseas research program (ORSTOM), and University interns provide additional technical assistance.

LAET has also forged a partnership with the Movement for the Survival of the Transamazon (MPST), an umbrella organization representing a variety of small farmer organizations along a 500-km stretch of the Transamazon Highway and along the lower Xingu River. LAET embraces 17 growers' associations, 9 rural labor unions, and 10 cooperatives (LAET, 1996). It works out of a small office in Altamira and focuses efforts on conducting surveys of farming systems, organizing meetings with farmer groups, and publishing recommended practices for such activities as managing timber production on small lots. In July 1996, LAET was instrumental in establishing a commercialization center that acts as a clearinghouse for negotiating commercial contracts for commodities produced by smallholders. Although it is too early to judge whether LAET will have much impact on the livelihood of farmers in the region, the approach appears to hold promise and may warrant replicating elsewhere.

The literature is singularly lacking in a careful analysis of the accomplishments - and failures - of NGOs in extension work in the Amazon. A number of NGOs are involved directly or indirectly in promoting agroforestry, but it is hard to ascertain in many cases whether they are having much of an impact. In addition to LAET, three other NGOs stand-out as particularly promising catalysts for agroforestry development: POEMA, PESACRE, and REBRAF. One of the better organized and managed NGOs in the region, POEMA has pioneered an ambitious rural development program that operates in 15 municipalities in Pará and Amapá. To date, over 300 families have implemented agroforestry as part of this program, which uses a didactic and highly flexible approach to agroforestry extension that could serve as a useful guide to other extension efforts in Amazonia. Based in Rio Branco, PESACRE works with some 30 families in the Peixoto settlement project, as well as with an indigenous group near Boca de Acre. As in the case of LAET, PESACRE collaborates effectively with a number of federal and state institutions, but its links to the private sector are still poorly developed. A Rio de Janeiro-based NGO that specializes in promoting agroforestry, REBRAF has conducted 32 training courses in the Amazon and reaches farmers in a wide variety of locations, including the Maracá Extractive Reserve in Amapá, parts of Rondônia, and the vicinity of Paragominas in Pará. Significantly, some of REBRAF's training courses have encouraged the creation of growers associations and organized communities, such as the Association of Alternative Producers (APA) near Ouro Preto, Rondônia, which has 80 participating families.

Factors that set these NGOs apart include their multiple-year funding from more than one source, in-house scientific expertise, smooth working relationships with a number of public institutions, emphasis on training activities, and a commitment to working directly with farmers. Not all the "successful" NGO models exhibit all of these factors, but they usually epitomize at least two or three.

Despite the many advantages of NGOs, such as their close proximity to farmers and their relatively simple and streamlined administrative procedures, their overall impact on agroforestry development in Amazonia is limited because they frequently:

- have insufficient funding to complete the projects they begin;
- have limited technical expertise;
- get spread too thin on a number of different initiatives;
- want to go it alone and do not work well with other organizations or relevant actors - particularly private enterprises;
- concentrate excessively on production and ignore market-related issues; and
- are confined to a limited geographic area.

If extension work is left entirely in the hands of the private sector, many small-scale farmers will not receive assistance. Even poor farmers are willing to pay for good quality technology, but for the most part, private companies and individual entrepreneurs are unlikely to provide training. Likewise, reliance on NGOs alone to fill the vacuum would be unwise. The public sector must play a role in assisting the poorer farmers with extension needs related to subsistence crops, an area where the private sector is less likely to be involved. Some agroforestry crops such as banana are important both for subsistence and cash income.

In short, the public sector can recoup lost ground in extension by:

- entering into contractual arrangements with agribusiness, cooperatives, and growers' associations so that extension is not completely dependent on the public purse;
- increasing collaboration with NGOs, which are playing a growing role in agroforestry extension throughout the Amazon region; and

- focusing efforts on training in administration, conflict resolution, accounting, and other areas that will strengthen farmer organizations.

## IV. Agroforestry in Practice

A comparison of experiences among existing projects or enterprises can provide some insights into cost-effective ways to promote agroforestry and spotlights pitfalls to be avoided. The case of Tomé-Açu in eastern Amazonia was discussed in the introduction. Three cases from western Amazonia are reviewed here.

*The RECA project*, located at km 150 of the Rio Branco-Porto Velho stretch of the BR 364, has received a lot of publicity and is on the "must see" list of agroforestry and rural development projects in Amazonia. Although it has achieved some success in training and extension, the RECA project is a case study of some of the pitfalls involved in promoting agroforestry. The main shortcomings of the approach taken at RECA can be summarized as follows:

- a rigid agroforestry configuration composed of three species - peach palm, cupuaçu, and Brazil nut;
- insufficient planning with respect to processing and marketing of agroforestry products;
- minimal interaction with the local business community due to concerns that RECA members would receive unfair prices and lose control over their organization; and
- a go-it-alone philosophy with respect to technical assistance, at least until recently.[35]

European charities[36] have provided hundreds of thousands of dollars in support for the RECA project. Instead of trying out the agroforestry model with a few farmers first, some 300 farmers were encouraged to plant the three indicated species in the late 1980s, spurred on by the generous financial incentives. Now, however, the number of active participants in the project has dwindled by half, due primarily to problems with product processing and marketing.

The first processing and marketing problem arose with peach palm. Plantations of this crop generated high yields, but the local market in Rio Branco (located 150 km distant) quickly saturated for all but the small, red, oily fruit. Unfortunately, only a relatively small percentage of the peach palms planted at RECA produce such fruits. No previous market analysis was done before introducing germplasm so the resulting heterogeneous assemblage of peach palms is good for disease and pest control, but bad news for commercially oriented growers. With insufficient market demand and without a processing facility to transform the large starchy fruit into flour, producers at RECA have stopped harvesting most of their peach palm and even started cutting it for palm heart.

Peach palm is one of the best sources of palm heart. The fast-growing palm is planted extensively for such purposes in parts of Costa Rica, Ecuador, and Brazil. Yet at RECA adequate facilities were not available to process the palm hearts,[37] and the project directors were reluctant to work with local private sector processors such as BONAL (see below). Unfortunately, RECA's donors have focused their support exclusively on crop production and appear reluctant to support processing and marketing. Unless RECA is successful in locating a donor to fund a palm heart factory - an investment ranging from US$50,000 to US$200,000, depending on scale - some growers are likely to abandon peach palm in favor of other crops or even pasture.

Another processing and marketing problem arose with cupuaçu. As the plantations came into production, the market for cupuaçu in Rio Branco soon became saturated. Other growers in Acre and in Rondônia expanded production of this crop in the early 1990s, thereby contributing to market saturation. The village where the RECA project is located, Nova Califórnia, is not linked to a utility grid and the small generator for the community only functions at night, and then only sporadically due to break-down problems, as occurred in late May 1996. Without reliable electricity, the pulp of cupuaçu cannot be stored until the off-season when prices are higher. To help overcome this problem, RECA built a small cold storage facility, but it soon filled up. The cold storage room at Nova Califórnia has a back-up generator, but such measures are expensive. To handle the 1996 harvest, RECA rented freezer space in Rio Branco[38] and Porto Velho, where 62 tons of cupuaçu pulp were stored before the end of the harvest season. By May 1996, the project was no longer buying cupuaçu from farmers and a good portion of that year's harvest was lost. The renting of cold storage facilities for pulp is cost effective as long as markets can be found for the product when cupuaçu is out of season, but RECA did not have buyers lined up at that time.

One option for RECA would be to become a supplier of high-quality fermented cupuaçu beans, which could be sold into an incipient market for cupuaçu chocolate. A trial batch of fermented beans was discarded by RECA because a potential buyer offered a price equivalent to processing costs. As interest in cupuaçu beans grows in the United States, Japan, and western Europe, increasing demand for cupuaçu as a dual purpose crop may lead to higher returns.

The Brazil nut trees in the RECA project have only just started producing, and it remains to be seen how successfully plantation Brazil nuts can compete in the market place with those collected in the wild. Nearby Bolivia produces Brazil nuts at prices 15-20% cheaper than in the Brazilian Amazon because of a more favorable exchange rate for export and lower labor costs and taxes. These factors could limit the RECA project's potential from Brazil nut.

Although the RECA project is reluctant to deal with private companies, management now recognizes that technical assistance is an important component of agricultural development. Accordingly, PESACRE and EMBRAPA's center in Acre (CPAF) are assisting some growers who are still active in the RECA project, and MLAL, an Italian NGO with funding from the Italian government, has posted a food technologist at Nova Califórnia to work with the project. The food technologist helped develop products for peach palm flour and cupuaçu, and has taken an active role in developing markets in Nova California and Rio Branco. As a result, some of the growers who had intended to eliminate part of their peach palm plantings are now planning to continue producing fruit.

RECA's main problems are reminiscent of those plaguing R&D institutions involved with agroforestry throughout the Amazon region: an overemphasis on crop production and little attention to processing and marketing. From a production standpoint the RECA project - which has generated impressive yields from tree crops on moderate to poor soils - is an unqualified success. Yet the project's future is clouded by an incapacity to resolve processing and marketing issues. With its chronic dependence on external financial aid, the RECA project is not a viable model for replicating in other parts of Amazonia.

*BONAL* (Natural Rubber, S.A.) provides an interesting contrast to the RECA project. A large rubber plantation and processing firm located halfway between the RECA project and Rio Branco, BONAL started in the mid-1970s with funding from PROBOR, the now defunct program that subsidized rubber planting in Amazonia. In contrast to many PROBOR clients, BONAL actually used this funding to plant more than 1,000 hectares of rubber trees, with kudzu as an understory cover crop. After leaf blight attacked the rubber plantation, BONAL obtained from INPA 400 seedlings of a high-quality, spineless variety of peach palm, which were used to establish a seed garden. In the mid-1980s the company began planting peach palm for palm heart production, and by 1996 it had established 900 hectares in peach palm plantations: 600 hectares intercropped with rubber and kudzu, and 300 hectares as a monocrop, with kudzu as a ground crop.

To fit into the rubber plantation and also allow space for the kudzu, the peach palms were planted at a wider spacing than that recommended for monocultures - 3 x 1 meters instead of 2 x 1 meters. This increased spacing inadvertently generated larger-than-normal palms, which in turn produced large diameter palm hearts. In the late 1980s BONAL set up a processing plant and identified a niche market for large diameter palm hearts: Brazilian barbeque restaurants. BONAL sends trucks of palm heart to markets in central and southern Brazil, and the demand is so great that the Acre plant is unable to provide adequate supply to BONAL's corporate headquarters in São Paulo because most of the product is sold en route. The director of BONAL's operation in Acre, Antônio Neto Vieira, is constantly improving production, processing, and management practices to reduce costs and is looking at other Amazonian fruits as a way to diversify further.

This case illustrates the importance for agroforestry-based enterprises in the Amazon region to focus on processing and marketing. The financial success of such enterprises usually depends on their capacity to identify - or, in this case, create - viable markets for their products.

The *Agroforestry Pole* program in Rio Branco, Acre, is another promising alternative to promoting agroforestry. The municipal government has acquired four pieces of property 16 to 50 kilometers from the city center for settlement by recent migrants to Rio Branco. Settlers in the program are allowed to farm relatively small pieces of land, approximately 5 hectares each (of which 2 hectares are destined for intercropped perennials), a factor that encourages more intensive use of the land than is typically found on 25-100 hectare lots in private or government-run colonization projects. Participants in the agroforestry pole program are offered a basket of crops to select from, including a wide variety of fruit trees, such as mango, banana, cupuaçu, peach palm, açaí, and passionfruit. Settlers receive technical assistance from PESACRE, the Confederation of Agricultural Workers of Acre (CONTAG), the Technology Foundation of Acre (FUNTAC), the local EMBRAPA center (CPAF-Acre), and the Federal University of Acre. The municipal government provides the loan of a tractor to prepare land for planting and other agriculturally-related tasks, and a truck to take produce to market.

The agroforestry pole program has two major goals. First, it aims to reduce the stress on municipal services imposed by the large number of rural-urban migrants that arrive every day in Acre's capital in search of a better life. And second, the program seeks to improve the living standards of the migrants. Candidates for plots in the four agroforestry poles are selected on the basis of previous agricultural experience and availability of family labor. The municipal government has received far more applications for lots than are currently available, an indication that there may be scope for expanding this project around Rio Branco and in other urban centers in Amazonia.

Established in 1993, the oldest agroforestry pole and also the one closest to Rio Branco has experienced unusually low rates of abandonment for an Amazonian settlement project (Slinger, 1996: 52, 73). In this pole alone, farmers have planted over 30 perennial and 28 annual crops (Slinger, 1996:36). As a result of this flexible approach, specialization is already under way. In the oldest agroforestry pole, for example, some farmers have specialized in growing sweet manioc and maize for pig production; others are growing vegetables near the reservoir where irrigation water is readily available; and still other farmers are growing a mix of food and fruit crops.

This unusual success in "fixing" people to the land is due to three factors. First, the municipal government has carefully selected participants for the agroforestry pole program. In contrast, some colonists in other settlement projects in Amazonia have no previous agricultural experience; they merely occupy their lots for a short period until buyers appear. Second, families in the agroforestry pole program are satisfied that their lives have improved and that no better option awaits them in the slums of Rio Branco. Third, and perhaps most importantly, the municipal government retains ownership of the land. Settlers in the program occupy the land on a no-cost lease basis, but cannot sell their plot. In federal colonization projects throughout Amazonia, the National Agency for Colonization and Agrarian Reform (INCRA) does not issue definitive titles for several years, but that has not stopped settlers from selling their lots anyway. Such is not the case in the agroforestry pole program near Rio Branco; if a family leaves their lot, it reverts to the municipal government. Eventually, though, it would seem just to issue titles to long-time residents in the Rio Branco agroforestry poles.

The agroforestry poles are unlikely to prove a panacea for urban squalor - only about 150 families have been settled in the four agroforestry poles - nor will they make a major dent in the large quantities of food Rio Branco has to import to feed the city's inhabitants. Nevertheless, the municipal government's vision in implementing the program is commendable. Even if the next administration decides to withdraw the services currently provided free to the peri-urban agroforestry poles, most of the urban-rural settlers are likely to thrive because:

- All the poles are near a major urban market, accessible by roads that are mostly paved and in good condition, and soon to be serviced by private vehicles.
- The settlement projects have round-the-clock electricity via the utility grid.
- No agroforestry model was imposed on the settlers; they were allowed to chose the crops of interest to them.
- Since the inception of the program, the municipal government has actively sought technical assistance from a wide array of organizations and institutions.

An agronomist who provides technical assistance to the settlers expressed concern that future city governments might prove hostile to the program, thereby "abandoning" the farmers. Such an event could prove a blessing in disguise. If there is any hope that the peri-urban agroforestry program at Rio Branco can be replicated elsewhere, politicians and donors will want to know how quickly such efforts can become self-sustaining. Future peri-urban agroforestry initiatives should have strict time limits for logistical assistance, so that other mayors might be encouraged to try similar schemes. The peri-urban agroforestry poles near Rio Branco cost about US$6,000 per family (Slinger, 1996:18), cheaper than colonization projects operated by INCRA in less privileged areas. Estimates on the cost of settling households in government-directed colonization schemes in the Brazilian Amazon have ranged as high as US$300,000 per family, depending on what is included in the cost analysis (Friedmann, 1996). Although US$300,000 seems on the high side, it is safe to say that Rio Branco's agroforestry pole project is likely to prove more cost effective than most INCRA colonization projects.

The above case studies illustrate a variety of approaches to implementing agroforestry in the Amazon region. The major lessons are that, to be successful, such approaches usually require:

- a focus on processing and marketing issues from the start;
- access to markets and sufficient infrastructure;
- a flexible agroforestry design that can respond to changing conditions;
- technical support to assure high quality germplasm and appropriate plantation management; and
- minimal - or at least short-term - reliance on external sources of funding.

## V. Unleashing Agroforestry's Potential

In the Brazilian Amazon, agroforestry is one of a mosaic of land uses, all of which have a role to play in developing and better managing the region's natural resources, conserving its rich biodiversity, and providing jobs and income for farmers, processors and merchants. Agroforestry has the potential to reduce slash-and-burn farming in certain areas, thereby alleviating the need to encroach on mature forest and allowing some secondary growth to return to forest. Although it is no panacea, agroforestry can help address the need to intensify agricultural production among small-scale farmers while reducing pressure on the rainforest (Browder, 1989; Current et al., 1995a,b).

Nonetheless, agroforestry is clearly under-represented among land use systems in Amazonia, and to achieve its full potential, major socioeconomic and technical constraints need to be overcome. In an increasingly global marketplace, Amazonia is at a distinct disadvantage due its inadequate infrastructure (particularly energy supplies and transportation facilities), lack of agroindustry, incipient farmer organizations, and largely ineffective R&D system. Additionally, the region's abundant pests, diseases, and weeds are powerful limitations to agricultural development. Due to these constraints, most tropical fruits, including those native to Amazonia, are grown and processed in Brazil's Northeast and Southeast where infrastructure is better, markets are larger and closer, and yields can be enhanced more easily. Despite its limitations, however, Amazonia's diverse array of underexploited crops and products provides potential opportunities for local producers and agroindustries.

Based on the preceding analysis, five key constraints to agroforestry development in the Brazilian Amazon and opportunities for overcoming them are briefly discussed below. Although each will be discussed separately, they are closely interrelated. Addressing these constraints will require coordinated regional and national policies and institutional reform (Tables 2 and 3).

### *A. Market Intelligence and Marketing Assistance*

Two of the three cases examined above (BONAL and the Rio Branco agroforestry poles), as well as the case of Tomé-Açu described in the introduction, exhibit a high degree of market awareness, either because a potential market was identified early or

Table 2. Some socioeconomic and political constraints to agroforestry development in Amazonia and proposed remedial measures.

| Problem | Remedial Measure(s) | Responsibility |
|---|---|---|
| Lack of information about markets | Disseminate information on market prices for products in local, regional, and international markets | EMATER, growers' associations, cooperatives, extension services, NGOs, rural radio programs, Globo and Manchete rural TV programs |
| Limited and/or shifting market demand | Innovation, flexibility, increased crop diversity | Private sector |
| Long distances to market in upland areas | Bring processing plants closer to producers so that less fruit and other products perish | Private sector with appropriate credit and tax incentives |
| Insufficient agroindustries to process agroforestry products | Provide greater incentives and credit for small- to large-scale agroindustries; encourage value-added processing rather than export of raw materials | FNO, state banks, BNDES, BASA, international lending agencies (such as IFC) and possibly commercial banks |
| Erratic energy supplies for agroindustrial development | Explore solar energy and hydro-energy options that do not require dams for small-scale industries; tap natural gas supplies in the Juruá basin; promote asceptic packaging instead of freezing | ELETRONORTE and state utility companies, EMBRAPA, EMATER, NGOs |
| Inadequate port facilities, hampering agroforestry development on flood plains and adjacent uplands | Re-direct some of the development programs that have historically focused on uplands to flood plain areas | SUDAM, BASA, EMBRAPA, Ministry of Commerce |
| Insufficient credit for agroforestry development | Remove any remaining biases against agroforestry; create or amplify lines of credit specifically for agroforestry systems where externalities justify them; encourage private sector partnerships | BASA, state banks, commercial banks, regional agroindustries |
| Cumbersome procedures to obtain credit and poor timing of disbursements | Streamline process to obtain credit and receive disbursements; explore other approaches to provide credit, such as through rotating funds | FNO, state banks, BASA, NGOs |

Table 3. Some constraints to agroforestry research and extension in Amazonia and proposed remedial measures.

| Problem | Remedial Measure(s) | Responsibility |
| --- | --- | --- |
| Top-down approach to agroforestry research | Involve farmers in design and implementation of agroforestry systems | EMBRAPA, INPA, Goeldi Museum, universities, and NGOs |
| Little or no analysis of economic and financial viability of agroforestry components or systems | Hire more economists and marketing specialists for various research departments rather than house them in a single unit | EMBRAPA, SEBRAE, INPA, universities, and NGOs |
| Local knowledge undervalued or ignored in agroforestry research and development | Conduct on-farm research on resource management systems of farmers | EMBRAPA, INPA, Goeldi Museum, and universities |
| Inadequate extension service | Partially privatize extension service and encourage closer links with the business community and NGOs; train farmers to carry out extension | EMATER, SENAR, SEBRAE, and NGOs |
| Agricultural research out of sync with market realities and entrepreneurial farmers | Encourage partnerships between the business community, farmers, and scientists to tackle emerging issues by creating a "pool" of research funds | Donor agencies, EMBRAPA, SEBRAE, INPA, universities, agribusiness, growers' associations, cooperatives, and NGOs |
| Lack of information on promising new crops for agroforestry, especially wild or semi-domesticated indigenous plants | Encourage research on the ethnobotany of plants with a wide variety of uses, for potential application in agroforestry; inventory home gardens and assess their subsistence value and commercial potential | EMBRAPA, Goeldi Museum, INPA, universities, and NGOs |
| Inadequate supplies of high quality planting material | Provide incentives for entrepreneurs and public sector institutions to produce more disease-free planting material for agroforestry | Private sector, EMBRAPA, and INPA |

because an existing market was in close proximity. At RECA, market awareness is only arising now, well after production started. Such market awareness has a crucial impact on the success of agroforestry initiatives. Yet none of the major Amazonian R&D institutions has internalized market awareness or used the market to set R&D priorities (Rosa Neto, 1996), and none uses cost-of-production analysis to set crop priorities (Clement, 1997). Without taking market information into account, it is unsurprising that so many Amazonian agricultural and agroforestry researchers work on currently fashionable crops like peach palm and cupuaçu.

EMATER-Rondônia is the only agency in Amazonia that makes a major effort to get price information to local farmers. This effort should be replicated by other extension agencies and expanded to include regional and international prices. In addition, information disseminated to farmers should include the prices of a wide range of native and exotic crops, as well as timber and non-timber forest products. Finally, this information should also include projections of future price variations caused both by seasonality of supply and demand and by increases in area planted. Such projections are especially important in the Brazilian Amazon, which is so extensive that any major planting of a currently marketable crop is likely to depress its price significantly (Fearnside, 1989).

Market intelligence is only one part of the equation, however. Marketing assistance is equally important, especially at the beginning of a project. Part of the Rio Branco agroforestry poles' early success has been due to the municipal government's assistance in providing trucks to get produce to market. This type of assistance is a direct subsidy that must be privatized as soon as possible. Additional assistance is necessary to create markets where none exist or to expand incipient markets. Such assistance can come from two sources: the public sector or joint ventures between various actors in the private sector.

The public sector has at least one agency that provides marketing assistance, SEBRAE, which is present in all state capitals. SEBRAE was created to provide training and assistance in organizational development and marketing to small businesses with the express intention of fostering entrepreneurship. As Clay (1996) points out: "Markets don't create themselves, people do," and these people are entrepreneurs. Local farmer groups may not have sufficient capital or managerial experience to launch and maintain a growers' association or cooperative, or to use market intelligence to take advantage of opportunities and create new markets. SEBRAE recognized this need early and now plays an important role in training farmers to be entrepeneurs, both in Amazonia and elsewhere in Brazil (Clay and Clement 1993).

Another, increasingly important source of marketing assistance for Amazonian farmers involves the formation of joint ventures or partnerships (Clay, 1996:13). One example of such a partnership involves AGROAMAZON, a vertically integrated company located between Vila Extrema and Nova Califórnia in Acre. AGROAMAZON provides financing and technical assistance to help farmers shift to pineapple and other perennial crops, which are processed and marketed by the company. AGROAMAZON has attracted some 45 collaborating farmers to date. While participating farmers lose control over their choice of commercial crops, this example illustrates how a private company can address many of the financial, technical, and marketing constraints presently faced by farmers.

Private companies are often more effective than farmers' associations or cooperatives in processing and commercialization because they are market-oriented and have the relevant contacts (e.g., BONAL).These companies can thus serve as effective partners for farmers and NGOs. Furthermore, such partnerships allow producers to gain part of the value added, while at the same time guaranteeing a steady flow of raw materials to agroindustries.

***B. Processing Technology and Infrastructure***

The three case studies presented above are at different stages in their adoption of processing technology. BONAL identified its needs early and has been perfecting its technology ever since. RECA only recognized the need for a major processing facility when it was flooded with peach palm and cupuaçu fruits and is now scrambling to identify appropriate technologies and get financing to build processing infrastructure. The Rio Branco agroforestry poles are so close to market that there has been no need to introduce processing technologies yet.

If agroforestry is to play a major role in Amazonia, however, processing technology and infrastructure will be needed far from urban centers and markets and for products that may not even exist today. Asceptic packaging is a promising alternative that could permit commercialization of a wide range of currently underexploited fruits. Yet no large scale adoption of this technology has yet occurred in Amazonia, and none of the regional R&D institutions are even experimenting with it today. The idea of putting a fruit processing plant on a barge has been floated several times since the 1960s[39] but has not yet been tried.

Processing technology and its associated infrastructure are often essential for enhancing income and making a viable proposition out of a marginal one. A facility for processing Brazil nuts operated by the Agroextractive Cooperative of Xapuri, Acre, is a case in point (Clay, 1996). Before the facility was established in the late 1980s, Brazil nut was sold by local residents and contributed to keeping family incomes just above subsistence levels. With the facility, these residents were able to add value locally and improve their incomes. Since then the Cooperative has been experimenting with different technologies for Brazil nut processing that hold the potential for adding value locally and at the same time reducing costs, thus making the final product more attractive on the market.

Both RECA and Xapuri required outside assistance to identify processing technologies and build the necessary infrastructure for processing. The need for such assistance is unlikely to change soon. As with marketing assistance, joint ventures with other actors in the private sector can provide processing technology and infrastructure, but the number of businesses in Amazonia ready to form joint ventures to work with local products is still very small. Consequently, farmer organizations will need assistance from other sources to identify processing technologies and finance the processing infrastructure. Unfortunately, the current R&D and extension system is generally poorly equipped to identify the best technologies and design appropriate infrastructure.

The issue of processing technologies is tightly linked to the Amazon region's comparatively poor infrastructure - in particular its availability of electrical energy. The constraints imposed on regional processing due to limited or unreliable electricity were examined earlier in this study. Some of those constraints are likely to be ameliorated in the near future as a result of Brazil's ambitious plans for infrastructural development in the Amazon (Soltani and Osborne, 1997). These plans include extending a transmission line from the Tucuruí dam to the Xingu River valley; constructing a gas pipeline from the Urucu River to Manaus; and paving the road between Manaus and Caracas, thus permitting increased petroleum imports from Venezuela. Various projects aimed at improving transport along roads, railways, and rivers should also enhance Amazonia's capacity to compete with other regions of Brazil.

### *C. New Crop and Product Development*

In industrialized countries, public investment in agricultural R&D is relatively high and institutions exist specifically to encourage new crop and product development (Armstrong, 1996; Janick et al., 1996). Amazonia's R&D system is an inefficient instrument for new crop and product development largely because public support for R&D is meager and inconstant. Paradoxically, however, most agricultural R&D institutions in Amazonia continue with the luxury of allowing individual researchers to establish priorities based on personal interests and experience, rather than in response to market demand. As a result, even if increased funding for agricultural R&D in Amazonia were available, it would only have a positive impact if regional institutions set priorities that are likely to generate new crops and products. As was argued above, market intelligence and cost-of-production analysis can be effective tools for setting priorities in the R&D system.

New crop and product development should not aim toward the single goal of improving the Amazon region's competitiveness vis-à-vis other regions of Brazil. As shown by this study, Amazonia presents a formidable array of constraints to production, processing, and marketing, and as a result its most successful native fruits are now produced elsewhere. Instead, the Amazon's main comparative advantage over other regions lies in its rich biodiversity, which holds the potential of providing a continuous supply of "new" crops and products. Some formerly new crops that originated in Amazonia are cassava, rubber, pineapple, annatto, guaraná, and Brazil nut, and several others are now expanding their markets, such as peach palm, cupuaçu, and camu-camu. The region also offers unique opportunities for gathering information about these and other genetic resources in a variety of settings - such as their use and significance in traditional cultures, their responses to untried planting and processing technologies, or their performance in incipient markets. Whether the new crops or products are ultimately produced in the Amazon or elsewhere, such information will be of immense economic value and could generate private sector transactions in support of regional R&D institutions. In short, shifting priorities toward developing new crops and products in response to market demand could help resolve the current impasse faced by agricultural R&D institutions in Amazonia.

***D. Extension***

The extension service should be an essential complement to the R&D system. Unfortunately this is not the case in Amazonia, where most of the extension service has been reduced drastically in recent years. If rural development is to proceed in the region, this trend must be reversed and the regional extension service - both public and private - made more effective. The main tasks of a renewed extension service should be to disseminate to farmers up-to-date information on crops, obtained largely through the R&D system. In addition, it should provide feedback to the R&D system and help define priorities. Finally, a well-run extension service should assist farmers in creating their own organizations for producing, processing, and marketing crops.

Many agencies have long recognized farmer organizations as essential components of sustainable agricultural development in Amazonia. In response to BASA's requirement that loans for small-scale producers be channeled through farmer organizations, many such organizations subsequently arose for the sole purpose of capturing credit. In addition to credit, however, successful farmer organizations require training in areas such as administration, accounting, marketing, and conflict resolution, so that farmers will be able to assume full responsibility for their organizations. Yet, with the exception of SEBRAE, few institutions in Amazonia are addressing this extremely important task.

To increase agroforestry's competitiveness with other land use systems, farmers require technical training in the propagation and management of perennial crops. In this context, the efforts of NGOs such as REBRAF and especially POEMA are exemplary. Recently these and other NGOs have focused on training extension agents in agroforestry technologies, so that these can train farmers more effectively and thus exert a multiplier effect. More such efforts are urgently needed to assure that agroforestry attains a more prominent place on the agenda of extension agencies in Amazonia.

Finally, given limited resources and the Amazon region's immense geographic area, agricultural extension needs to be increasingly strategic, focusing field visits on priority locales, using appropriate media such as radio to reach wider areas, and building strong farmer organizations through training in some of the critical areas identified above.

***E. Credit***

As discussed earlier in this study, commercial interest rates in Brazil are too high for either farmers or entrepreneurs interested in processing agricultural products. In addition, two factors - lack of information and high transaction costs - reduce the effectiveness of the few government-subsidized credit programs in Amazonia that target small-scale producers and agroforestry. Lack of information on native perennial crops and cropping systems greatly limits the capacity of regional and state banks to evaluate the economic viability of proposed agroforestry systems. While FCAP has done an excellent job to date in generating such information for a few perennial crops, the involvement of other R&D institutions will be needed to produce studies for a wider range of crops and cropping systems in Amazonia.

High transaction costs are inherent to credit programs aimed at small-scale producers, especially in a sparsely populated region such as Amazonia. One way of reducing such costs is to improve the efficiency of credit programs. BASA, for example, has recently computerized much of its application process and requires that a collaborating extension agency, IDAM, supply applications on diskette. For this to work smoothly, IDAM must be computerized as well. BASA also requires that IDAM meet strict deadlines to get credit to the farmer at the right time. According to BASA,[40] improved efficiency resulted in timely credit disbursements to small-scale producers during 1996-97.

Increasingly, new institutional actors are beginning to furnish credit for agroforestry initiatives in the Brazilian Amazon. International development agencies and locally based agribusinesses are exploring new strategies for extending loans to small-scale producers engaged in this land use. If successful, these efforts could point the way for regional banks to play a more effective role in promoting agroforestry.

***F. Agroforestry as a Knowledge-Based Land Use***

The preceding paragraphs summarize the major constraints and opportunities facing agroforestry development in the Amazon region - which constitute the central theme of this study. The constraints to agroforestry development in the region are formidable, and overcoming them will require strategic and coordinated efforts on an unprecedented scale. As a result, prospects for success are uncertain. Yet Amazonia is not an isolated case: the essential changes needed to promote agroforestry development there are part of a larger process of change in the way agriculture is practiced worldwide.

This change involves the paradigms guiding agricultural development, which are shifting away from commodity oriented, high input models toward more knowledge intensive systems that rely on skillful resource management. In Amazonia, much of this paradigm shift is manifest in the need for new approaches to agricultural research. One new approach, for example, involves disciplinary focus. This study has shown that the major constraints to agroforestry development are social and economic in nature, yet all too frequently, regional centers undertake biophysical research with little if any attention to the social or economic viability of proposed land use systems. This must change if R&D institutions hope to remain relevant to farmers' needs.

In addition, the changing paradigm of agricultural research urgently requires greater emphasis on participatory research with farmers (Cooper et al., 1996; Pichón and Uquillas, 1996; Tamale et al., 1995; Thrupp et al., 1994). Participatory research can stretch scarce R&D funds and garner support from society for increased funding.

Such research often builds on the knowledge of farmers. Along the Maracá River in Amapá, for example, local producers plant or encourage valuable fruit, nut, and timber trees in their agricultural plots after food crops have been harvested. In addition to requiring minimal investment, such fallow management has the advantage of generating minimal environmental impacts. Testing this option could reveal strategies for promoting agroforestry that are socially acceptable, cost-effective, and environmentally sound.

Finally, the changing paradigm of agricultural research requires modern approaches as well. Recent advances in understanding of soil biology, plant fertility, and plant-animal interactions offer opportunities for reduced use of chemical inputs in agricultural systems, with resulting economic and environmental benefits. And new breakthroughs in biotechnology open up exciting possibilities for use of the Amazon region's rich biodiversity. Progress in promoting agroforestry, in short, hinges on a judicious blend of modern scientific research, indigenous knowledge, and the conservation of forest environments - all filtered through the market.

## Endnotes

[1] This and other compensatory mechanisms are expected to be defined in the December 1997 conference of the Global Climate Change Convention in Kyoto.

[2] See Appendix 1 for scientific names of plants cited in the text that are used in agroforestry systems in the Brazilian Amazon.

[3] A prominent example of forest enrichment following slash-and-burn farming involves high-density stands of the açaí palm found adjacent to human settlements in the Amazon estuary.

[4] In extensive areas of the Tocantins River valley of Pará state, for example, cattle ranches are rapidly supplanting enriched forests of Brazil nut.

[5] In the vicinity of the community of Araras in Tocantins River valley, for example, mature forests enriched with Brazil nut and cupuaçu are maintained as part of the local production systems and provide a major source of income for small-scale farmers.

[6] N.J.H. Smith, unpublished field notes.

[7] Jonas Veiga, personal communication.

[8] According to the last published agricultural census of 1985 (IBGE, 1987), of the total area in rural properties in six Amazonian states (Acre, Amapá, Amazonas, Pará, Rondônia, and Roraima), 3.0% was used for cultivation of traditional food crops and at least 3-4 times this area if forest fallows are included. By contrast, only 1.5% was allocated to perennial crops - including both monocropping with perennials and agroforestry.

[9] Jason Clay, personal communication.

[10] Rogério Perin, personal communication.

[11] Of the 43 farmers interviewed who had adopted agroforestry, 25 (58%) had included timber species as part of their agroforestry systems.

[12] John O. Browder, personal communication.

[13] The information presented on asceptic packaging was provided by Jason Clay

personal communication.

[14] Edward Richardson, personal communication.

[15] Jason Clay, personal communication.

[16] In mid-1996, commercial interest rates were 5-6% per month, even though inflation was under 2% a month.

[17] Fernando Silva, personal communication.

[18] "Prefeito queixa-se da demora na liberação de verbas pelo BASA." *O Liberal*, Belém, Pará, 9 May 1996.

[19] "BASA faz acordo sobre FNO para Transamazônica." *O Liberal*, Belém, Pará, 9 May 1996.

[20] Farmers in the Altamira region of the Transamazon appear to have received a disproportionate share of the financing thanks to political pressure from an umbrella group called the Movement for Survival on the Transamazon (MPST). But even there, less than 10 percent of the farmers have presented proposals for financing from FNO Especial. In the Municipality of Santarém, only about 300 of the 2,000 applicants for financing from FNO Especial had their loans approved and processed in 1995 (Mário Tanaka, personal communication).

[21] In 1997, the average exchange rate for the Brazilian real was R$1.07/US$.

[22] Mauro J. Arruda, personal communication.

[23] Fernando Silva, personal communication.

[24] John O. Browder, personal communication.

[25] Jason Clay, personal communication.

[26] For example, among the 53 farmer families surveyed as part of this study, 43 (81%) had adopted agroforestry systems. Of these, 25 (58%) possessed some form of legally recognized title; the rest either had informal use rights or were squatters.

[27] John O. Browder, personal communication.

[28] Márcio Miranda, personal communication.

[29] The timber species tested were morototó, quaruba, mahogany, tatajuba, freijó, and cumaru.

[30] Alfredo Homma, personal communication.

[31] N.J.H. Smith, unpublished field notes.

[32] To place the issue in perspective, in 1994 the United States allocated 2.5% of its GNP to R&D, while the corresponding figure in Brazil was only 0.77% of a much smaller GNP (CNPq, 1996). And within Brazil, a mere 1.5-2% of the R&D budget--or about US$75-100 million per year--is allocated to the Amazon region (Ernesto de Paula, personal communication).

[33] Fernando Silva, personal communication.

[34] Imar Cesar de Araújo, personal communication.

[35] Projeto RECA has now established fruitful partnerships with PESACRE and CPAF, EMBRAPA's center in Acre.

[36] RECA's main supporters have been CEBEMO, a charitable Catholic organization in the Netherlands, and CCFD (Catholic Committee against Hunger and for Development), a similar organization in France.

[37] RECA's processing plant for cupuaçu is occasionally switched over to heart-of-palm processing for small loads, but facilities do not exist for properly sterilizing bottles.

[38] The Rio Branco cold storage facility went out of business in late 1996, making it even more difficult for RECA to handle its 1997 cupuaçu crop (Sonia Alfaia and Beatriz Telles, INPA, personal communication).

[39] Flaviano Guimarães, personal communication.

[40] Mauro J. Arruda, personal communication.

## References


Anderson, A.B. 1988. Use and management of native forests dominated by açaí palm (*Euterpe oleracea* Mart.) in the Amazon estuary. *Advances in Economic Botany* 6:144-154.

_ (Editor). 1990. *Alternatives to Deforestation: Steps Toward Sustainable Use of the Amazon Rain Forest.* Columbia University Press, New York.

_ and E.M. Ioris. 1992. Valuing the rain forest: economic strategies by small-scale forest extractivists in the Amazon estuary. *Human Ecology* 20(3): 337-369.

Anonymous. 1997. Estudos setoriais 10: A cadeia produtiva do côco-da-bahia na região norte e as interrelações de mercado. BASA/FCAP, Belém.

Armstrong, R. 1996. The Alternative Agricultural Research and Commercialization Center (AARC), U.S. Department of Agriculture. In: *Progress in New Crops*, J. Janick (Editor), pp. 119-120. American Society for Horticultural Sciences, Alexandria, VA.

Balée, W. 1989. The culture of Amazonian forests. *Advances in Economic Botany* 7:1-21.

_ and A. Gély. 1989. Managed forest succession in Amazonia: the Ka'apor case. *Advances in Economic Botany* 7:129-158.

Bandy, D.E. 1994. ICRAF's strategies to promote agroforestry systems. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho*, L.J. Montoya and M. Medrado (Editors), Vol. 1, pp. 15-31. EMBRAPA (Centro Nacional de Pesquisas de Florestas/Centro de Pesquisa Agroflorestal de Rondônia), Colombo, Paraná.

Brondizio, E.S., E.F. Moran, P. Mausel, and Y. Wu. 1994. Land use change in the Amazon estuary: patterns of caboclo settlement and landscape management. *Human Ecology* 22(3): 249-278.

Browder, J.O. and B.J. Godfrey. 1997. *Rainforest Cities: Urbanization, Development and Globalization of the Brazilian Amazon.* Columbia University Press, New York.

_, E.A.T. Matricardi and W.S. Abdala. 1996. Is sustainable timber extraction financially viable? A comparative analysis of mahogany silvivulture among small farmers in the Brazilian Amazon. *Ecological Economics* 16:147-159.

_. 1989. Development alternatives for tropical rain forests. In: *Environment and the Poor: Development Strategies for a Common Agenda.* H. J. Leonard (Editor), pp. 111-133. Transaction Books, New Brunswick.

Castellanet, C., J. Alves, and B. David. 1996. A parceria entre organizações de produtores e equipe de pesquisadores: a pesquisa participativa no PAET. *Agricultura Familiar* 1(1): 139-161.

Caviedes, C.N. and K.D. Muller. 1994. Fruticulture and uneven development in Northeast Brazil. *Geographical Review* 84(4): 380-393.

Clay, J.W. 1996. *Generating Income and Conserving Resources: 20 Lessons from the Field.* World Wildlife Fund, Washington, D.C.

Clay, J.W. and C.R. Clement (eds). 1993. *Selected Species and Strategies to Enhance Income Generation from Amazonian Forests.* Misc/93/6 Working

Paper, Forestry Dept., FAO, Rome.
Clement, C.R. 1996. Erosão genética nas coleções de germoplasma da Amazônia brasileira: causas, conseqüências, opções. In: Resumos do 8° Encontro de Pesquisadores da Amazônia, Mesa Redonda - Recursos Genéticos Vegetais, p. 213. Univ. Fed. Rondônia, Porto Velho, 14-17 October.
Clement, C.R. 1997. Development of underutilized crops in Latin America. Presented at: 2nd Mediterranean Selected Fruit Inter-Country Network (MESFIN) Meeting on Plant Genetic Resources and Fruit Production, MESFIN/FAO/ICUC, Funchal, Madeira, Portugal, 5-8 August.
CNPq. 1996. *Indicadores Nacionais de Ciência e Tecnologia.* Conselho Nacional de Desenvolvimento Científico e Tecnológico, Ministério de Ciência e Tecnologia, Brasília.
Cooper, P.J.M., R.R.B. Leakey, M.R. Rao, and L. Reynolds. 1996. Agroforestry and the mitigation of land degradation in the humid and sub-humid tropics of Africa. *Experimental Agriculture* 32:235-290.
Current, D., E. Lutz, and S. J. Scherr. 1995a. *Costs, Benefits, and Farmer Adoption of Agroforestry: Project Experience in Central America and the Caribbean.* Environment Paper 14, World Bank, Washington, D.C.
_ 1995b. The costs and benefits of agroforestry to farmers. *The World Bank Research Observer* 10(2):151-180.
Denevan, W.M. and C. Padoch (Editors). 1987. *Swidden-Fallow Agroforestry in the Peruvian Amazon.* Advances in Economic Botany 5, The New York Botanical Garden, New York.
Dubois, J.C. L. (Editor). 1996. *Manual Agroflorestal para a Amazônia.* Instituto Rede Brasileira Agroflorestal (REBRAF), Rio de Janeiro, Vol. 1.
Fearnside, P.M. 1989. Deforestation and agricultural development in Brazilian Amazonia. *Interciencia 14*(6): 291-297.
_. 1990. Environmental destruction in the Brazilian Amazon. In: *The Future of Amazonia: Destruction or Sustainable Development?*, D. Goodman and A. Hall (Editors), pp. 179-225. MacMillan, London.
_. 1993. Deforestation in Brazilian Amazonia: The effect of population and land tenure. *Ambio 22*(8): 537-545.
_. 1995. Agroforestry in Brazil's Amazonian development policy: the role and limits of a potential use for degraded lands. In: *Brazilian Perspectives on Sustainable Development of the Amazon Region*, M. Clüsener-Godt and I. Sachs (Editors), pp. 125-148. UNESCO/Oxford University Press, Paris.
Friedmann, J. 1996. Borders, margins, and frontiers: myth and metaphor. In: *Frontiers in Regional Development*, Y. Gradus and H. Lithwick (Editors), pp. 1-20. Rowman and Littlefield, London.
Hammond, D.S., P.M. Dolman, and A.R. Watkinson. 1995. Modern Ticuna swidden-fallow management in the Colombian Amazon: ecologically integrating market strategies and subsistence-driven economies? *Human Ecology* 23(3): 335-355.

Hiraoka, M. 1989. Agricultural systems on the floodplains of the Peruvian Amazon. In: J.O. Browder (Editor), *Fragile Lands of Latin America: Strategies for Sustainable Development*, pp. 75-101. Westview Press, Boulder.

Homma, A.K.O., R.T. Walker, R.A. Carvalho, C.A.P. Ferreira, A.J. Conto, and A.I.M. Santos. 1994. Dinâmica dos sistemas agroflorestais: o caso dos agricultores Nipo-Brasileiros em Tomé-Açu, Pará. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho*, L.J. Montoya and M.J.S. Medrado (Editors), Vol. 2, pp. 51-61. EMBRAPA (CNPF/CPAF-RO), Colombo, Paraná.

IBGE. 1987. *Sinópse Preliminar do Censo Agropecuário: Censos Econômicos 1985*, Vol 4(6). Fundação Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro.

Janick, J., M.G. Blase, D.L. Johnson, G.D. Jolliff, and R.L. Myers. 1996. Diversifying U.S. crop production. In: *Progress in New Crops*, J. Janick (Editor), pp. 98-108. American Society for Horticultural Sciences, Alexandria, VA.

Johnson, D. and P.K. Nair. 1985. Perennial crop-based agroforestry systems in Northeast Brazil. *Agroforestry Systems* 2:281-292.

Kishor, N. M. and L. F. Constantino. 1996. *Voting for Economic Policy Reform: Efficiency Gains and Redistribution Impacts of Removing the Log Export Ban in Costa Rica.* World Bank, LATEN Dissemination Note 15, Washington, DC.

LAET. 1996. *Relatório Anual do LAET (Ano 1995).* Laboratório Agro-Ecológico da Transamazônica, Altamira, Pará.

Leeuwen, J. 1994. Planejamento de ensaios com sistemas agroflorestais. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho*, L.J. Montoya and M.J.S. Medrado (Editors), Vol. 1, pp. 463-473. EMBRAPA (CNPF/CPAF-RO), Colombo, Paraná.

_ and J.B.M. Gomes. 1995. O pomar caseiro na região de Manaus, Amazonas: um importante sistema agroflorestal tradicional. In: *Anais do Segundo Encontro da Sociedade Brasileira de Sistemas de Produção*, pp. 180-189, IAPAR/SBS, Londrina, Paraná.

_, M.M. Pereira, F.C.T. Costa, and F.A. Catique. 1994. Transforming shifting cultivation fields into productive forests. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho*, L.J. Montoya and M.J.S. Medrado (Editors), Vol. 2, pp. 431-438. EMBRAPA (CNPF/CPAF-RO), Colombo, Paraná.

, J.M.T. Menezes, J.B. Moreira Gomes, J.H. IriarteMartel, and C.R. Clement. 1997. Sistemas agroflorestais. In: *Vinte anos de pesquisas agronômicas no INPA*, H. Noda, L.A.G. Souza, O.J.M. Fonseca, and M.F. Freitas (Editors). Instituto Nacional de Pesquisas da Amazônia, Manaus. (In press)

Matricardi, E. and W. Abdala. 1993. Mogno em Rondônia. Unpublished report to the United States Fish and Wildlife Service, Washington, D.C.

Miller, R. P. 1994. Estudo da fruticultura tradicional dos índios Waimiri-Atroari: base para a extensão agroflorestal. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho*, L.J. Montoya and M.J.S. Medrado (Editors), Vol. 2, pp. 449-462. EMBRAPA (CNPF/CPAF-RO), Colombo, Paraná.

Murrieta, R.S.S., E. Brodízio, A. Siqueira, E.F. Moran. 1992. Estratégias de subsistência da comunidade de Praia Grande, Ilha de Marajó, Pará, Brasil. *Boletim do Museu Paraense Emílio Goeldi, Série Antropologia* 8(2):185-201.

Myers, N. 1992. Tropical forests: the policy challenge. *The Environmentalist (Spring)*.

Nair, P.K. 1990. *The Prospects for Agroforestry in the Tropics*. Technical Paper 131, World Bank, Washington, D.C.

_. 1991. State-of-the-art of agroforestry systems. *Forest Ecology and Management* 45:5-29.

_ and J.C. Dagar. 1991. An approach to developing methodologies for evaluating agroforestry systems in India. *Agroforestry Systems* 16:15-81.

Newton, A.C., R.R.B. Leakey, W. Powell, K. Chalmers, R. Waugh, Z. Tchoundjeu, P.J. Mathias, P.G. Alderson, J.F. Mesén, P. Baker, and S. Ramnarine. 1994. In: *Tropical Trees: the Potential for Domestication and the Rebuilding of Forest Resources*, Leakey, R.R.B. and A.C. Newton (Editors), pp. 256-266. HMSO, London.

Padoch, C. 1988. Aguaje (*Mauritia flexuosa* L. f.) in the economy of Iquitos, Peru. *Advances in Economic Botany* 6:214-224.

_ and W. de Jong. 1995. Subsistence and market-oriented agroforestry in the Peruvian Amazon. In: *The Fragile Tropics of Latin America: Sustainable Management of Changing Environments*, T. Nishizawa and J. Uitto (Editors), pp. 226-237. United Nations University Press, Tokyo.

_, J. Chota Inuma, W. de Jong, and J. Unruh. 1985. Amazonian agroforestry: a market-oriented system in Peru. *Agroforestry Systems* 3:47-58.

Peters, C.M., M.J. Balick, F. Kahn, and A.B. Anderson. 1989. Oligarchic forests of economic plants in Amazonia: utilization and conservation of an important tropical resource. *Conservation Biology* 3(4):341-349.

Pichón, F. and J.E. Uquillas. 1996. *Sustainable Agriculture and Poverty Reduction in Latin America's Risk-Prone Areas: Opportunities and Challenges*. World Bank, Latin America and the Caribbean Technical Department, Regional Studies Program, Report No. 40.

Pimentel, D., U. Stachow, D.A. Takacs, H.W. Brubaker, A.R. Dumas, J.J. Meaney, J.A.S. O'Neil, D.E. Onsi, and D.B. Corzilius. 1992. Conserving biological diversity in agricultural/forestry systems. *Bioscience* 42(5):354-362.

PLANAFLORO. 1995. *Sistemas Agroflorestais como Alternativa Auto-Sustentável para o Estado de Rondônia 1: Histórico, Aspectos Agronômicos e Perspectivas de Mercado*. PLANAFLORO, Porto Velho.

POEMA. 1995. Alternatives for indigenous groups: indigenous groups seek sustainable development alternatives at POEMA/UFPA. *POEMA Forum Alliances for Life* 2(4):1, 11.
Pollak, H., M. Mattos, and C. Uhl. 1995. A profile of palm heart extraction in the Amazon estuary. *Human Ecology* 23(3): 357-385.
Rizzini, C.T. and W.B. Mors. 1995. *Botânica Econômica Brasileira*, 2nd ed. Âmbito Cultural, Rio de Janeiro.
Rosa Neto, C. 1996. Marketing e inovação tecnológica: um estudo de caso em uma instituição de pesquisa agropecuária. In: *Resumos, VIII Encontro de Pesquisadores da Amazônia - Ecodesenvolvimento da Amazônia*, p. 70, Universidade de Rondônia, Porto Velho, RO.
Salick, J., N. Cellinese, and S. Knapp. 1997. Indigenous diversity of cassava: generation, maintenance, use and loss among the Amuesha, Peruvian Upper Amazon. *Economic Botany* 51(1): 6-19.
Sanchez, P. 1995. Science in agroforestry. *Agroforestry Systems* 30:5-55.
Saragoussi, M., J.H.I. Martel, and G.A. Ribeiro. 1990. Comparação na composição de quintais de três localidades de terra firme do Estado do Amazonas, Brasil. In: *Ethnobiology: Implications and Applications*, Posey, D.A. and W.L. Overal (Editors), pp. 295-303. SCT/CNPq, Museu Paraense Emilio Goeldi, Belém, Pará.
Serrão, E.A.S., D. Nepstad, and R. Walker. 1996. Upland agricultural and forestry development in the Amazon: sustainability, criticality and resilience. *Ecological Economics* 18:3-13.
Slinger, V.A.V. 1996. *Analysis of a Planned Agroforestry System in Amazon Resettlement: A Case Study of the Pólo Municipal de Produção Agroflorestal of Acre, Brazil.* Master of Arts Thesis, University of Florida, Gainesville.
Smith, N.J.H. 1982. *Rainforest Corridors.* University of California Press, Berkeley.
_. 1995. Human-induced landscape changes in Amazonia and implications for development. In: *Global Land Use Change: A Perspective from the Columbian Encounter*, B.L. Turner II, A. Gómez, Fernando González, F. Castri (Editors), pp. 221-251. Consejo Superior de Investigaciones Científicas, Madrid.
_. 1996. Home gardens as a springboard for agroforestry development in Amazonia. *International Tree Crops Journal* 9:11-30.
_, T.J. Fik, P. Alvim, I.C. Falesi, and E.A.S. Serrão. 1995a. Agroforestry developments and potential in the Brazilian Amazon. *Land Degradation and Rehabilitation* 6:251-263.
_, E.A.S. Serrão, P. Alvim, and I.C. Falesi. 1995b. *Amazonia: Resiliency and Dynamism of the Land and its People.* United Nations University Press, Tokyo.
_, I.C. Falesi, P.T. Alvim, and E.A.S. Serrão. 1996. Agroforestry trajectories among smallholders in the Brazilian Amazon: innovation and resiliency in pioneer

and older settled areas. *Ecological Economics* 18:15-27.
Soltani, A. and T. Osborne. 1997. *Arteries for Global Tade, Consequences for Amazonia.* Amazon Watch, Malibu, CA.
Souza, V. F., C.M.V. Almeida, P.M.P. Alves, W.S. Abdala, J.M.T. Menezes, and J.M. Sales. 1994. Sistemas agroflorestais no Estado de Rondônia. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho,* L.J. Montoya and M. Medrado (Editors), Vol. 1, pp. 133-140. EMBRAPA (Centro Nacional de Pesquisas de Florestas/Centro de Pesquisa Agroflorestal de Rondônia), Colombo, Paraná.
Tamale, E., N. Jones, and I. Pswarayi-Riddihough. 1995. *Technologies Related to Participatory Forestry in Tropical and Subtropical Countries.* World Bank Technical Paper 299, Washington, D.C.
Thrupp, L.A., B. Cabarle, and A. Zazueta. 1994. Participatory methods in planning and political processes: linking the grassroots and policies for sustainable development. *Agriculture and Human Values* 11(2-3): 77-84.
Toniolo, A. and C. Uhl. 1995. Economic and ecological perspectives on agriculture in the eastern Amazon. *World Development* 23(6):959-973.
_ and C. Uhl. 1996. Perspectivas econômicas e ecológicas da agricultura na Amazônia Oriental. In: *A Evolução da Fronteira Amazônica: Oportunidades para um Desenvolvimento Sustentável,* O.T. Almeida (Editor), pp. 68-96. IMAZON, Belém.
Virginia Tech. 1996. *Planting Seeds of Change in the Ashes of the Rainforest: the Rondônia Agroforestry Pilot Project.* Virginia Polytechnic Institute and State University, Blacksburg, VA.
Walker, R.T., A.F.O. Homma, R.A. Carvalho, C.A.P. Ferreira, A.J. Conto, F.N. Scatena, A.C.P. Rocha, A.I.M. Santos, and P.M. Oliveira. 1994a. Sistemas agroflorestais como processo evolutivo: o caso dos agricultores da Rodovia Cuiabá-Santarém, no Estado do Pará. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 July,* L.J. Montoya and M.J.S. Medrado (Editors), Vol. 2, pp. 29-42. EMBRAPA (CNPF/CPAF-RO), Colombo, Paraná.
_, A.K.O. Homma, A.J. Conto, R.A. Carvalho, C.A.P. Ferreira, A.I.M. Santos, A.C.P. Rocha, P.M. Oliveira, and F.N. Scatena. 1994b. Farming systems and economic performance in the Brazilian Amazon. In: *Anais do I Congresso Brasileiro sobre Sistemas Agroflorestais, Porto Velho, 3-7 Julho,* L.J. Montoya and M.J.S. Medrado (Editors), Vol. 2, pp. 415-429. EMBRAPA (CNPF/CPAF-RO), Colombo, Paraná.

## *Appendix*

Common and scientific names of some plants found in agroforestry systems in the Brazilian Amazon.

| **English Name (s)** | **Portuguese Name(s)** | **Scientific Name** |
|---|---|---|
| Açaí | Açaízeiro | *Euterpe oleracea* |
| Angico | Angico | ? |
| Annatto | Urucum | *Bixa orellana* |
| Avocado | Abacate | *Persea americana* |
| Babaçu | Babaçu, côco | *Orbignya phalerata* |
| Banana | Banana | *Musa* spp. |
| Barbados cherry | Acerola | *Malpighia punicifolia* |
| Black pepper | Pimenta do reino | *Piper nigrum* |
| Brachiarão | Brachiarão, brizantão | *Brachiaria brizanthum* |
| Brazil nut | Castanheira | *Bertholletia excelsa* |
| Breadfruit | Fruta-pão | *Artocarpus altilis* |
| Cacao | Cacao | *Theobroma cacao* |
| Camu-camu | Camu-camu, sarão | *Myrciaria dubia* |
| Canafista | Canafista | ? |
| Cedar | Cedro | *Cedrela odorata* |
| Coconut | Côco | *Cocos nucifera* |
| Cumaru | Cumaru | *Dipteryx odorata* |
| Cupuaçu | Cupuaçu, cupu | *Theobroma grandiflorum* |
| Erythrina | Eritrina | *Erythrina fusca, E. poeppigiana* |
| Faveira | Faveira | Legume family |
| Figueira | Figueira | *Ficus* sp. |
| Freijó | Freijó | *Cordia alliodora, C. goeldiana* |
| Gameleira | Gameleira | *Ficus* sp. |
| Gmelina | Gmelina | *Gmelina arborea* |
| Guaraná | Guaraná | *Paullinia cupana* var. *sorbilis* |
| Guava | Goiabeira | *Psidium guajava* |
| Guinea grass | Colonião | *Panicum maximum* |
| Ingá | Ingá | *Inga* spp. |
| Ipê | Ipê | *Tabebuia* sp. |
| Itaúba | Itaúba | *Mezilaurus itauba* |
| Jackfruit | Jaca | *Artocarpus heterophyllus* |
| Jarana | Jarana | *Holopyxidium latifolium* |
| Kapok | Sumaúma | *Ceiba pentandra* |
| Kudzu | Pueraria | *Pueraria* sp. |
| Lime | Limão | *Citrus aurantifolia* |
| Madre del cacao | Madre del cacao | *Gliricidia sepium* |

| English Name (s) | Portuguese Name(s) | Scientific Name |
|---|---|---|
| Mahogany | Mogno | *Swietenia macrophylla* |
| Malaya apple | Jambu | *Syzygium malaccense* |
| Mango | Mangeira | *Mangifera indica* |
| Manioc, cassava | Mandioca, macaxeira | *Manihot esculenta* |
| Melancieira | Melancieira | ? |
| Mororó | Mororó | *Bauhinia bicuspidata* |
| Morototó | Morototó | *Didymopanax morotoni* |
| Murici | Murici | *Byrsonima crassifolia* |
| Orange | Laranjeira | *Citrus sinensis* |
| Oil palm | Dendê | *Elaeis guineensis* |
| Palheteira | Palheteira | *Clitoria racemosa* |
| Papaya | Mamão | *Carica papaya* |
| Paricá | Paricá, bandarra | *Schizolobium amazonicum* |
| Passionfruit | Maracujá | *Passiflora edulis* |
| Pau mulato | Pau mulato | *Peltogyne paniculata* |
| Peach palm | Pupunha | *Bactris gasipaes* |
| Pindaíba | Pindaíba | *Xylopia frutescens* |
| Pineapple | Abacaxi | *Ananas comosus* |
| Pinho cuiabano | Pinho cuiabano | *Parkia* cf. *multijuga* |
| Quaruba | Quaruba | *Vochysia* sp. |
| Robusta coffee | Café | *Coffea canephora* |
| Rubber | Seringueira | *Hevea brasiliensis* |
| Soursop | Graviola | *Annona muricata* |
| Sweetsop | Ata | *Annona squamosa* |
| Tamarind | Tamarindo | *Tamarindus indica* |
| Tangerine | Tangerina | *Citrus reticulata* |
| Tatajuba | Tatajuba | *Bagassa guianensis* |
| Tauari | Tauari | *Cariniana* sp. |
| Teak | Teca | *Tectona grandis* |
| Umarí | Umarí | *Poraqueiba sericea* |
| Yellow mombim | Taberebá, cajá | *Spondias mombim* |
| No English name | Biribá | *Rollinia mucosa* |

This study - and the publication series of which it is part - was supported by the **Pilot Program to Conserve the Brazilian Rain Forest.** Launched in 1991 and funded by the G-7 countries, the European Union, and the Brazilian government, the Pilot Program is implemented by numerous governmental agencies and NGOs, under the coordination of the Secretariat for the Coordination of Amazon Affairs in Brazil's Ministry of Environment and the World Bank. With currently about US$ 250 million in grant funds, this program represents the largest multilateral donation for environmental conservation in a single country. Its 12 core projects cover a wide array of initiatives in Brazil's Amazon and Atlantic forest regions, including the consolidation of protected areas, extractive reserves and indigenous reserves; innovative approaches to management of forests and flood plains; environmentally sound development initiatives carried out by local communities; strategic research and strengthening of key research centers; and improved surveillance and enforcement of environmental policies.

*Conservation and Development of Brazil's Tropical Forest Regions* is a publication series produced jointly by the World Bank and the Secretariat for the Coordination of Amazon Affairs. The series consists of 50 - to 100-page booklets, amply illustrated and written in jargon-free language (English and Portuguese), which provide state-of-the-art synthesis of key issues of relevance to the Pilot Program in particular, and to tropical forest conservation and development in general. In addition to the current volume on agroforestry, future volumes will address issues such as forest fires, logging, demarcation and sustainable use of indigenous lands, and strategies for biodiversity protection and use. The series is aimed to rise awareness of such issues among a broad audience in Brazil and internationally.

World Bank

MINISTRY OF ENVIRONMENT,
WATER RESOURCES AND THE LEGAL AMAZON
SECRETARIAT FOR THE COORDINATION OF AMAZON AFFAIRS

It's time for Brazil