Agroforestry in Sub-Saharan Africa

A Farmer’s Perspective

Cynthia C. Cook and Mikael Grut
RECENT WORLD BANK TECHNICAL PAPERS

No. 56. Silverman, Kettering, and Schmidt, Action-Planning Workshops for Development Management: Guidelines
No. 57. Obeng and Wright, The Co-composting of Domestic Solid and Human Wastes
No. 58. Levitsky and Prasad, Credit Guarantee Schemes for Small and Medium Enterprises
No. 59. Sheldrick, World Nitrogen Survey
No. 60. Okun and Ernst, Community Piped Water Supply Systems in Developing Countries: A Planning Manual
No. 61. Gorse and Steeds, Desertification in the Sahelian and Sudanian Zones of West Africa
No. 63. Mould, Financial Information for Management of a Development Finance Institution: Some Guidelines
No. 64. Hillel, The Efficient Use of Water in Irrigation: Principles and Practices for Improving Irrigation in Arid and Semiarid Regions
No. 65. Hegstad and Newport, Management Contracts: Main Features and Design Issues
No. 66F. Godin, Préparation des projets urbains d'aménagement
No. 68. Armstrong-Wright and Thiriez, Bus Services: Reducing Costs, Raising Standards
No. 69. Prevost, Corrosion Protection of Pipelines Conveying Water and Wastewater: Guidelines
No. 70. Falloux and Mukendi, Desertification Control and Renewable Resource Management in the Sahelian and Sudanian Zones of West Africa (also in French, 70F)
No. 71. Mahmood, Reservoir Sedimentation: Impact, Extent, and Mitigation
No. 72. Jeffcoate and Saravanapavan, The Reduction and Control of Unaccounted-for Water: Working Guidelines (also in Spanish, 72S)
No. 73. Palange and Zavala, Water Pollution Control: Guidelines for Project Planning and Financing (also in Spanish, 73S)
No. 74. Hoban, Evaluating Traffic Capacity and Improvements to Road Geometry
No. 75. Noetstaller, Small-Scale Mining: A Review of the Issues
No. 76. Noetstaller, Industrial Minerals: A Technical Review (also in French, 76F)
No. 77. Gunnerson, Wastewater Management for Coastal Cities: The Ocean Disposal Option
No. 78. Heyneman and Fagerlind, University Examinations and Standardized Testing: Principles, Experience, and Policy Options
No. 79. Murphy and Marchant, Monitoring and Evaluation in Extension Agencies (also in French, 79F)
No. 80. Cernea, Involuntary Resettlement in Development Projects: Policy Guidelines in World Bank-Financed Projects (also in Spanish, 80S)
No. 81. Barrett, Urban Transport in West Africa
No. 82. Vogel, Cost Recovery in the Health Care Sector: Selected Country Studies in West Africa
No. 83. Ewing and Chalk, The Forest Industries Sector: An Operational Strategy for Developing Countries
No. 84. Vergara and Brown, The New Face of the World Petrochemical Sector: Implications for Developing Countries

(List continues on the inside back cover)
Agroforestry in Sub-Saharan Africa
A Farmer’s Perspective

Cynthia C. Cook and Mikael Grut

The World Bank
Washington, D.C.
Technical Papers are not formal publications of the World Bank, and are circulated to encourage
discussion and comment and to communicate the results of the Bank's work quickly to the development
community; citation and the use of these papers should take account of their provisional character. The
findings, interpretations, and conclusions expressed in this paper are entirely those of the author(s) and
should not be attributed in any manner to the World Bank, to its affiliated organizations, or to members
of its Board of Executive Directors or the countries they represent. Any maps that accompany the text
have been prepared solely for the convenience of readers; the designations and presentation of material in
them do not imply the expression of any opinion whatsoever on the part of the World Bank, its affiliates,
or its Board or member countries concerning the legal status of any country, territory, city, or area or of
the authorities thereof or concerning the delimitation of its boundaries or its national affiliation.

Because of the informality and to present the results of research with the least possible delay, the
typescript has not been prepared in accordance with the procedures appropriate to formal printed texts,
and the World Bank accepts no responsibility for errors.

The material in this publication is copyrighted. Requests for permission to reproduce portions of it should
be sent to Director, Publications Department, at the address shown in the copyright notice above. The
World Bank encourages dissemination of its work and will normally give permission promptly and,
when the reproduction is for noncommercial purposes, without asking a fee. Permission to photocopy
portions for classroom use is not required, though notification of such use having been made will be
appreciated.

The complete backlist of publications from the World Bank is shown in the annual Index of Publications,
which contains an alphabetical title list and indexes of subjects, authors, and countries and regions; it is of
value principally to libraries and institutional purchasers. The latest edition is available free of charge
from the Publications Sales Unit, Department F, The World Bank, 1818 H Street, N.W., Washington, D.C.

Cynthia C. Cook is a sociologist in the Environment Division of the World Bank's Africa Technical
Department, and Mikael Grut is a senior forestry specialist in the Agriculture Division of the same
department.

Library of Congress Cataloging-in-Publication Data

Cook, Cynthia C., 1944-
Agroforestry in Sub-Saharan Africa.

(World Bank technical paper, 0253-7494 ; no. 112)
Includes bibliographical references (p. )
II. Title. III. Series.
S494.5.A45C66 1989 634.9'9'0967 89-25047
ISBN 0-8213-1389-4
ABSTRACT

This study reviews agroforestry practices in Sub-Saharan Africa as seen from the farmer's perspective. Agroforestry, broadly defined as the integration of trees and shrubs in farming systems, offers one of the most promising technological options for reversing soil degradation, restoring tree cover, and improving agricultural productivity in Africa. The literature on agroforestry was reviewed in order to identify a limited number of successful experiences for further field study. Seven case studies were then conducted by an interdisciplinary team, covering indigenous and innovative systems found in the highlands of East Africa, the semi-arid zone, and the humid lowlands of West Africa.

This review identified a number of issues that need to be considered in the design and implementation of agroforestry projects for Africa in order for them to be successful. Key findings include the importance of understanding the economics of agroforestry systems from the farmer's point of view as well as from the broader perspective of the benefits to society. Project evaluation should therefore take into account local markets and opportunities for off-farm employment offered by tree products, as well as the opportunity costs perceived by farmers in making adoption decisions. Farm households are not homogeneous, and project design should be adapted to the socioeconomic level, age and gender of the people who are expected to adopt the proposed technology. In Africa, trees are integral parts of agro-sylvo-pastoral farming systems and should be considered in this sociocultural context, with particular attention to the constraints imposed by customary and legal rules regarding land and tree tenure. The institutional framework for implementation should be selected and developed with a view to long-term sustainability. Recommendations are made for the technical, economic, social, and institutional design of projects and for the direction of future research.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>vii</td>
</tr>
<tr>
<td>I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Background</td>
<td>2</td>
</tr>
<tr>
<td>Scope of the Study</td>
<td>2</td>
</tr>
<tr>
<td>Methodology</td>
<td>3</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>6</td>
</tr>
<tr>
<td>II. Agroforestry in Africa</td>
<td>9</td>
</tr>
<tr>
<td>Savanna Grazing</td>
<td>9</td>
</tr>
<tr>
<td>Farmed Parklands</td>
<td>10</td>
</tr>
<tr>
<td>Tree Crops and Shade Trees</td>
<td>11</td>
</tr>
<tr>
<td>Forested Fallow</td>
<td>12</td>
</tr>
<tr>
<td>Planted Farm Trees</td>
<td>13</td>
</tr>
<tr>
<td>Homegardens</td>
<td>14</td>
</tr>
<tr>
<td>Farm Woodlots</td>
<td>15</td>
</tr>
<tr>
<td>Forest Plantation Farming (&quot;Taungya&quot;)</td>
<td>16</td>
</tr>
<tr>
<td>Fodder Trees</td>
<td>17</td>
</tr>
<tr>
<td>Alley Cropping</td>
<td>17</td>
</tr>
<tr>
<td>Land and Tree Tenure</td>
<td>18</td>
</tr>
<tr>
<td>General Comments</td>
<td>19</td>
</tr>
<tr>
<td>III. Seven Case Studies</td>
<td>21</td>
</tr>
<tr>
<td>CARE/Kenya Agroforestry Extension</td>
<td>21</td>
</tr>
<tr>
<td>Chagga Homegardens, Tanzania</td>
<td>24</td>
</tr>
<tr>
<td>Agro-Pastoral Project, Rwanda</td>
<td>26</td>
</tr>
<tr>
<td>Alley Farming in Western Nigeria</td>
<td>29</td>
</tr>
<tr>
<td>Agroforestry in Northern Nigeria</td>
<td>31</td>
</tr>
<tr>
<td><em>Acacia albida</em> in Southeast Niger</td>
<td>32</td>
</tr>
<tr>
<td>Majjia Valley Windbreaks</td>
<td>35</td>
</tr>
<tr>
<td>IV. Identified Issues</td>
<td>37</td>
</tr>
<tr>
<td>Technical Issues</td>
<td>37</td>
</tr>
<tr>
<td>Economic Issues</td>
<td>38</td>
</tr>
<tr>
<td>Social Issues</td>
<td>40</td>
</tr>
<tr>
<td>Institutional Issues</td>
<td>42</td>
</tr>
<tr>
<td>Research Issues</td>
<td>44</td>
</tr>
<tr>
<td>V. Conclusions and Recommendations</td>
<td>47</td>
</tr>
<tr>
<td>General</td>
<td>47</td>
</tr>
<tr>
<td>Economic Analysis</td>
<td>48</td>
</tr>
<tr>
<td>Institutional Support</td>
<td>48</td>
</tr>
<tr>
<td>Research Priorities</td>
<td>49</td>
</tr>
<tr>
<td>Policy Issues</td>
<td>50</td>
</tr>
<tr>
<td>Notes</td>
<td>51</td>
</tr>
<tr>
<td>Persons Contacted for this Study</td>
<td>53</td>
</tr>
<tr>
<td>Bibliography</td>
<td>63</td>
</tr>
</tbody>
</table>
This paper presents the results of a study carried out jointly by the Environment Division and the Agriculture Division of the Technical Department, Africa Region, the World Bank, under the supervision of Leif E. Christoffersen, Division Chief, Environment Division. It is part of a broader program of research designed to identify new directions for agricultural and natural resource management in Sub-Saharan Africa, which was initiated two years ago. This paper is intended to provide guidance for all those involved in agroforestry planning for Africa, in the World Bank, in other donor agencies, in NGOs, and in the countries concerned. Work on this study has been closely coordinated with the International Center for Research on Agroforestry (ICRAF), based in Nairobi, as well as with other African research institutions, bilateral donors, and NGOs working with agroforestry projects in the field. Norway's Ministry of Development Cooperation contributed funding to the field work and review of this study.

The medium-term prospects for economic growth in Africa depend critically on expanding the productivity of agriculture. Currently low levels of technology, combined with rapidly expanding population, are fast pushing farmers and herders onto ever more marginal lands, or forcing them to encroach on the remaining tropical forest areas. This economically and environmentally destructive process of expansion can only be controlled if ways can be found to make current agricultural practices more productive and more sustainable. In this context, agroforestry seems to hold great promise for the future. Not only does it help to stabilize soils, increase infiltration of water and reduce soil erosion, and under some circumstances actually restore soil fertility, thereby enhancing the productivity of cultivated land -- it also provides practical benefits to the farmer, by generating a variety of useful products including food, fuel and fodder, diversifying local diets, and creating new opportunities for the productive use of land and labor in ways that often complement the traditional agricultural cycle.

Agroforestry is not new to Africa. Many traditional farming systems include elements of agroforestry. At the same time, research programs are beginning to yield new technologies that can make such systems considerably more productive. The challenge now is to find ways to integrate the new knowledge with the knowledge that farmers already have, so that widespread adoption of agroforestry systems will improve the welfare of farmers today, as well as the prospects for sustainable economic growth in the future. It is hoped that this study will contribute towards that objective.

Hans Wyss
Director, Technical Department
Africa Region
I. INTRODUCTION

There is increasing worldwide concern about environmental degradation in sub-Saharan Africa and its effects on the economic future of the continent. Africa's population is still largely rural and depends primarily on agriculture for its income. Rapid population growth, without corresponding improvements in agricultural technology, has increased pressure on the limited arable lands of Africa, leading to shortened fallow cycles and the extension of cultivation onto unsuitable or marginal lands. Population growth also generates more need for fuelwood, building materials, and other products traditionally extracted from the natural vegetation. The result has been growing deforestation, increased wind and water erosion, and declining productivity of agricultural lands, in what appears to be an ever-widening spiral of environmental degradation.

Faced with this, African governments and external donors have sought ways to reverse the process, both by preserving the fertility of agriculturally productive areas and by restoring the productivity of degraded lands. The task is enormous -- it is estimated that some 750 million hectares of land in Africa, or about one-quarter of the total, has already lost or is now losing its productive capacity. The problem far exceeds the abilities of governments and donor organizations to design and carry out projects. If Africa's agricultural lands are to be saved, it can only be done through the combined efforts of many millions of individuals who live on the land, and whose economic future depends on its sustainable development.

Since the removal of trees and vegetative cover is an important cause of land degradation, attention has recently focused on the role of trees in African agriculture and the prospects for restoring soil fertility and improving land productivity through incorporating trees and tree products with crops and/or livestock in integrated farming systems. Such integrated systems are sometimes referred to as agroforestry systems. According to this definition, agroforestry is similar in many ways to what African farmers have been doing for thousands of years. However, a systematic attempt by governments and donors to understand agroforestry in Africa, and its possible role in a strategy for sustainable development, is relatively new. While agroforestry cannot provide the sole solution to the problem of environmental degradation in Africa, it could potentially make a significant contribution to a sustainable agricultural development strategy for the continent.

International research centers, government agencies, and non-governmental organizations (NGOs) have been particularly active in promoting agroforestry in Africa. The success of their efforts ultimately depends on adoption by farmers of the strategies and techniques that they recommend. The purpose of the present study is therefore to evaluate some experiences with agroforestry in Africa from a farmer perspective, in order to better understand what motivates farmers to invest their land, labor, and capital in agroforestry activities.
Background

International organizations have been focusing attention on agroforestry for little more than a decade. The World Bank’s Forestry Sector Review of 1978 called attention to the need to conduct research and expand forestry lending in this area. Soon afterward, the Food and Agriculture Organization (FAO) carried out a review of worldwide experience with agroforestry. The International Center for Research in Agroforestry (ICRAF), founded in Nairobi in 1977, has developed a typology of agroforestry activities. During the early eighties, considerable agroforestry research was conducted at experimental stations in Africa and elsewhere. Meanwhile, some attempts were made, often with NGO support, to implement promising systems at the community level.

Responding to a growing concern for the future well-being of people in Sub-Saharan Africa, the World Bank has conducted a comprehensive review of agricultural research activities in the region. This review concludes, among other things, that more attention must be given to the sustainability of the new technologies emerging from agricultural research programs. It identifies agroforestry as one of the more promising technologies that can enhance land productivity and absorb increasing amounts of labor in a sustainable production system. Developing workable agroforestry "packages" and delivering these to the farmer should therefore become part of the agenda for agricultural extension services.

Experience has shown, however, that agroforestry projects in Africa have had only limited success in mobilizing farmer participation. The World Bank is now developing materials intended to assist governments in implementing social forestry programs, focusing on the need for a high level of local participation and strong political commitment to long-term solutions. In this context, it appears appropriate to examine some of the recent agroforestry initiatives in Africa to see what can be learned about technical, social, economic, and institutional issues related to successful project design and implementation, and priorities for future research. It is hoped that this review will provide useful guidance to those involved in planning future agroforestry projects for Africa, whether in the Bank, in other donor agencies, in NGOs, or in the countries concerned.

Scope of the Study

In 1987-88 the World Bank’s Environment Division for Africa undertook a review of agroforestry practices in sub-Saharan Africa as seen from a farmer perspective. The purpose of the study was to identify agroforestry practices which have been successfully adopted by African farmers, and to understand why farmers are following these practices. It is hoped that this information will lead to a better understanding of the conditions under which such practices could be replicated, and the potential for future agroforestry interventions in Africa.

From the outset, the study cultivated a farmer-centered approach. Thus, this report views agroforestry activities through the eyes of those involved at the local level: men and women, old and young, farmers and herders, landowners and laborers. However, the success of agroforestry activities is also conditioned by the broader ecological, social, economic, and institutional context. This study seeks to demonstrate how the dynamics of local systems are interwoven with these larger systems.

The technical definition of agroforestry is more limiting than the commonly understood meaning of the term. ICRAF defines agroforestry as follows:

Agroforestry is a collective name for all land-use systems and practices in which woody perennials are deliberately grown on the same land management unit as crops and/or animals. This can be either in some form of spatial arrangement or in a time sequence. To qualify as agroforestry, a given land-use system or practice must permit significant economic and ecological interactions between the woody and non-woody components.
For this review, the term "agroforestry" has been defined more broadly, to include many different activities involving the incorporation or retention of trees or shrubs into agricultural or pastoral systems. Such activities may include planting fruit trees around a homestead, growing trees in a woodlot to produce fuelwood or building poles, or intercropping trees with other crops on a farm plot. They also include passive systems that are based on protection and natural regeneration of indigenous trees. From the farmer's perspective, all of these interventions are simply choices to be made among different possible production activities. Rarely do local producers make distinctions among such interventions in the way that governments, donors, and other organizations do.

However, the agroforestry practices reviewed for this study are focused at the farm level. This study does not cover activities such as community woodlots or commercial plantations which are carried out at a larger scale with limited farmer involvement.

Methodology

The study was undertaken in two phases. During the first phase, a literature search was carried out to identify available information on factors affecting farmer adoption, as well as cases of reported success which might form the basis for future field work. Interviews were also held with agroforestry professionals based in Washington and at ICRAF in Nairobi. Since not all cases could be covered in depth, a sample of successful cases was drawn according to the following criteria:

1. Cases drawn from East and West Africa;
2. Cases based on indigenous agroforestry systems and cases where new systems were introduced from outside; and
3. Cases drawn from three different ecological zones: the humid lowlands, the semi-arid lowlands, and the cool highlands.

A Phase I report was prepared on 12 case studies, listed below.

Highland Case Studies

Chagga Homegardens, Tanzania (East Africa - Indigenous)
Acacia albida, Ethiopia (East Africa - Indigenous)
CARE Village Forestry, Uganda (East Africa - Innovative)
Kenya Woodfuel Project, Kenya (East Africa - Indigenous)
CARE Agroforestry, Kenya (East Africa - Innovative)
Kenya Renewable Energy (East Africa - Innovative)
Gituza Forestry, Rwanda (East Africa - Innovative)
Nyabisindu Agropastoral, Rwanda (East Africa - Indigenous)

Semi-Arid Lowland Case Studies

Water Harvesting, Burkina Faso (West Africa - Innovative)
Majjia Valley Windbreaks, Niger (West Africa - Innovative)
Guesselbodi Forest, Niger (West Africa - Innovative)

Humid Lowland Case Studies

Alley Cropping, Nigeria (West Africa - Innovative)
The Phase I case study reports were reviewed in December 1987 by a panel of five experts (listed at the end of this report). The panel agreed that the literature review should be followed up with field work on seven of the cases studied. It recommended that field studies should be carried out by an interdisciplinary team. The team included a technical person familiar with farm production systems (an agroforester or range management specialist), a farming systems economist, a rural sociologist or anthropologist, and an institutional development expert. This approach was followed in preparing the case studies presented in Chapter III of this report.

The Phase I review panel also drew the following operational lessons from the material presented in the literature review:

1. There is a need for better integrating agroforestry into national development planning. The World Bank could assist governments in formulating appropriate policy and in promoting improved interministerial coordination. The Bank could also act as a clearinghouse for information concerning agroforestry, both to benefit countries and to promote donor coordination.

2. Planning for agroforestry should involve several sectors, including but not limited to agriculture and forestry ministries. Informal task forces or working groups could play a coordinating role, helping countries to address land use problems with a more holistic approach.

3. Because some governments have not yet developed adequate institutional capacity to oversee and implement all agroforestry activities, NGOs should be considered as a short term solution. However, a constant effort should be made to integrate NGO activities with those of national institutions.

4. While long term environmental concerns are often an important component of agroforestry interventions, they should not be the sole criterion used for project justification. Whenever possible, agroforestry projects should be justified in terms of the concrete, tangible benefits to be derived by farmers. When agro-forestry activities are justified mainly by environmental benefits to society, provision should be made to ensure that participation in such projects is profitable to farmers.

5. The best indicator of success in agroforestry projects is the extent to which the recommended practices have been adopted by farmers. Project evaluations should focus on this issue. Local people and local institutions should be involved in all project evaluation efforts.

6. An effective farmer-oriented extension system is a key factor in the promotion of agroforestry. In most cases it will be logical to integrate agroforestry into the agricultural extension system. A complementary, collaborative approach to assist national extension services may be possible through the support of political parties, church groups, schools, and other local institutions.

7. Training or retraining of extension staff needs to occur at two levels. In-service training should be provided to project or extension staff. More formal training of higher level staff is also required.

8. Technical knowledge is still inadequate to define sound technical packages for agroforestry. Therefore, a research component should be incorporated in all agroforestry activities.
Following the panel review, field visits were made in early 1988 to five of the sites identified through the literature review, three in East Africa and two in West Africa. In addition, at the request of Bank staff, the field teams visited two areas in West Africa which had not been covered in the literature review. This provided the team an opportunity to observe the traditional *Acacia albida* system in West Africa (eastern Niger), and the integration of agroforestry with livestock in an agro-sylvopastoral farming system (northern Nigeria).

Approximately one week was spent in each study area. Data gathering was conducted in villages by key informant and group interviews using a basic set of open-ended questions. Respondents included men and women, wealthy farmers and poor farmers, project beneficiaries and non-beneficiaries. Projects staff, government officials, donor organizations, and others involved in agroforestry activities were also contacted. But most of the time was spent in the field with villagers.

Field data were developed into case studies and analyzed in a comparative perspective in order to identify common technical, economic, social, and institutional issues and to help set the agenda for future research as well as for future project design and implementation. A draft report was prepared in late 1988 and was extensively reviewed both within and outside the World Bank prior to its presentation to a second panel of African experts in March 1989. The Phase II panel reached the following conclusions:

1. There are three basic types of agroforestry interventions in Africa: (a) Interventions that build on existing indigenous systems to improve their productivity and/or sustainability; (b) Projects designed primarily to enhance the physical environment rather than to improve farmer incomes; and (c) Introduction of new farming technologies that may emerge from agricultural research. More may be learned by comparing projects within these three broad categories than by trying to compare them across these types.

2. Projects to introduce new technologies should follow the established pattern of farming systems research. This pattern starts with diagnostic research at the farm level to identify problems, moves to on-station research to find possible solutions, then to adaptive on-farm research linked to extension, demonstration, and adoption. Failure to follow this pattern leads to a poor "fit" between projects and farmer needs.

3. The intersectoral and interdisciplinary nature of agroforestry needs to be emphasized. Project initiatives with a narrow institutional base lead to a lack of strong and coherent support at the national level. In particular, there is a need for NGO-initiated projects to establish and maintain contact with government agencies and national research institutions.

4. Project designers should seek a balance between long-term and short-term benefits as well as between quantifiable benefits to individuals and more qualitative benefits to society.

5. Governments should make a commitment to support agroforestry projects -- whether donor-financed or not. Such a commitment should be demonstrated both by creating a positive policy climate and by providing recurrent budget support for project activities.

6. The World Bank should expand its support to agroforestry research, training, and related activities. In view of widespread confusion about what agroforestry really is and what it involves, the Bank should also sponsor information programs for policy makers, planners, extension workers, and rural people. Future Bank work on agricultural research strategies for Africa should include agroforestry research and development.
The present report reflects the findings and conclusions of this panel as well as comments received from many study participants. Chapter II reviews the state of the art in agroforestry for Africa. In Chapter III, the seven field case studies are presented. Chapter IV describes lessons learned both from the literature review and from the case studies in order to identify key technical, social, economic, and institutional issues in agroforestry projects. Chapter V draws general conclusions and makes recommendations for future project design and implementation. A list of persons interviewed and an annotated bibliography are appended to this report.

Acknowledgments

This study was initiated and supervised by Leif E. Christoffersen, Division Chief, Environment Division, Africa Region. It is based on case material collected and analyzed by Douglas McGuire and Diana de Treville. The preliminary literature review and initial contacts with institutions in the field were carried out by Douglas McGuire. Field work on the seven case studies was done by a team consisting of Douglas McGuire, Diana de Treville, H.A.J. Moll (East Africa), Obinani A. Okafo (East Africa), E.P. Riezebos (West Africa), and Gunnar Poulsen (West Africa). The study could not have been done without the active participation of many people at the World Bank, ICRAF, ILCA, within the case study countries, in other donor organizations, and in NGOs. The work of the Phase I and Phase II Review Panels was particularly useful. Members of the Phase I panel included:

- Dr. Edouard Bonkoungou, Director, Institute for Research in Tropical Biology and Ecology, Ouagadougou, Burkina Faso
- Mr. Robert Kirmse, Agroforestry Expert, Food and Agriculture Organization, Rome, Italy
- Mr. Bjorn Lundgren, Director, ICRAF, Nairobi, Kenya
- Dr. C. H. D. Magadza, Director, University Lake Research Station, Kariba, Zimbabwe
- Dr. Fredrick Owino, Dean of the Department of Forestry and Wildlife Management, Moi University, Nairobi, Kenya

Phase I Panel members also commented extensively on the draft case studies and the final report.

Phase II panel members included:

- Dr. Bede Okigbo, Director of Research, International Institute for Tropical Agriculture, Ibadan, Nigeria
- Dr. Fredrick Owino, ICRAF, Nairobi, Kenya
- Dr. Sharif Harir, Department of Anthropology, University of Khartoum, Sudan
- Dr. Robert Winterbottom, World Resources Institute, Washington
- Dr. Faye Benedict, Institute of Environmental Analysis, Bo, Norway
Helpful comments were also received from Don Pickering, John Peberdy, R.D.H. (Chip) Rowe, Michael Cernea, John Spears, Stephen Carr, Poul Sihm, C.D. Carlier, Francois Wencelius, Jeffrey Lewis, Kathleen McNamara, Chris Keil, William Magrath, and Francois Falloux (World Bank); Michael McGahuey (USAID), J.E.M. Arnold (Oxford Forestry Institute), B.T. Kang (IITA, Ibadan), A.N. Atta-Krah (ILCA, Ibadan), Walter Msimang (Director, CARE/Kenya), Olav Bakken Jensen (Agroforestry Programme Manager, CARE/Niger), Allan Turnbull (former Director, CARE/Niger), Sara J. Scherr (ICRAF), Benjamin Kamugasha, Emmanuel Asibey, Tomas Hexner and Obaidullah Khan. The study was particularly strengthened through the arrangements made by Joseph Wambia (World Bank) for the field team to visit northern Nigeria and eastern Niger.

The annotated bibliography was prepared by Lawrence Mastri, who also provided editorial assistance.

The Ministry of Development Cooperation in Norway contributed substantial funding for the field work and review process of this study.
II. AGROFORESTRY IN AFRICA

Agroforestry in the broadest sense can be seen everywhere in Africa. The main types of agroforestry include grazing or farming under savanna trees, coffee and cocoa grown under shade trees, planting of individual trees or woodlots by farmers, intercropping between young plantation trees or grazing between older ones, sowing of tree seeds on abandoned fallow land to speed up the restoration of fertility, the "garden" type of agriculture in fertile and densely populated areas where trees, shrubs, and annual crops are grown on the same piece of land, and modern forms like alley cropping. Tree crops like oil palm and rubber trees, and the traditional migratory slash-and-burn agriculture, are also forms of agroforestry, the latter being of a sequential kind. This chapter describes the different types of agroforestry (combinations of agriculture and forestry) and silvopastoralism (combinations of animal husbandry and forestry) found in sub-Saharan Africa, starting with the more passive and traditional types and ending with modern types involving the active planting and management of trees as part of integrated farming systems.

The term "trees" as used in this study also includes shrubs. The latter are very important in agroforestry, as they often yield products earlier than trees, and subsistence farmers cannot afford to wait a long time to obtain a return on an investment of land and labor. Some shrubs, e.g. Calliandra calothyrsus, can be cut back every year for 15 to 20 years to yield fuelwood and fodder.(10) Yet shrubs are generally neglected, as they fall in between the areas of expertise of forestry and agriculture.

Species used in agroforestry are generally multipurpose species. Useful lists of such species have been produced for the different climatic zones of Africa, with information on their uses and characteristics.(11) There are basically three climatic zones considered for this study: (a) the humid tropics of Western and Central Africa and many coastal areas, (b) the tropical highlands of Eastern and Southern Africa, and (c) the arid and semi-arid regions found to the north and south of the tropical zones. The vegetation of the humid tropics is characterized by tropical rain forests. The tropical highlands are covered by grasslands and montane forests, while the arid and semi-arid regions are characterized by savannas ranging from the low and very open Sahelian type on the border with the desert to the tall and dense Guinean type on the border with the rainforest.

In many of the above mentioned agroforestry systems, trees play the role of "nutrient pumps." Because their root systems are generally deeper than those of non-woody plants, they bring to the soil surface, in the form of litter, nutrients which the rains have leached down beyond the reach of other plants. This is why the re-invasion of the fallow by woody species regenerates the abandoned land in slash-and-burn agriculture.

Savanna Grazing

The open woodlands known as savanna cover an area of about 1.3 billion ha (13 million km²) in Africa. This area is about six times larger than that of the closed forest. The savannas are mainly situated in two broad bands to the north and south of the equatorial rainforest belt. Vast areas of savanna are infested by insects carrying sleeping sickness and river blindness, and are therefore not used for human habitation. Even these areas, however, provide grazing for wild animals, which in turn provide meat for the neighboring populations. Elsewhere, about 5 ha of Sahelian type woodland is required to feed one tropical livestock unit.(12) The area required decreases as the rainfall increases. In the Sahel, up to one third of all forage is supplied by trees and shrubs. Camels and goats especially derive much of their food from this source.
An important tree in the drier savannas is *Acacia senegal*, the gum arabic tree. Besides producing the gum arabic for which it is best known, it yields pods and leaf fodder for livestock, fibers, and excellent wood for charcoal and tool handles. The trees also enrich the soil through their ability to fix nitrogen, and they have proved useful for windbreaks in the Sudan. This species generally grows in areas too dry for agriculture, and it is therefore classified as a silvopastoral species. However, it is also planted in areas where agriculture is possible, where it can then be intercropped.

Gum arabic has been exported from the Sudan to the Middle East and Europe for over 4,000 years. It is used in food and beverages, in confectionery, and in a wide range of industrial applications. The main producers are Sudan, Mauritania, Senegal, Mali, Nigeria, Niger, Chad, Tanzania, Ethiopia, and Somalia. The gathering of gum arabic is the main source of revenue for many people in the eastern Sahel. Most of the gum is gathered from natural stands, but in the Sudan the tree is also grown in "gum gardens." Genetic variation between trees is enormous, and much treebreeding is needed. Until recently, the total annual world production of gum arabic was about 40,000 tons. Potential demand is projected to be at least twice this amount, provided that security of supply can be guaranteed and that prices remain reasonably stable.

Another, even more drought-hardy species providing both wood and animal feed is *Acacia tortilis*, one of the characteristic umbrella thorn trees of Africa. It can survive on very poor soils, with a mean annual rainfall of as little as 100 mm. It is a prolific producer of pods, which fall to the ground and provide food for both domestic livestock and wildlife. The pods have an average protein content of 19 percent. Acacia leaves are also palatable. The wood provides an excellent charcoal, much sought after in the urban centers.

The mean annual yield (MAY) of useful wood in the savannas, expressed in m\(^3\)/ha/year, has been estimated with the equation \(0.05 + 1.08R^2\), where \(R\) is the mean annual rainfall in meters. For example, where the mean annual rainfall is 800 mm, the MAY would be 0.7 m\(^3\)/ha on the average. Where mean annual rainfall is 1,200 mm, MAY = 1.6 m\(^3\)/ha. This equation is valid where the mean annual rainfall is between 600 and 1600 mm. Where both savanna wood and rainforest wood is available, as in Ghana or Rwanda, charcoal made from savanna wood is preferred to that made from rainforest wood -- probably because the latter tends to be lighter.

**Farmed Parklands**

In vast areas of the African savannas, farmers are protecting some of the original trees and cultivating the land underneath. Such agroforestry areas are often referred to as "farmed parklands," and the trees as "economic trees." In the Guinea-type savanna in northern Ghana, the most important trees in the farmed parklands are the shea butter tree (*Butyrospermum parkii*) and the West African locust bean or dawadawa (*Parkia clappertoniana*).

Shea butter is derived from the nut of the tree. It is important in the local diet, and is also used as a medicine, a cosmetic, in soap, and in cooking. Some is exported. The tree has a rather narrow crown, and therefore does not cast much shade on the crops around it. The density of economic trees is often greater in agricultural areas than in the surrounding unprotected savanna, because in the cultivated fields the trees are protected from the annual bushfires, which tend to kill tree seedlings. The average number of trees per hectare is about 30, but may reach as many as 150. The tree bears fruit from the 12th year, but does not reach full production until the age of 40 to 50 years. The average annual yield of nuts per tree in northern Ghana is 5 kg. At a producer price equivalent to US $0.25/kg and at a density of 100 trees/ha, the average yield is worth about US $125/ha/year to the farmer. In addition to benefitting from the agricultural crop grown under the tree canopy, the farmer can also harvest dead trees for fuelwood.
The dawadawa tree is leguminous, nitrogen-fixing, and thus soil-improving. The pulp around the seed is used for food, while the bean itself is used as a spice in soup. It bears fruit from the fifth year, and is said to be even more profitable than the shea butter tree.

As one moves from the Guinea-type savanna into the drier Sudan type, shea butter and dawadawa trees yield place to *Acacia albida*, also known as *Faidherbia albida* or gao, a very popular tree with herdsmen and farmers alike. Although the gao agro-silvo-pastoral system is mainly a passive one in the sense that the farmers preserve rather than plant the tree, and although it is mainly characteristic of the West African Sahel, gao is today being planted as a soil improver even as far south as Malawi. The recommended density when this species is planted for agroforestry purposes is 30 trees per hectare, which can add 125 to 150 kg/ha of nitrogen to the soil. However, as is the case with *Acacia senegal*, the genetic variation between trees and strains is great, with some trees not fixing nitrogen at all. Again, this calls for more tree breeding.

Research in Senegal has indicated that yields of millet and groundnuts on poor soils can increase from 500 to 900 kg/ha in the presence of gao trees.(16) This is not only due to nitrogen fixation by the roots, but also to the fact that cattle tend to congregate under the gao trees for shade and for the pods, and their wastes add further nutrients to the soil. While most deciduous savanna species lose their leaves during the dry season, a peculiarity of gao is that it loses its leaves during the rainy season, so it does not shade crops during the growing season. Gao and other nitrogen-fixing tree species can play an important part in the necessary transition from itinerant to settled agriculture in the African drylands.

**Tree Crops and Shade Trees**

In the same way that, in the West African dry savannas, the farmers generally leave "economic" trees among their crops, so they often leave shade trees when they colonize the rainforest. Under these tall shade trees they plant tree crops like cacao, coffee or kola. These crops are originally forest trees or shrubs, and require or prefer shade. The cacao tree comes from the rainforests of Central and South America; the different varieties of the coffee shrub come from forests at different elevation in East and Central Africa; and the tree which bears the caffeine-containing kola nut, much appreciated and traded in West Africa, comes from the West African coastal forests.

Young cacao plants prefer 60 to 70 percent of the light to be shaded out, while older trees prefer the shading to be about 30 percent. Until recently, coffee shrubs were also grown under shade trees. While shading is still required for young coffee shrubs, recent tree crop research advises against it for adult trees. Smallholders, however, often prefer not to reduce shade on coffee and cacao plantations because they replant to replace individual trees that have died or decreased in productivity, rather than replanting all at once. Therefore, shade is permanently required to protect the young plants. When the joint benefits of both wood and tree crop production are taken into account, maintaining shade trees on coffee and cacao plantations may well be justified.

The Australian species *Grevillea robusta* ("silky oak," "silver oak") was introduced as a shade tree planted in the coffee plantations of East Africa. It has now become one of the most appreciated agroforestry species in the area, where it is considered to be friendly to crops, in contrast to the faster growing but more voracious eucalyptus. *Grevillea* wood is also used for sawtimber and the leaves can be used for mulching.

In dry areas, the banana plant begins to show signs of deterioration when it receives more than about 2,400 hours of sunshine per year. In the dry and sunny climate of the Comoros, for example, one sees vast areas of banana grown in the shade of quite dense forest cover. Some of these plantations are on very steep slopes, but the soil is maintained in place. The danger with any system of cropping under shade trees is that the farmers may not allow
enough of the shade tree regeneration to come up through the crops, and the canopy may eventually disappear.

Agroforestry should not be encouraged in areas of undisturbed tropical forest, or on soils which basically are not suitable for conversion to agriculture. But when tropical forest land is being cleared for agriculture, it would be better from an environmental point of view that some trees be left as shade trees, with tree crops planted under them, instead of replacing the whole forest by annual crops. Under the latter conditions, annual crops tend to be very destructive to the soil.

In some West African countries, the farmers are not the owners of the shade trees on their land. Instead, the state or the chief's own them, and include the trees in the felling concessions which they allocate to private loggers. When loggers cut the shade trees on the farmers' land, not only do the crops lose the benefit of the shade, but they are also damaged by the falling trees. This is a disincentive for farmers to keep trees on their land in the rainforest zone.

**Forest Fallow**

Slash-and-burn agriculture, also known as swidden agriculture, is the traditional form of shifting cultivation in Africa. It is a sequential type of agroforestry, where the trees first provide mineral fertilizer in the form of ash, and then act to restore soil fertility. A farmer clears a plot of land, burns the cleared materials, and crops the land for two or three years until declining soil fertility combined with weed growth causes him to abandon the land and begin the process again at another spot. Bushes and small trees install themselves on the abandoned land, and recycle the leached soil nutrients. After 6 to 15 years of such wooded fallow, the soil fertility is sufficiently restored to allow the farmer to return to the same piece of land. The required fallow period is usually longer in Sahelian areas than in rainforest areas.

The main problem with slash-and-burn cultivation is that it is wasteful of land, soil nutrients, and wood. Assuming a three-year period of cultivation followed by a ten-year fallow period, i.e. a thirteen-year cycle, the farmer will need about four times as much land as he would need if he could maintain the fertility of the soil on the land he cultivates each year. To put it in a different way, with this system of shifting cultivation, about three quarters of the land needed to sustain the farmer are tied up in fallow at any given time. Also, at each burning, most of the nitrogen is volatilized and lost to the air, and much of the mineral ash is washed away by rains. Finally, the wood, which in many areas could be marketed as charcoal, literally goes up in smoke.

One of the main challenges in African agriculture today is to move from shifting to permanent cultivation. In theory this could be achieved by using artificial fertilizers, but in practice these are too expensive for all but a few African farmers. Agroforestry offers more realistic alternatives, for example the use of nitrogen-fixing tree species to maintain and enhance soil fertility. Another option is to sow the seed of a soil-improving species over the abandoned fallow in order to speed up the restoration of its fertility. In the Comoros, farmers use *Cajanus cajan* or pigeon pea in this way. Pigeon pea is a nitrogen-fixing woody shrub which can grow on very poor soils and in very dry climates. Besides protecting and improving the soil, the woody stalks are used for fuel, the peas for food, and the pods and foliage for feed. When densely sown, with at least 30,000 plants/ha, about 2 tons/ha of woody stalks can be cut for fuel at the end of every growing season.
Planted Farm Trees

African farmers plant vast numbers of trees on their land. This is perhaps most evident in the densely populated highlands of East Africa, in Kenya, Rwanda and Burundi. These highlands, which were nearly treeless a hundred years ago (see early photographs), are today well endowed with trees. Virtually all of these have been planted. The tendency in Africa is that the forests decrease but that the number of trees on the farms increases. In other words, there is an observable increase in spontaneous agroforestry.

Farmers plant trees for many purposes: for fuelwood, building poles, fruit, shade, amenity, field demarcation or other live fencing, timber, fodder, soil improvement, honey production, or protection against wind. Fuelwood comprises 90 percent of the wood used in Africa. The remainder is mainly building poles for traditional construction. The roundwood equivalent of sawnwood, panel products, and paper represents a very small part of total wood consumption.

Most of the fuelwood and building poles are used by rural people in rural areas. This wood must be found within walking distance of the farmers' homes because farmers cannot afford to buy the wood they need. For Africa's rural people, most wood needs must be met on the farms, not in the forests.

If fuelwood is insufficient, farmers will burn agricultural wastes which, if just left on the fields, could have a beneficial effect on soil conservation and fertility. Fuelwood is usually collected by women and children, which means that men are not usually interested in planting trees for fuelwood purposes. Women may also be discouraged by men from planting trees on farm fields, since this could be interpreted as making a claim on the land. However, men are normally held responsible for providing building poles, and this can be used to stimulate men's interest in agroforestry activities. Farmers' interest in tree planting may also be stimulated if there is a nearby urban market for charcoal, building poles, or fuelwood.

Over the past dozen years, the World Bank has supported farm forestry in some fifteen African countries. Although stress has been placed on the use of multipurpose trees, the main purpose of these projects has been to help meet fuelwood needs. The urban household fuel progression in Africa is generally from fuelwood (still dominant in many Sahel cities) to charcoal (Dakar, Khartoum, Lusaka), to kerosene (Lagos). But in the rural areas the only affordable alternative to woodfuel is agricultural wastes. If a project is to produce fuelwood for urban markets, the economic benefits of the project can be determined in terms of the value of the kerosene which would have to be imported if the fuelwood were not produced. In the case of fuelwood for rural household consumption, the economic value can be estimated in terms of the agricultural output which would be lost as a result of crop or animal wastes being burnt if the fuelwood were not available. These benefits are, of course, additional to the unquantified environmental benefits provided by the trees before they are cut down.

In developing farm budgets for tree planting to meet needs for local consumption of fuelwood and poles, it makes sense to use hours spent rather than monetary units, as farmers collect and do not buy such products. In other words, the cost would be represented by the number of hours required to fetch a number of seeds or seedlings, plant them, and look after them until they are ready for harvesting. The benefits would be the hours gained by collecting fuelwood and poles from trees planted near the homes rather than collecting the same amount of wood from further away. In this way a rate of return on time invested can be determined. For farmers to find the time saving attractive enough to invest their land and labor, this rate of return must normally be greater than 30 percent.
Individual free-growing trees generally grow faster than plantation trees, which must compete with their neighbors for water, soil nutrients, and light. Careful spacing trials over a long time have shown that the volume of free-growing *Eucalyptus saligna/grandis* trees at the age of ten years is at least five times that of trees which have grown at a stand density of 1600 trees/ha, and that after ten years the volume differential between the two types of trees increases even more rapidly. Research on neem and gao trees in northeastern Nigeria also suggest a large differential in the mean annual volume increment of free-growing as compared to plantation trees. Farmers are likely to be aware that trees planted individually in fields rather than together in woodlots will provide more wood per hour invested in planting. This is especially important when trees have to be planted during the rainy season, thus competing with other crops for the farmer's time.

Fruit trees are very popular with farmers, and they, too, eventually provide fuelwood. Also, as mentioned earlier, shrubs generally produce usable products earlier than trees. If there is a tradition of farmers growing their own tree seedlings, in their backyards or along the nearest stream, projects should assist by providing seeds rather than seedlings, in order not to destroy that tradition.

Wood can be continuously harvested from farm trees by cutting the branches rather than the stem. This is known as lopping or pruning. Besides yielding a regular flow of leaf fodder and fuelwood, lopping reduces the shading effect of farm trees, which is sometimes desirable. When cutting the stem of a coppicing species, i.e. a species capable of sending out new shoots from the cut, it is useful to do so not at ground level, as it done in industrial plantations, but above the height to which goats can browse, about 2 meters. This technique is known as pollarding.

Farm trees have an important role to play in promoting household food security. Their leaves and fruits add to the palatability of basic food grains and tubers, and provide essential nutrients to the daily diet. In addition, tree products can become important sources of food as well as income during the "hungry season" just before the harvest of the main food crop. Snack foods derived from trees may also be used during periods of peak demand for agricultural labor, when little time can be spared for lengthy food preparation. The cultivation and harvesting of farm trees can usually be carried out during periods when agricultural labor is not in demand for other purposes.

**Homegardens**

Homegardens are complex, multi-storied farming systems enabling the intensive production of a rich variety of crops in relatively small quantities on limited amounts of land. Such systems usually involve trees and shrubs producing nuts, berries and fruit as well as wood; also vines, shade tolerant food crops, and tubers. In addition to providing food, fodder, fuelwood, and marketable forest products, the trees and shrubs in such systems provide important environmental services by stabilizing slopes, reducing the erosive force of heavy rainfall, slowing the rate of runoff, and increasing infiltration of water into the soil. The layering of plants above and below the land surface facilitates nutrient recycling processes similar to those found in forests.

Homegardens are generally indigenous farming systems that have been evolved over time in response to local needs and conditions. They often require quite complex management techniques based on an intimate knowledge of indigenous species and their interactive effects. They require little in the way of purchased inputs and consequently do not degrade the soil with heavy machinery or agrochemicals. The diversity of species included in complex patterns of intercropping helps to protect the farm household against the risk of crop failure due to extreme climatic conditions.
In Africa, homegardens have developed mainly in areas of high population density and in hilly terrain with relatively fertile soils. They demand a high labor input, particularly if the maintenance of soil fertility and moisture depends on continual additions of water or organic matter (agricultural residues or manure from livestock). Consequently, they are usually found in association with highly structured social arrangements, involving complex patterns of cooperation and exchange, between individuals within households, between households within communities, and between communities sharing common resources.

As an intensive farming system, homegardens can support higher densities of population than slash-and-burn cultivation or purely pastoral systems. However, continued population pressure will eventually lead to declining soil fertility and decreasing marginal returns to labor. With the introduction of cash cropping and opportunities to increase income through off-farm employment, homegardens tend to revert to less complex forms of land use often based on tree crops or tree products alone.

**Farm Woodlots**

To get the maximum volume of wood from a given piece of land, trees should be planted closely together and thinned just ahead of natural mortality. In other words, one should maintain maximum stand density without actually inducing overcrowding and tree death. It is important to understand that maximizing the volume of production per tree does not necessarily lead to maximizing the volume of production per unit area. Planting of farm woodlots has been encouraged under many agricultural projects in densely populated parts of Africa where natural fuelwood supplies have nearly disappeared.

Growing poles is more lucrative than growing fuelwood, as poles fetch a far higher price per cubic meter. Consequently, most farmers establish woodlots in the hope of producing poles rather than fuelwood. However, the pole market is limited, and not every stem is straight enough to be sold as a pole. Thus, only a relatively small number of farmers should be expected to find the farm woodlot option attractive.

A 1984 analysis of the rate of return on cash, land, and labor invested in different agricultural activities in Malawi showed the following results:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Returns to Cash (IRR)</th>
<th>Returns to Land (MK/ha)*</th>
<th>Returns to Labor (MK/day)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing poles</td>
<td>185%</td>
<td>858</td>
<td>8.9</td>
</tr>
<tr>
<td>Growing fuelwood</td>
<td>65%</td>
<td>84</td>
<td>1.0</td>
</tr>
<tr>
<td>Collecting fuelwood</td>
<td>Over 1000%</td>
<td>n.a.</td>
<td>0.3</td>
</tr>
<tr>
<td>Improved maize with fertilizer</td>
<td>240%</td>
<td>198</td>
<td>1.4</td>
</tr>
<tr>
<td>Local maize without fertilizer</td>
<td>Over 3000%</td>
<td>69</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*Net present value, discounted at 25 percent.

This analysis indicates that in Malawi at the time, fuelwood on public land was still plentiful enough to make collecting fuelwood a far more profitable activity than planting and tending a woodlot. Even for pole production, the rate of return on cash invested in woodlots was lower than the rate of return on cash invested in fuelwood collection and maize production. Returns to labor and land, but not cash, favor pole production as long as few farmers make such investments, and the price of poles remains high. Fuelwood collection provides low returns to labor but has no land and practically no cash costs, and the labor invested has a low perceived opportunity cost. Consequently, most farmers prefer to allocate as much farm land as possible to maize production, and have little incentive to establish woodlots on their farms in order to meet fuelwood needs.
One reason why woodlots are less profitable is the time it takes for trees to reach maturity. More research needs to be done on fast-growing species as well as on agroforestry systems. However, the fact that African farmers plant so many individual trees and so few trees in woodlots indicates that, from the farmer’s perspective, trees planted on farm fields are more profitable than trees planted in woodlots.

**Forest Plantation Farming ("Taungya")**

"Taungya," derived from a Burmese word -- also called "the shamba system" in Kenya -- is an agroforestry method widely used in East and West African to avoid weeding costs, and sometimes land clearing costs, in establishing forestry plantations. The taungya system entails allowing forest workers or farmers to grow annual crops between the newly established trees for two or three years, until the crops are shaded out by the trees. Sometimes the taungya cultivators even do the land clearing. They may then be allowed to cultivate the entire cleared land surface for a year or two before the trees are planted, after which they are allowed to intercrop as described above.

The organization establishing the plantation benefits by not having to pay for the land clearing, or at least not for weeding. In the tropics, especially the humid tropics, these are generally the largest items in the establishment costs. Taungya farmers gain access to land which would not otherwise be available to them. Cultivators usually will not be interested in taungya unless the soils are reasonably good for agriculture. The system has been widely practiced for a long time on the good soils of the Kenya highlands, but it is rare on the poorer soils of southern Africa. Where population pressure is low, farmers may demand additional incentives such as having the land ploughed.

The danger with taungya is that the cultivators may damage the young tree seedlings, since they are not "their" trees. Supervision must therefore be very close. The Forestry Department, or other organization establishing a plantation, enters into a contract with each taungya cultivator, including penalties to be paid for damaged trees. Experience indicates that farmers have generally done better than foresters out of the taungya system, the resulting stands being all too often understocked as a result of the tree seedlings that died. Taungya has been used most successfully in Kenya, where the Forestry Department only allowed its own workers to participate.

A related system could be started once the trees have reached a certain height and been thinned once or twice. At this point, farmers could be allowed to underplant them with coffee, cacao, kola, or another of the shade tolerate crops which are grown under the natural forest canopy, against the payment of a nominal land rent. For example, in a plantation of tropical hardwoods with a rotation of 80 years, coffee plantations could be allowed during the last 40 years. In this way, local farmers would gain access to additional land, while the plantation owner would gain some early income from the land rent. Plantation owners, however, are often reluctant to enter into such agreements, fearing that the farmers will eventually establish a permanent claim to the land.

Grazing can also be combined with plantation forestry, although this is less common. Grazing can be useful to reduce weed growth, convert weeds to soil-improving animal wastes, and earn some early revenue. Cattle and goats are too destructive for young plantations, but sheep can be allowed in. Once the trees have reached a certain height, the other livestock can be allowed to graze, but they should be prevented by a herder or a fence from getting into the young plantations. Simple, easily moveable electric fences can be used to protect small plots where seedlings are being raised.
Grazeable weed growth in plantations is most likely to be plentiful where either rainfall is high, or stand density is low. In the World Bank financed Second Forestry Project in Burundi, experiments are being conducted with sheep under eucalyptus and pine. The Department of Animal Husbandry at the university in Bujumbura is providing advice, and monitoring inputs and outputs so that the profitability of the system may one day be accurately determined.

Fodder Trees

Tree fodder (forage and feed) is mainly of two kinds: leaves and pods. It is particularly important in dry regions, where it is sometimes the only food still available for animals at the end of the dry season. By pruning them heavily at the end of the rainy season, even deciduous species can be made to sprout during the dry season. While the leaves of almost all woody species can be eaten by livestock, some species are more resistant to browsing and yield higher quality fodder than others. These are known as fodder trees. Some naturally occurring fodder trees have been mentioned in connection with grazing in the savanna: Acacia albida, Acacia senegal, and Acacia tortilis, all of which produce both leaves and pods suitable as livestock feed. Although these species occur naturally in Africa, they are planted too.

So far, World Bank forestry projects in Africa have paid little attention to the promotion of fodder trees, perhaps because only a small proportion of livestock is stall-fed. However, browsing of bushes and trees by goats, camels, and cattle is a common sight in Africa. This suggests that economic benefits could be obtained from more systematic promotion of fodder species in farm forestry. Some fodder species of non-African origin, but useful in Africa, are:

Albizia lebbeck
  For semi-arid areas.

Leucaena leucocephala
  For humid tropics. Not on acid soils. Nitrogen-fixing. Toxic to some animals if not complemented by other feed.

Prosopis juliflora
  For arid areas. Thorny. Excellent fuel. Invasive where not checked by strong fuelwood demand.

Sesbania grandiflora
  For humid tropics. Leaves and pods also used as human food.

Alley Cropping

Alley cropping, or alley farming, entails the planting of rows of nitrogen-fixing trees or shrubs (hedgerows) and growing agricultural crops between them. The hedgerows, besides adding nitrogen to the soil, also provide leaf mulching, fuelwood and soil conservation benefits. On slopes, the hedgerows are planted along the contours. On flat land they are aligned so as to minimize shading or to maximize wind protection. The distance between rows is generally 2 to 4 meters.

Alley cropping is best suited for areas with good rainfall. In dry areas, the trees may use too much of the soil moisture, and the planting of dispersed nitrogen-fixing species is more appropriate. Some species often used in alley cropping are:

On non-acid soils: Leucaena leucocephala
  Glicidica sepium

On acid soils: Calliandra calothyrsus
General use: *Sesbania* species  
*Acio barterii*  
*Alchornea cordifolia*

The following figures show the effects of alley cropping on soil erosion under a maize-cowpea rotation, measured in 1984:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil erosion (t/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughed</td>
<td>14.9</td>
</tr>
<tr>
<td>No-till system</td>
<td>0.03</td>
</tr>
<tr>
<td>Alley cropping</td>
<td></td>
</tr>
<tr>
<td>- <em>Leucaena</em>, 4 m between rows</td>
<td>0.2</td>
</tr>
<tr>
<td>- <em>Leucaena</em>, 2 m between rows</td>
<td>0.1</td>
</tr>
<tr>
<td>- <em>Gliricidia</em>, 4 m between rows</td>
<td>1.7</td>
</tr>
<tr>
<td>- <em>Gliricidia</em>, 2 m between rows</td>
<td>3.3</td>
</tr>
</tbody>
</table>

There are indications that the high aluminum content which makes many tropical soils toxic can be abated by increasing the organic content of the soil, thereby reducing the need for expensive soil amendments. Alley cropping is one way to increase the organic content of the soil. In this system, branches are regularly lopped off the hedgerow trees to reduce shading, to mulch the soil with leaves, and to provide fuelwood.

Alley cropping is a relatively new technique. It has been researched in particular by the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria, and by the International Council for Research in Agroforestry (ICRAF) in Nairobi, Kenya. For further details, see the case study on alley cropping in Chapter III.

**Land and Tree Tenure**

The range of agroforestry systems described above, moving from the most passive to the most active systems, also corresponds to a range of possibilities with regard to land and tree tenure. Land and tree tenure, including both ownership and usufruct rights, are highly complex issues in Africa, and the prevailing rules differ widely from one part of the continent to another. An understanding of who owns land and who owns the trees on that land (not necessarily the same individuals or even the same group) and who has the right to harvest some or all of the tree products, at any time or at certain times of the year, is critical to understanding the incentive system that applies to agroforestry interventions in the context of particular cultures.

Generally speaking, under traditional tribal law, land and the fruits of the land belong in the first instance to the spirit world. The first human beings to occupy the land, through the spiritual intermediation of their leaders, covenant with these spirits to gain use rights in exchange for certain ceremonial services. Participation in this covenant is passed down over time through the institution of chieftaincy, a social role which binds community leaders in covenant with the spirits, the ancestors, the present generation, and future generations. Traditional leaders have the responsibility to provide for all their followers by allocating to them specific land use rights. Where more land is available than is needed for the community's immediate use, traditional leaders may also enter into agreements with "strangers" or groups outside the community, by which these groups may also enjoy specified use rights. Such arrangements between groups may persist over many generations, as in the case of pastoralists and agriculturalists making use of the same lands for different but complementary purposes within the southern Sahelian zone.
In some societies, the right to cultivate land does not necessarily mean exclusive rights to exploit trees on that land. Naturally occurring trees may be regarded as common property or as the property of the chiefs. In other societies, trees may belong to whoever "planted" them, regardless of who is cultivating that land at a particular time. Many societies have gender-specific rights and prohibitions with regard to planting trees and exploiting tree products, as well as for access to land for cultivation and grazing. Frequently, use rights arrangements with "strangers" include prohibitions on tree planting since such activities are regarded in local law as establishing a permanent claim to the land.

The situation becomes even more complicated when the modern state intervenes. Many African governments have attempted to take over the traditional role of local leaders as the owners and custodians of all the land on behalf of all the people. This statist view has been congruent with colonial policy by which vast tracts of land were set aside, with or without agreement from the local authorities, for reserves or large plantations of timber or tree crops. Forest management in Africa has frequently come into conflict with the needs and priorities of local people. Consequently, attempts by the state to promote agroforestry are often met with suspicion and distrust.

The introduction of the cash economy and the discovery of the value of trees and tree crops as export commodities has also helped to undermine traditional systems of land and tree tenure. Such systems are now under attack not only by the modern state but also by policy makers and local entrepreneurs who see in the partitioning of the commons and the commercialization of land rights the only possible incentive for more intensive production systems and improved resource management. The appropriate answers to these questions are far from clear. What is clear though is that the widespread adoption of agroforestry systems needed to maintain and restore the productive base of African agriculture can only be achieved if planners take adequate account of existing land and tree tenure systems, and try to resolve any conflicts in such a way that those who are asked to bear the costs of these activities will have a reasonable chance of sharing in their benefits.

General Comments

Agroforestry is present throughout Africa, in the form of both traditional and innovative farming and grazing systems. As a practice, it is as old as agriculture itself, which began everywhere with the sequential agroforestry system of itinerant slash-and-burn agriculture. As a formal discipline, however, it is new. For this reason, it sometimes tends to fall between the cracks of the conventional disciplines of agriculture, animal husbandry, and forestry. Practitioners of these professions need to make a special effort to include agroforestry in their project designs. The best vehicles for promoting agroforestry are agricultural and livestock projects, because such projects have direct contacts with the farmers and the herders, in whose hands lies the fate of agroforestry in Africa.
III. SEVEN CASE STUDIES

CARE/Kenya Agroforestry Extension

The CARE/Kenya Agroforestry Extension Project began in 1984 in Siaya District, Western Kenya. Siaya District suffers from increasing demographic pressure and land fragmentation, together with intensive exploitation of natural wood and brush resources. Crop production throughout the district is mainly geared to self-sufficiency of the farm households; and the area under crops is more directly related to the requirements and composition of the household than to the total farm size. The proportion of grassland and fallow land is larger on larger farms and thus the maintenance of soil fertility is less of a problem on these farms. The part of the farm not under crops can be used for livestock production and firewood collection.

Firewood and poles for building are the main wood products required by the farm households. An average household uses firewood with a value of KSh 1600 to KSh 3600 (US $80-180) per year, roughly comparable to the value of food consumed. However, firewood is not generally available in local markets. Instead, in all households women spend from one to two hours daily on firewood collection. The value of firewood per hour spent collecting it is about KSh 5 or US $0.25, a return to labor equivalent to a daily wage of US $2.00. Firewood can be collected on-farm by households with at least 0.6 ha of fallow land. Poorer women collect firewood from public land or from the fallow land of wealthier farmers.

Annual building pole requirements for an average household are estimated at 10-15 poles with a total value of KSh 120-200, or less than US $10. The majority of farmers cut the poles required for building repair and maintenance from their own land; however, poles may be purchased from neighboring farmers when new houses are under construction. Agroforestry, in particular the production of building poles, was not mentioned by the farmers interviewed for this study as a significant source of cash income.

A wide variety of agroforestry practices was observed on farms in Siaya District, both with and without contact with the CARE forestry project. Most farms had some fruit trees such as papaya and citrus, and all homesteads were encircled by a fence, in most cases of Euphorbia, Lantana, and/or Sisal. On farms with contacts with the project, more and a greater variety of trees were planted: grafted citrus, papaya and avocado as fruit trees; passion fruit for home consumption and cash income; Melia azedarach for shade. One farmer had planted about 1,000 seedlings of Cypress and Aberia caffra as a fence around the homestead.

A variety of species are used for boundary plantings: Aberia caffra, Cassia, Markhamia, Euphorbia, Sisal, Grevillea, and others. Woodlots of Eucalyptus or Cassia are the main form of trees or shrubs planted in pure stands. The woodlot areas are small, 50 to 400 m2, and densely planted, with more than one seedling per m2. Trees, often Markhamia, are scattered in fields throughout the District, and farmers recognize the benefits in the form of soil improvement as well as firewood. Alley cropping with Leucaena is practiced by a number of farm households. Other agroforestry activities include Leucaena or Gliricidia -- planted to stabilize slopes -- and Leucaena -- planted for fish pond feed or goat fodder.

The land and labor requirements of agroforestry activities, whether introduced by the CARE project or the already existing practices, are small compared with those required by the total farm. The capital required is also small; the (subsidized) price for seedlings is KSh 15 per 100. The price of seedlings is not a major determinant in the decision to plant trees.
The availability of seedlings in the immediate neighborhood of the farms is more important, because of the problems of transporting seedlings over more than five kilometers. The cost to farmers of seedlings produced by women's groups or schools supported by the CARE project is limited to the value of a few afternoons of communal work on the nursery during the dry season. The costs to the project are mainly the costs of staff, transport, and materials.

Trees and shrubs planted on homesteads and along farm boundaries do not compete for land with other types of land use, and the labor involved in planting and maintenance is minimal. By selecting deep-rooted species, the competition with crops can also be minimized. The returns (fruits and building poles) make a substantial contribution to the household economy, and any surplus production may bring in cash. The possible contribution to the firewood requirements of the household, however, is limited. It is estimated that 0.3 to 0.4 ha planted with *Leucaena* would provide sufficient firewood for a family of 5 persons. From the farmer's point of view, however, the opportunity costs of the land and capital involved are likely to exceed the value of the marginal labor savings achieved.

Trees and shrubs planted in pure stands compete directly with other crops for land, and the production foregone must be added to the costs of labor and capital. The value of foregone production of maize can be estimated at KSh 90 per year for a 300 m² woodlot. These costs, plus the costs of labor and capital for the seedlings, compare well with the production of 500 poles from the same woodlot with a total value of KSh 5000 to KSh 7500 after five years, or more than KSh 925 per year at a discount rate of 15 percent. The production of poles from woodlots is thus profitable if there is a sufficient demand. Pole requirements per household are limited, and if a large proportion of the farm households were to start woodlots the profitability of this operation would decline.

The profitability of trees and shrubs grown in combination with other crops is unknown as no data are available on inputs of land, labor and capital or on outputs of crops and wood products. Evidence concerning the effects on soil fertility would require data collection over a period of five to ten years, which means that no analysis based on actual field data can be expected in the near future. The profitability of trees and shrubs grown for the purposes of erosion control, food for fish ponds or for goat fodder cannot be separated from the complementary crop, fish or animal production activities. No data are available on these integrated activities.

The CARE project is considered by many to be one of the most successful attempts at disseminating simple and appropriate agroforestry technologies in Kenya. The project is funded by the Canadian Government. Work was started in close collaboration with the District Forest Officer, who was already involved in farm forestry activities. The project began work with nine nurseries and four multi-purpose tree species. By the end of the first year, over 50 groups and schools had applied for assistance from the project. The project aims at strengthening local knowledge of indigenous agroforestry systems, mainly by helping local groups and institutions to establish tree nurseries. Other agroforestry activities that have been promoted by the project include alley cropping, hedgerow planting, fruit tree planting, woodlots, and shade trees.

The project is designed to be responsive to local perceptions of priority needs for tree products and services. It involves use of ICRAF's Diagnosis and Design methodology with local groups to establish priority problems, assess the current uses of indigenous trees, and identify the potential contribution of agroforestry. A typical community group might include about 25 persons, mostly women, of whom about half are already involved in tree planting. CARE extension agents assist these groups in establishing small, private tree nurseries and use them as intermediaries to introduce new agroforestry practices.
Key project inputs (seeds, plastic bags, wheelbarrows, etc.) have been supplied free by the project. Rapid and extensive adoption of the recommended practices has been made possible by using an independent cadre of extensionists trained, paid and transported by CARE. Since there has been relatively little contact between these workers and staff of the Forestry Department, it is questionable whether the Department will be able to continue these activities without support from CARE. However, to the extent that the recommended activities are demonstrably profitable to farmers, agroforestry is likely to continue. Local distribution systems are potentially capable of supplying the needed inputs and handling expanded demand for marketing of outputs.

One of the most interesting aspects of this project is the way in which the members of women's groups have responded to these initiatives by integrating agroforestry into their own agricultural and off-farm enterprise activities, successfully modifying these interventions to meet their own subsistence and commercial needs. Women's self-help groups are not a recent phenomenon, but rather represent a contemporary reformulation of traditional, kin-based age-grades. Historically, women have been involved primarily in the "domestic" economy and related agricultural, processing and marketing activities, while men have been engaged in broader economic and political activities and in more physically demanding tasks such as land clearing and game hunting. Women's groups are key intermediaries linking individual women to the goods, services, and other resources that are available to individual men.

Land, and trees on the land, are considered to be a productive resource owned primarily by men. Women have usufruct rights to bush fruit and a variety of forest products. These rights may apply not only to a husband's land, but also to land and trees owned by kinsmen and/or age-mates. Women may plant trees, with a man's permission. Many of the early beneficiaries of the project were better-off farmers--both men and women--who could handle a small amount of risk. As agroforestry land use practices became better known, persons from more economically vulnerable groups have also become involved. Women's groups play an important role by allowing small producers to pool their risks and resources in order to take advantage of technological innovations.

The active involvement in and support of AF activities by local chiefs has been an important feature of success for many of the groups. CARE staff have been involved in public awareness campaigns, including participation in chief's barazas. At the national level, the government's active "pro-tree" posture is reflected in the daily press. Strong support from government has been a key feature both in consciousness-raising among the general public and in stimulating actual tree planting activities.

Although the shortage of fuelwood in Siaya District was one of the key reasons for selecting this site for the project, fuelwood is not a priority as perceived by the farmers. The selection of species to be grown in the nurseries has been based on the needs expressed by the group involved. These needs have included food, fruit, fodder, fencing, poles, timber, shade, soil fertility (nitrogen fixing species), and cash. The economic value of the trees appears to be the key factor in farmer adoption. To promote project sustainability, marketing studies should now be done to determine what species are most likely to be wanted in the future. In addition, the prospects for processing activities that could be run by women or women's groups should be investigated. Such agroforestry-linked activities have great potential to become self-sustaining, as they would be fully integrated into the local economy.

During the first phase of the project, many of the initial targets were exceeded, including the numbers of farmers assisted, the number of seedlings raised in the nurseries and planted out, and the number of extension staff trained and employed. However, the project has focused on providing seedlings to farmers. On-farm research receives little, if any attention. The project provides few insights into the farming system and the actual and
potential role of agroforestry on the farms. Furthermore, the focus on input delivery makes it difficult to evaluate the socio-economic impact of the project.

**Chagga Homegardens, Tanzania**

The Chagga homegardens are an indigenous, multi-storied agroforestry system practiced on the slopes of Mt. Kilimanjaro in northern Tanzania. They are characterized by intensive integration of numerous multipurpose trees and shrubs with food crops and animals, simultaneously on the same unit of land. The system enables farmers to obtain sustained production with a minimum of external inputs. Because the system is both intensive and sustainable, it has supported large numbers of people for many years. However, rapid population growth and the lack of additional land suitable for homegardens now threatens this system.

Chagga farms consist of a homegarden plot and a plot on the lower plains. The homegardens are located between 900 and 1900 m above sea level on the south and east slopes of the mountain. This area has highly favorable ecological conditions, including fertile volcanic soils and good rainfall. In addition, each family has another plot 10 to 16 km away on the drier and less fertile plains. This plot has only very few trees and is used for growing annual crops. Although land use on the two plots is different, the activities on both plots are related and draw on the same family resources. Sustained cultivation in the homegardens is closely linked to the less sustainable system of lowland agriculture. Much of the crop residue from the lowlands plots is carried up the slopes and incorporated into the homegardens. This practice, combined with extensive deforestation, is contributing to rapid depletion of the topsoil on the plains.

Coffee and cardamom are the main cash crops grown in this system. Surplus bananas and other food crops are also sold. There are at least 15 different types of banana grown on the homegardens. Leaves and stems are used for fodder and as mulch for the coffee bushes. The Chagga have an intimate knowledge of the various crops and plants and their ecological requirements. They apply time-tested management practices, including the protection of plant species known to repel or eradicate various pests. Each homegarden is part of a network of irrigation/drainage furrows that tap runoff from the forest reserve at the top of the mountain.

An important feature of the homegardens is a high biomass production resulting from an efficient use of solar energy, water, and nutrients. This is due mainly to continuous inputs of organic matter through decaying plant material and farm manure. As a consequence, soil infiltration is very high in the homegardens, and surface runoff is not evident. The relatively young volcanic soils of the area are also fairly deep and fertile. The various crop species and varieties in the homegarden represent years of natural selection for survival and farmer selection for better production and quality. These species have a good resistance to prevalent pests, compete well with weeds, and have a generally high level of genetic variability. The Chagga homegardens thus represent a valuable gene pool for use in breeding programs to improve crop varieties for multistory cropping systems.

Crop production activities provide the major proportion of farm income. The annual production of a typical homegarden, based on coffee and bananas, is estimated to be worth TSh 80,000 (US $880) per hectare. The main input is family labor. The costs of purchased inputs, tools and equipment amount to approximately TSh 3000, yielding a gross return per hectare of TSh 77,000 (US $850). The major contribution is from bananas. For an average homegarden of 0.7 ha, after allowing for home consumption of bananas, annual cash income is estimated at TSh 44,000 (US $480). The production of other crops grown in the homegarden such as vegetables, beans and root crops adds to the production value.
The average production of the common maize/beans combination on the lowland plot is estimated to have a total value of TSh 18,600. The costs of inputs, including land preparation by tractor, fertilizer, and transport of produce and crop residues to the farm, are around TSh 4000. This leaves a gross return of TSh 14,600 per hectare, or TSh 10,000 (US $110) for an average plot of 0.7 ha. The returns from the homegarden plot are significantly greater than the returns from the lowland plot. Consequently the homegarden benefits more from the labor and management capacity of the farm household.

Livestock production is an integral part of the farming system. Dairy cows and goats are stall-fed with banana plants, leaves of trees and shrubs, grass planted along boundaries or on small plots in the homegarden, and crop residues. Productivity is low, but the few litres of milk produced per day form a welcome contribution to the diet.

Agroforestry activities mainly support crop and livestock production. The canopy of shade trees in the homegarden is carefully controlled to maintain the balance between light and moisture for bananas and coffee. Other trees and shrubs, such as Ficus spp., Gliricidia and Leucaena, are used for fodder. Fruit trees such as avocado, citrus, papaya, and guava, are planted in all homegardens, and excess production is sold at local markets. Grevillea robusta, Albizia schimperiana and other species are planted and managed for timber and poles.

The prunings from shade trees, the branches remaining after foliage has been eaten by goats, crop residues, and trees especially cut or pruned are used for firewood. The supply from the average homegarden is not sufficient and, as the plots in the lower zone are already depleted, additional firewood must be taken from public land or from the forest. The value of household firewood consumption is estimated at approximately TSh 30 per day or TSh 11,000 (US $120) per year. Farmers do not consider the limited supply of firewood to be a problem, although it represents an enormous drain on public land and bordering forests and the drier area at lower elevations.

The Chagga farm households produce sufficient food for themselves and a quantity of crops which provide a considerable cash income on farms with an average size of 1.4 ha. However, many homegardens have reached the limit of their productivity under the current management system. Despite the potential for further increases in productivity, it is doubtful if such improvement can keep pace with the needs of the increasing population. Growing land shortages have encouraged the migration of some Chagga to Mt. Meru, which has similar ecological conditions. The Meru people, formerly pastoralists, appear to have successfully adopted the Chagga homegarden system over a period of about 50 years.

The political, economic, and social structures of the Chagga are historically based upon corporate lineage structures. Lineage elders continue to act as key decision-makers in many activities. Adult household labor is not pooled, but is managed according to the crops being grown by individual family members. Women's crops are banana and yams; they also hire other women to perform various tasks associated with the cultivation, harvesting, or sale of these crops. Men's crops of coffee, maize, and finger millet are similarly organized. Women are responsible for marketing the surplus bananas, vegetables, and milk, with them keeping the proceeds. Men get the money from coffee, poultry, and egg sales. In the past, farm lands were divided between sons, but now daughters can inherit as well.

Labor demands are particularly important in this intensive farming system. Traditionally, kin-based work groups formed the basis for irrigation management and for harvesting activities. However, the incorporation of coffee as a cash crop has led to conflicting demands for labor at peak seasons. Consequently, women's labor is often preempted from their own crops at this critical time. Among both men and women, patron-client relations are used to define unequal exchanges of labor, goods, and services. In this
way, poorer people who cannot produce sufficient food crops on their fragmented lands must meet their needs by exchanging labor for food.

The introduction of coffee in the Chagga homegardens has resulted in a marked division of economic spheres between men's commercial coffee crop activities and their associated linkages with coffee boards and related government agencies on the one hand, and women's food crop activities and their active participation in a thriving, informal market on the other. While coffee production has stagnated in recent years, the flow of "subsistence" crops through local markets has been increasing, partly in response to an increase in private lorry transport services. There is a surprisingly resilient, demand-led market for bananas and yams, purchased by long-distance merchants who bulk on to the coast. Thus, women are increasingly engaged in cash transactions as they participate in the distribution system associated with food crops. This has important implications for their future participation in agroforestry activities.

The growth of coffee production over the past fifty years has also been associated with increasing socioeconomic stratification in the area. Successful coffee growers are from families of local elite status, who employ less well-off, landless or nearly landless workers on seasonal coffee activities. Maintenance of the Chagga homegardens and their related irrigation systems requires a degree of labor organization, supervision, and specialized knowledge that, even in the traditionally stateless system of the Chagga, depends on and promotes a highly stratified social structure. Differences in wealth, land quality and quantity, and management ability have become increasingly important in defining the forms of agroforestry that Chagga families are able and willing to practice. Clearly, whether men or women, the adopters of newer or more intensive forms of agroforestry amongst the Chagga are members of the local elite.

It is hoped that the Chagga homegarden system can be replicated in the surrounding lowlands. But this is not likely to happen. Homegardens represent an intensive agroforestry system responding to intense demographic and land pressures under favorable social and ecological conditions. In the lowlands, land pressure does not exist. From the perspective of the producers, there is no compelling reason why scarce labor, management skills, and capital should be invested in lowland agroforestry systems, when economic gains can be more readily secured by extensive clearing, mechanical plowing, and monocropping of grains.

**Agro-Pastoral Project, Rwanda**

Started in 1969, this project was originally planned as a joint effort between the Government of Rwanda (Ministry of Agriculture and Livestock) and the Federal Republic of Germany to assist in reorganizing the Dairy of Rwanda and its milk collecting scheme. Over the years, the scope of the project has broadened to include all aspects of integrated farming systems, including crop cultivation, animal husbandry, forestry, agro-industries, rural infrastructure, and farming systems research. The farming systems approach strives to maximize both productivity and sustainability on smallholdings that are threatened by severe ecological degradation.

The project area covers seven communes in three agro-ecologic zones: the Zaire-Nile Divide, at an altitude above 1800 m; the Central High Plateau, between 1550 and 1800 m; and the Eastern sloping savannas, 1400 to 1550 m in elevation. The topography is hilly to mountainous and most fields are situated on moderate to steep slopes. Communal woodlots, mainly planted with *Eucalyptus*, are maintained throughout the project area, and every commune also operates a tree nursery with technical support from the Forestry Department. Soil conservation measures are essential for sustained agricultural production.
Farms are divided into a number of parcels with different types of land use. Around the house is the banana plot, often undercropped with beans and vegetables. Coffee is grown in pure stands next to the banana plot. Beyond these plots with permanent crops are the parcels with cassava, sorghum, maize and beans, often grown in combination. If the size of the farm permits, part of this area is left in fallow. Cattle are mainly owned by the larger farmers, those with more than one hectare of land. They are grazed during the day on communal grazing land or on fallow. Most farmers keep goats and sheep tethered on waste land or along roads. The integration of crops and livestock is minimal.

Firewood and poles for building are produced on most of the farms, but on the smaller farms the production of firewood is generally not sufficient to cover household requirements. Small farmers meet their fuelwood needs by collecting dead branches from communal forests and waste lands and by using crop residues. The annual value of firewood consumed per family is estimated at FRw 4000 (US $55).

The project has developed a range of farming methods and technologies aimed at boosting agricultural productivity while maintaining soil fertility and minimizing the use of external inputs. The approach was adapted from a successful traditional system that included the use of trees in multi-story farming. Under the project, 170 local tree nurseries were established, and seedlings were given to farmers as compensation for communal labor. The project has placed considerable emphasis on research in order to develop the most appropriate and balanced system for farmers. However, research activities are now being transferred to the government agricultural research institute. Future donor support will concentrate on extension through the government's existing extension services. Many of the key project personnel have been seconded to the project from government, assuring future coordination with other agroforestry and related activities.

In central and southern Rwanda, a traditional, extensive fallow system has been gradually transformed into an intensive farming system that utilizes every parcel of land in this hilly country. Techniques used include hillside terracing, valley floor fishponds or raised gardens, composting, mulching, living fences, hedgerows, woodlots, fodder banks, and intercropping of trees, crops and livestock. Farming systems are often organized around valley floor-hillside complexes that form small micro-ecosystems.

Wealthier areas are characterized by more intensive and innovative agroforestry practices on individual plots, while poorer areas show less intensive and diversified agroforestry practices. The inhabitants of more richly-endowed micro-ecosystems have been able to capitalize on coffee production, while the inhabitants of poorer micro-ecosystems have been largely tied either to food crop production or to wage labor for wealthier patrons. While the agro-pastoral extension project initially benefitted primarily the more enlightened farmers of resource-rich regions, it is now working at the commune level to develop agroforestry interventions that can be profitable as commune projects which benefit poorer members.

Regional communes provide a mechanism by which inhabitants of resource-poor regions can gain access to inputs and management skills while also sharing risk. Since by law communes can raise taxes, run their own enterprises, and establish joint ventures, there is great potential for introducing a variety of agroforestry activities at the commune level. The commercialization of fruit and the development of small enterprises based on processing tree products may offer the most interesting prospects in this area.

Project interventions such as tree planting on farms, improved animal husbandry practices, use of organic ("green") manure, and erosion control measures, were developed within the context of the total farming system. For example, one agroforestry intervention is based on planting trees and shrubs in combination with other crops. In addition to promoting crop production, this system generates substantial additional production which
can be used for various purposes; the leaves can be used for mulch to increase crop production or for fodder for goats; the firewood and timber can be used in the household or sold for cash income. The choice of tree species can be adapted to suit the particular preferences of individual farm households.

To illustrate, *Grevillea robusta* can be planted on crop land over a period of 9 years with a final density of 360 trees per hectare. In the early years, *Cajanus cajan* and *Sesbania sesban* are also planted to provide some income and to improve soil fertility. The trees must be pruned annually to reduce competition with crops for light and nutrients. The labor input per year is small and can be carried out at any time, so the opportunity cost is low. Cash requirements are limited too, and from the third year the sale of some firewood will cover annual cash requirements.

Cash costs include FRw 800 for the purchase of 40 seedlings of *Grevillea* each year (the others are indigenous trees whose seeds can be obtained locally). The value of leaves (used as mulch for coffee) and branches (used for firewood) exceeds the cost incurred for seedlings in the second year, and this value increases sharply in year nine when the first forty trees can be cut for timber. Returns to labor are low in the early years, but are predicted to reach levels nearly three times as high as the return to bananas, the crop with the next highest labor productivity, after ten years.

Commune organization and *umuganda* group labor build on a long historical tradition in Rwandese society. Pre-twentieth century inhabitants identified with non-corporate clans that cut across the ethnic boundaries of Tutsi (pastoralist) and Hutu (agriculturalist) groups. Well into the colonial period, land could be allocated to non-lineage members by the lineage chief. Such outsiders became clients of the lineage, to whom they paid annual "rent." With the expansion of Tutsi political control over the land farmed by Hutu peasants, this land-based clientship between outside rentor and a lineage found a parallel in manual labor that could be demanded by a Hutu chief from his lineage members as a form of client payment to Tutsi overlords.

By the turn of the century, Tutsi chiefs, as agents of the state, succeeded in transforming lineage-based labor obligations into direct obligations of all inhabitants to Tutsi chiefs. The colonial government encouraged local chiefs to grow coffee as a cash crop and to plant trees for erosion control. Labor for these activities was provided by Hutu peasants. In addition, peasants were required to pay an annual poll tax by providing unpaid labor for public works, including anti-erosion earth works and tree planting.

The basic paradigm of these patronage-based relations was not destroyed by the 1959-61 revolution in which the Hutu majority gained political ascendancy. Rather, it formed the basis for an institutional arrangement by which the newly-constituted communes would form *umuganda* labor groups to perform public works, no longer in the service of local chiefs, but in the service of the jointly managed commune. The systematic activities of these work groups has resulted in the visible success of both centrally and locally defined public works in erosion, gully control, and reforestation.

Since the revolution, state support has been key in promoting a variety of forestry, land management, and agroforestry activities. At the local level, the political message translates into action on the part of *umuganda* work groups actively engaged in a variety of tree-planting or land reclamation activities. At the same time, the focus on conservation, including tree planting, has stressed supply-side activities and de-emphasized the important role of distribution and demand that would encourage agroforestry and related activities from the market end.
Alley Farming in Western Nigeria

Alley farming is a recently developed agroforestry system that holds much promise for the humid and sub-humid tropics. Food crops are grown in alleys formed by hedgerows of nitrogen-fixing trees or shrubs. The hedgerows are cut back at planting and kept pruned to prevent shading and to reduce competition with food crops. The hedgerows provide mulch for the crops, help to control weed growth and soil erosion, increase infiltration rates, help to fix nitrogen in the soil, and provide other tree products (fodder, fuelwood, and stakes). The main benefit of alley farming is that cropping and fallow phases can take place at the same time, allowing a farmer to engage in continuous cropping on the same piece of land.

Alley cropping research trials have been carried out by the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria. On-station results have been impressive. In one trial, when grown with *Leucaena leucocephala*, maize yields over a three year period were more than double the average yield in Nigeria. Rice grown between rows of *Sesbania rostrata*, and mulched with four tons of leaves per hectare, yielded 36 to 55 percent more than a control plot. Furthermore, yields can be expected to increase over time as the organic content of the soil increases.

In 1981 the International Livestock Center for Africa (ILCA) began testing the fodder potential of selected trees at the IITA campus. A program combining alley farming with fodder species was introduced to farmers in 1983 in tandem with a program of free vaccinations for livestock. Studies of four alley farming models incorporating small ruminants, based on field data and experience in southwest Nigeria, indicated that alley farming should provide a profitable alternative for farmers forced to reduce their fallow cycle to less than three years.

ILCA felt that an important element in success would be to establish contact with farmers through appropriate channels in order to stimulate interest in the program. Village chiefs were contacted and meetings were organized to present and discuss the project. Field tours were organized to give the farmers the opportunity to visit alley farms that had already been established. Vaccinations against PPR (*Peste des Petits Ruminants*) were provided free to all smallstock owners in the villages that agreed to participate in the project.

Participation of women in the program was hampered because the time for planting seedlings coincided with the palm fruit harvest, which is traditionally a women's activity. Group instruction in the rather complex techniques of planting and management caused some problems because of the lack of follow-up with individual farmers. However, despite these problems, the initial results showed promise as farmers rapidly adopted the new technology.

On-station yield increases of up to 100 percent were observed for alley cropping with maize as compared to maize grown on newly cleared bush fallow land. The benefits of alley cropping become even more important in later years when the productivity of bush fallow fields drops rapidly. In comparison, labor requirements on alley farms with maize increase by about 30 percent over the requirements for bush fallow farms, due to the work involved in pruning and spreading the branches between the crop rows. This work has to be done carefully and correctly, and at the right time each year; thus it involves important management skills as well as labor. The average value of incremental maize production per hectare in alley cropping is estimated at US $300, corresponding to a return of US $8 per day of additional labor. This provides a substantial profit to the landowner who can employ wage labor for about US $1 per day.

Alley cropping also provides useful farm products such as staking material for yams and climbing beans. Other products include fodder and fuelwood from twigs and leaves. Research has shown that up to 25 percent of the prunings can be used for fodder without reducing the system's positive impact on soil fertility. After the leaves have dropped off, the
branches spread between the crop rows for mulch can be collected for fuelwood. The economic value of these byproducts is limited where alternative materials can be found in bush fallow. However, the value of these byproducts can become significant in densely populated areas where there is no longer any bush fallow. Alley cropping also provides indirect benefits through suppression of weeds and control of soil erosion in sloping areas.

Alley farming combines a variety of activities that have been traditionally managed by different members of the household, quite independently of one another. Given the intensive management requirements of alley farming, the availability of skilled labor becomes an important issue. There is less flexibility than in traditional systems for the timing of labor inputs. On the other hand, there is no need for annual clearing of new land, and less weeding is required.

Shortage of labor is one of the more serious constraints preventing smallholders in western Nigeria from intensifying their activities. Nearly all farmers hire labor, in kind or in cash, for various farming and food processing tasks. Seasonal migrant male labor is used for heavy tasks like land preparation and weeding. Women are actively involved in food processing, both for household consumption and for the market. These constraints have important implications for the ability of farmers to adopt alley cropping, and for the design of associated training and incentive systems. Alley farming has been more readily adopted by resident villagers who own or have access to more than average amounts of land, more by men than by women, and by older, wealthier farmers whose farming and off-farm activities are already diversified, cushioning the risk entailed in adopting a new farming technique.

Agroforestry has been traditionally practiced in Nigeria in the form of oil palm and cocoa cultivation together, with yam and cassava. A variety of rural food processing industries are based on oil palm, which provides a secure and highly competitive market for off-farm enterprises. Other important tree crops used in traditional agroforestry include fruit and browse species. Thus, alley farming must be integrated with a highly market-competitive and management-complex array of cropping and processing activities. The theoretical profitability of alley farming becomes questionable when the costs associated with increased management intensity are taken into account. However, the association of small ruminant keeping with alley farming provides an early benefit from the system and enhances its attractiveness to smallholders with both crop and livestock concerns.

From a biological perspective, alley farming is considered a low input technology, and most inputs can be handled through local markets. However, management is complex and will require a high level of extension assistance, which may not be available in many areas. Expanded adoption of alley farming may require setting up specialized, project-based extension programs targetted at specific pilot locations within each zone. Alternatively, local merchants and indigenous NGOs such as trade associations could be used as intermediaries to provide extension advice to farmers.

Ownership of trees and tree products is generally treated independently of the land on which trees are planted. The person who plants a tree is considered the owner. This caused some initial confusion as to whether the trees planted by ILCA on the early demonstration farms belonged to the villagers managing the farms or to ILCA. Wives, and persons renting or borrowing land from the owner, must seek the owner's permission to plant trees; in this way, each lineage protects itself against possible claims from other lineages. However, in ILCA's alley farming activities, these customary arrangements have not created any difficulties.

Although local officials express considerable interest in agroforestry activities, positive and sustained political support has not been forthcoming from top levels of government. Government pricing policies continue to place smallholders at a disadvantage, such that farmers prefer to invest in education, trade, and credit supply rather than in agriculture.
Until this basic issue is addressed at the policy level, it is unlikely that agroforestry will be undertaken on a large scale. The support of traditional leaders at the local level is also critical in galvanizing the interest and involvement of smallholders. Where village chiefs in the ILCA project areas are actively supporting alley cropping, results are most successful.

**Agroforestry in Northern Nigeria**

This case study covers two projects in northern Nigeria. The first project includes work on fodder banks conducted in Kaduna by ILCA and disseminated under the World Bank-financed Second Livestock Development Project. In the second, a variety of agroforestry interventions are being implemented by the Forestry Department and by the Kano State Agriculture and Rural Development Authority (KNARDA). This case study was included in the review on an opportunistic basis, because of the involvement of Bank staff; it was not selected as a result of the Phase I literature review on successful agroforestry projects.

ILCA originally intended to focus on the development of alley farming as a means of improving farmer production. However, the presence of a shallow hardpan in the soil made alley farming impractical. Consequently, the ILCA project refocused on fodder bank development, using the forage legume *stylosanthes*. Fodder banks enhance the productivity of croplands during fallow periods while simultaneously providing forage for cattle. Some farmers are renting out their fodder banks to herders as an income-generating activity. The Second Livestock Project envisages using fodder banks in conjunction with settlement schemes aimed at pastoralists.

Fodder banks are being actively adopted by farmers working with the ILCA project and are popular among both agriculturalists and pastoralists. Farmers plant forage legumes on fenced land to be fallowed. Cattle are brought in to browse on the fodder crop. Their manure adds to the soil fertility that is further enhanced by the forage legumes. Herd owners have experienced a marked decrease in herd fatality, while field owners are pleased with the marked increases in crop production following the fallow/grazing cycle and with the cash income from pastoral renters.

Although the fodder bank technology was originally aimed at Fulani herders, the majority of adopters are Hausa farmers practicing both agriculture and herding. This is partly due to cultural affinities and patronage linkages between extension staff and Hausa farmers. However, traditional distinctions between pastoralists and farmers have also been breaking down under the pressures of drought and dislocation. A new class of herd owners is emerging, composed of both farmers and wealthier pastoralists, paralleled by the emergence of a class of "herdless pastoralists" dependent on share-herding or wage labor for their income.

Fodder banks appear potentially adaptable to a wide variety of ecological and socio-economic conditions. However, additional resources should be foreseen for more adaptive research that will enable the integration of local agronomic, economic, sociocultural, and institutional factors into the design of technological packages for particular areas.

Planned agroforestry activities in the Kano area include the plantation of eucalyptus windbreaks and the establishment of community nurseries and woodlots. Windbreaks were planted about 15 years ago, but no management plan has been formulated for their maintenance or harvesting. Nor has any research been carried out to determine the actual effects of windbreaks on crop production in adjacent fields. The financial cost of establishing windbreaks is considerable (estimated at US $67 per ha protected, including land, labor, seedlings and fencing), and the recurrent budget resources of the Forestry Department do not provide for adequate protection, management, or research activities.
Windbreaks consist of 2 to 10 closely planted rows of trees, placed perpendicular to the prevailing wind direction. The space left between windbreaks, which varies from 100 to 200 meters, is used for annual crops, mostly maize or millet intercropped with cowpea. The Forestry Service buys the land on which the windbreaks are planted, and receives revenue from the sale of tree products (mainly fuelwood and poles from *Eucalyptus*). The farmers bear the costs of lower crop yields near the windbreaks and enjoy the benefits of higher crop yields. The expected effect on crop yields has been estimated at between 15 and 25 percent average increase.

Community nurseries are being extended through both KNARDA and the forestry department. The technological package for growing seedlings in nurseries seems to be appropriate. However, more studies are needed to determine the best locations for these nurseries in relation to local demand for seedlings. Although the nurseries are located in villages, management is done under strict supervision of project staff, and community involvement is minimal.

The project originally assumed that local people would plant multipurpose seedlings, such as *acacia* and *neem*, in their fields. In fact, project staff have found that people are more interested in fruit and shade trees for their compounds. Pressure to meet quantitative targets for the distribution of unwanted species has led extension agents to demand that farmers accept *acacia* and *neem* seedlings as a condition of obtaining desired species. Little is known about the ultimate fate of these unwanted seedlings. It seems unlikely, however, that farmers have invested much labor in their planting and protection.

In this area, few local institutions have been identified with the capability to manage agroforestry activities. Village councils lack the managerial skills and staff needed to implement project activities. Thus, village assets such as windbreaks, woodlots, or nurseries tend to be transformed into the private assets of local leaders or elites. In order to avoid this, the Forest Department may decide to take over their management. But they will then become "enclave" activities with little connection to the community.

Certain agroforestry activities appear manageable at the local level, by individual entrepreneurs or by community organizations having sufficient management and technical skills (schools, indigenous NGOs, religious groups, etc.). Other activities, because they are based on long-term public benefits, may be better managed by public sector institutions. For example, this is true with large scale windbreaks and roadside tree planting. Yet, it is not enough for public sector institutions to organize tree planting activities. They must also plan and provide resources for the sustainable management of these assets, including recurrent cost recovery from the beneficiaries.

*Acacia albida* in Southeast Niger

The indigenous gao (*Acacia albida*) agroforestry system is a central feature of agriculture in the southern Sahelian zone that can be traced back many centuries. It allows the integration of pastoral and agricultural activities in an area of minimal and highly irregular rainfall. Groves of gao trees provide shade, prevent wind erosion of sandy soils, fix nitrogen, and provide mulch for crops, fodder for livestock, and raw materials for a variety of farm and off-farm productive activities.

The gao system is passive, that is, it is not purposely established and maintained by farmers. Instead, it relies on the complex interaction of pastoral and agrarian populations for its propagation. Gao pods are eaten by cattle and the seeds are eliminated in manure during their seasonal migrations. Farmers recognize the beneficial effects of gao trees on farm soils, and they will protect the young seedlings during land preparation. However, farmers have not responded well to government sponsored planting programs.
The intercropping of millet and cowpeas under *Acacia albida* was observed in the area around Zinder in south central Niger. Because of its very deep rooting, *Acacia albida* has a remarkable capacity to bring nutrients to the surface. In addition, it is a nitrogen fixer. Under a full canopy (100-150 trees/ha), the trees provide nutrients equivalent to 300 kg/ha of nitrogen, 30 kg/ha of phosphorus (the most critical nutrient in Sahelian agriculture), and 25 kg/ha of magnesium. Soil water retention has been reported to be 40 percent higher under *Acacia albida* than in open fields. Millet production has been reported at 100 to 150 percent higher than in the open. These effects occur when leaves and pods are left to fall in the dry season; however, increasingly branches are lopped for fodder and fuel, reducing the beneficial impact on soil quality.

In addition to fodder and fuel, the gao tree produces wood and bark, which ideally should be harvested only after the tree has exceeded its natural lifespan of 70 to 90 years. Most of the wood is used for fuel, but the trunk is carved into mortars and pestles; the bark is used for tanning hides. In a full and well maintained stand, the annual quantity of wood from dead trees would be on the order of 5 cubic meters, representing a value of US $45 equivalent. However, such full stands have become extremely rare. Natural regeneration has also come under pressure, as gao seed pods are increasingly collected by farmers to feed their penned animals, and are thus less available to the traveling animals on whom the process of natural regeneration depends.

The history of the area is one of competing city states with rural hinterlands whose wealth was traditionally based on control of the caravan trade and on a diversified farming system involving both dryland and irrigated (fadama) agriculture. The destiny of these agriculturalists was intertwined with that of pastoral groups making seasonal use of the same lands. Environmental degradation was avoided during periods of drought by extending herd movements further south and by importing grain to meet food needs.

However, state boundaries now substantially restrict the movements of both settled farmers and pastoralists. Colonial rule secured large areas from the threat of pastoral raids, encouraging the expansion of settlement on agriculturally marginal lands. The collapse of the caravan trade in the present century substantially reduced the movement of food crops through local markets and across national boundaries. All these factors have increased the area's vulnerability to ecological degradation under drought conditions.

The authority and power of traditional Hausa leaders was largely swept away in Niger under French colonial rule. The new nation-state inherited a tradition of highly centralized control which has little legitimacy at the local level. Consequently, villagers often show little enthusiasm for state-initiated project activities. In some areas, conflicts over control of agroforestry activities between government representatives and local leaders also appeared to have sapped or misdirected local energy and initiative. Village nurseries intended to promote gao planting have had low success rates.

But in the one area visited where local leaders were actively involved in project activities, a substantial difference was noted in the degree of interest and participation by farmers and the related success of the agroforestry activity. This was in Tanout, an area north of Zinder, where a group of villages are involved in an integrated rural development project led by the Department of Agriculture. The project's agroforestry component included construction of a community nursery and tree planting in farmers' fields -- but this approach was unsuccessful. The project then supported the interest of village heads in actively managing gao stands in the fields and fallows of their villages. Fifteen local leaders, through their agricultural cooperative, made a pact to protect young gao trees found in their fields. These leaders then instructed villagers to tie yellow plastic bands, supplied by the project, around all gao trees that were to be protected.
In large part, this exercise seemed to be working due to good cooperation between project staff and local leaders. Project staff were prepared to allow local political initiative and leadership both to define and manage the broad parameters of the project, while local leaders were genuinely interested in involving themselves and their people in activities that could be successful in the context of their labor, time, and management constraints. As senior members of the major lineage of each village, these leaders already commanded the respect of their village clients and thus were able to mobilize support. Furthermore, the power and authority of traditional leaders in this area, by contrast with villages further south in Niger, had not been substantially undermined by the central government.

At the farm level, there is a strict division of labor by gender. Field preparation, herding, and certain long distance trade, local marketing, processing and craft activities are primarily performed by men. Women engage in a variety of petty trade, processing and craft activities that are generally related to food crops. In addition, wood and water are collected by women. Both men and women may own small livestock, and both may separately manage their own agricultural plots. Labor in a household is not commonly pooled on farming plots. Each plot manager pays in cash or in kind, or through labor exchange, for work done by other family members or by outsiders. During planting and harvest times, hired labor by pastoral people provides an important addition to the local labor pool.

Informal work groups or age groups are not central features in this area. Consequently, there is no customary basis in Hausa society for the implementation of communal activities, like woodlots and nurseries, beyond the level of the extended family. However, there is a very well developed, traditional labor market based on cash and in-kind payment. This labor market is closely associated with economic diversification at the farm level, which in turn is embedded in a network of middlemen, periodic local markets, and long distance trading.

A feature of this diversified system is the full utilization of all biomass. Millet, maize or sorghum stalks are not left in a field unless they form part of a contractual arrangement between a farmer and a herder, by which herds are allowed to graze on the stubble in exchange for manuring the field. Alternate uses for crop residues include fodder for own consumption or for sale, craft materials, or building construction materials. Forest products such as timber, poles, grasses, brush, herbs, and medicinal plants, also have economic uses and are collected for sale. Gao pods are now systematically collected, dried, bagged, and bulked for sale in regional markets. Some traders now specialize in marketing locally processed animal concentrates and feeds, including dried gao pods.

Farmers feel that their appropriate role in the gao system is the protection of trees found in the field, rather than in planting. Gao seedlings planted by people have had uniformly low rates of survival. This implies a high labor cost associated with each surviving tree. People understandably prefer to let the livestock do the work of planting, and to devote their own efforts to saving the small number of surviving seedlings. In addition, mature gao trees in the area are visibly declining. Farmers attribute this to the effects of drought and insects. Under these circumstances, farmers do not feel encouraged to invest additional effort in tree planting.

The drought of the 1970s affected vast areas of recently settled drylands under conditions where customary methods of dealing with environmental stress were no longer possible. Gao stands in the fields of these villages have developed fairly recently, in conjunction with traditional bush fallow farming combined with cattle. The poor condition of these gao trees may indicate that this system is not really sustainable on such marginal lands under more than ordinarily dry conditions.
Majjia Valley Windbreaks

The Majjia Valley is located in the districts of Bouza and Birni N'Konni in western Niger. Average annual rainfall has been 400-600 mm in the past but has decreased to 350 mm in recent years. The valley floor has a relatively high water table and a seasonal watercourse, as well as relatively deep and fertile soils, making agriculture possible and often highly productive. The valley is inhabited largely by sedentary Hausa farmers and a small percentage of sedentary Tuaregs. Fulani herders pass seasonally through the valley. The mainstay of the economy is rainfed millet production. During the dry season the Harmattan wind blows from the north, carrying dust and sand that ravages the landscape. Vegetation is sparse at this season and the topsoil blows away at rates which can reach 20 tons per hectare each year in unprotected areas.

The Majjia Valley was first settled in the late nineteenth century, when it was well wooded and wildlife was abundant. Since then, the valley has undergone a steady process of deforestation, intensifying the destructive effects of wind and water erosion. In the early 1970s, accelerated environmental deterioration in the valley under drought conditions led two area foresters to contact CARE in 1974 with a proposal to sponsor a windbreak and live fencing project.

The Majjia Valley Windbreak Project is often considered one of the most successful examples of agroforestry in Africa. Originally proposed by a Nigerien forester and a Peace Corps volunteer, the project has been carried out by CARE/Niger in collaboration with the Niger Department of Water and Forests. After ten years of operation, the project has three nurseries producing about 60,000 seedlings (mainly neem) annually, and the Majjia Valley is traversed by about 300 km of double-row neem windbreaks, protecting about 3,000 hectares of cropland. Private and public woodlots have been established in many villages with seedlings from the project nurseries, easing pressure on the valley's natural wood reserves.

When the project started, the Nigerian Forest Service had an authoritarian tradition and a history of adversarial relations with the local population. CARE sought to introduce a community focus into the project design, but with little success during the initial planning of the project. However, villagers did participate in planting windbreaks on their land under Forest Service supervision. The trees were initially viewed by villagers as the property of the state and had to be constantly protected from cutting for fuelwood and grazing by livestock. Armed guards were hired by the Forest Service for this purpose and fines were levied against offenders.

The windbreaks consist of double rows of closely planted neem trees placed at 100 meter intervals. The cost of seedlings and planting labor is estimated at $20 per hectare protected. The annual cost of armed protection was about $10 per ha protected for the first three years. After three years, the trees begin to have an effect on crop yields in adjacent fields. Grain yields may increase 15 to 20 percent, but the biomass of the protected crops is nearly 70 percent higher than in the open. Taking this effect into account, the annual value of the benefits due to the windbreaking effect is estimated to be about $60 per hectare protected.

However, the windbreaks appear to have a negative effect on yields in their immediate vicinity, due to shading effects and to competition between trees and crops. In addition to tap roots, neem trees have a shallow root system, causing them to compete with crops for water and nutrients. The effect of reduced yields in areas shaded by the shelterbelt is estimated at $8 per hectare protected, and the effects of competition between neem trees and crops for water and nutrients is valued at $7 per ha protected. The annual value of production foregone on the land used for shelterbelts (5 percent of the total area) is estimated to be, on the average, $20 per hectare protected.
Eight years after planting, the trees can be harvested for the first time. Labor costs of harvesting are estimated at $15 per hectare protected for the first cut and $8 per hectare protected for subsequent harvests every four years. The value of wood produced is estimated at $160 per ha protected for the first cut and $54 per ha thereafter. Based on these figures, the internal rate of return for the shelterbelt intervention would be 41 percent. The return to farmers would be even higher if they receive the benefits of wood sales, since they did not incur the initial seedling cost or the cost of protection during the early years.

Subsequently, the Forest Service started a woodlot program on land leased from larger farmers. The initial purpose of this program was to meet fuelwood needs. Some farmers have adopted the idea and started planting private woodlots, but these are more often aimed at the market for construction poles, which offers higher returns on investment. Fuelwood is still gathered, often over great distances, and sold in local markets.

The project did not take into account the grazing needs of the herders who made seasonal use of the Majjia Valley, nor those of local owners of small livestock, who are mainly women. Land on which the windbreaks were planted has been totally protected from incursions by livestock. As a result, many fewer herders now pass through the valley on their seasonal migrations. Also, local stock losses during the drought have not been replaced, and surviving animals are less productive since they have to be fed on dry fodder. Women's incomes have been negatively affected by the increasing costs of maintaining small livestock.

The project's technical success can be partly attributed to the favorable conditions for tree growth in the Valley: fertile soils combined with a high water table. The species selected (neem) is well-adapted to local conditions and serves many uses. Its wood provides a high quality fuel and a tough, decay-resistant timber. Oil from the seeds can be used as lamp fuel, and the residual cake is an excellent fertilizer. Farmers understand and appreciate these benefits as well as the favorable effects of the windbreaks on crop yields.

The project has experimented with different wood harvesting techniques to determine their effects on tree growth and crop production, in order to develop a sound management plan for the windbreaks. Initial attempts to distribute the harvest through the village development council resulted in highly favorable treatment for a few farmers, and resentment on the part of the others. The current arrangement is that farmers who have windbreaks on their fields receive a share of the harvested wood, and a newly formed village cooperative receives the rest for sale to villagers who do not have trees on their plots. This arrangement benefits the villagers in two ways: (1) at least for a short while they will not have to travel so far to find fuelwood, and (2) the proceeds from sale of local firewood will be used to establish consumer goods and pharmaceuticals shops in the village. It is expected that the village cooperative will eventually take over management of the windbreaks from CARE, with continued technical inputs from the Forest Service.
IV. IDENTIFIED ISSUES

The literature review described in Chapters I and II and the field work presented in Chapter III suggest that a number of issues need to be taken into account in the design and implementation of agroforestry projects in Africa. These issues have been grouped, in somewhat arbitrary fashion, into five categories: technical, economic, social, institutional, and research issues. Conclusions and recommendations deriving from this discussion of the issues are presented in Chapter V of this report.

Technical Issues

1. Selection of species. The case studies suggest that, all other things being equal, (a) improving the use of indigenous species is better than introducing exotic species of trees and shrubs, (b) multipurpose trees are more acceptable than single purpose trees, and (c) fast-growing trees or trees that otherwise yield early benefits (e.g. fruit trees) are preferable to trees that have a long maturity period. More research should be done on the multiple uses of indigenous trees and shrubs and the ways in which they are combined with cropping and livestock activities in traditional farming systems, in order to design technical agroforestry packages that will meet real needs and minimize the risks assumed by farmers. Provenance trials also need to be done on nitrogen-fixing species, to select the strains which are more efficient in this respect. New strains are also needed which tolerate soils of high acidity or aluminum content.

2. Availability of land and water. Trees take up a certain amount of space and have requirements of their own for nutrients and water. Deep rooted trees bring otherwise unutilized nutrients to the surface, whereas shallow rooted trees may compete with crops for water and nutrients. Trees that propagate naturally under normal climatic conditions may require extra protection under drought conditions. For example, the sustainability of the gao system in Niger is threatened by the environmental stress produced by drought. The success of the Majjia Valley windbreaks is partly attributable to an unusually high water table in the area and soils capable of producing significant yield increases under protected conditions. Where these conditions are not present, the windbreak technology may not prove so successful. Alley cropping is another technology which is highly sensitive to the availability of water and soil nutrients.

3. Passive vs. active agroforestry systems. Under conditions of low population density, farmers appear more ready to adopt passive systems of protecting useful species found in their fields and forests than to engage in active afforestation programs. Passive systems are more congruent with traditional management methods handed down from a time when land and tree cover were more abundant in relation to population than they are now. At the same time, such systems are vulnerable to environmental stress from factors such as drought and overgrazing. As population pressure on the land intensifies, passive systems like the gao system in Niger or the gum arabic system in Sudan are likely to be gradually transformed into more active agroforestry systems like the fodder banks of northern Nigeria or the agropastoral systems of Rwanda.

4. System complexity and management skill requirements. Farmers understand the usefulness of trees and incorporate them in a variety of land use practices. However, it is difficult for farmers to adopt agroforestry packages that require them to organize and supervise labor to perform new tasks in a fairly precise sequence or at precise time intervals. Simply acquiring, transporting, planting and caring for seedlings may require more resources and more management skills than the average farmer can spare from subsistence activities.
Systems that require continuous protection, pruning, or weeding involve a high opportunity cost to the farm household and a greater risk of failure due to unforeseen changes in the agricultural calendar.

Economic Issues

1. Costs and benefits of agroforestry interventions. The resources required for agroforestry interventions are small in comparison with total resources used for agricultural activities on the farms. Annual labor requirements, even for intensive agroforestry activities, are calculated in days rather than weeks. The cash requirements for agroforestry are also minimal, mainly restricted to the costs of seedlings. All farms in the areas studied offer possibilities to plant trees and bushes without entering into competition with other crops. The main problem for farmers is the amount of time it takes to realize a return on even the most minimal investment.

   The benefits of agroforestry practices can be divided into two groups. Direct benefits include: fruits and leaves for food and fodder; wood for fuel, building material, and stakes; bark for tanning or medicine. The commercial value of these benefits is generally small in comparison with that of the total output of the farms, particularly if the time dimension is taken into account. Tree products, however, are important in ensuring the self-sufficiency of the farm household, and they can supplement cash income at critical periods. Indirect benefits are also obtained through the positive mechanical and/or biological effects of trees on crops. These include shade, reduction of wind velocity, suppression of weeds, improved moisture retention, reduction of erosion, reduction of albedo, and the provision of nutrients through the addition of organic matter to the soil. Through both direct and indirect benefits, agroforestry makes an important contribution to increased farm productivity, assisting Africa’s transition from itinerant to permanent agriculture.

   A theoretical comparison of costs and benefits for the farming systems studied, using a discount rate of 20 percent, yielded benefit/cost ratios greater than one in all cases. However, the farmer’s discount rate appears to rise as the degree of his or her desperation increases. This may result in a preference for realizing direct, one-time benefits through cutting down trees, at the expense of a stream of indirect benefits in the form of future agricultural production. This was demonstrated in several of the areas visited where farm families had no other option than to cut down trees, bushes and shrubs to meet their immediate needs, regardless of the consequences for future production. In other words, their time preference is high, corresponding to a discount rate substantially greater than 20 percent, which in turn is higher than the discount rate usually assumed in evaluating public investments.

   On the other hand, where opportunities for earning off-farm income exist (in Asia, for example), it has been shown that farmers, no longer dependent on their land to meet immediate subsistence needs, may choose low-technology, low-input agroforestry systems despite the relatively long gestation period for returns on their investment. In such situations, the opportunity cost of labor once again becomes the limiting factor rather than the opportunity cost of the land itself. This conclusion suggests that African farmers are more likely to demonstrate widespread adoption of environmentally sound agroforestry practices once African economies have diversified to such an extent that they offer viable opportunities for off-farm income generation by farm households.
Agroforestry practices mainly result in increased and more sustained food and wood availability for the farm household and for local markets. With the exception of tree crops such as coffee or cocoa, or the case of fuelwood plantations substituting for kerosene imports, positive effects on the generation of foreign exchange are non-existent or small. This calls for restraint in the use of foreign exchange to support agroforestry project activities, in particular if this foreign exchange is borrowed. To the greatest extent possible, agroforestry inputs should be procured locally, and all project expenditures should be made in local currency.

2. Smallholder perceptions of opportunity costs. Farmers will weigh the opportunity costs of a new activity in relation to their entire array of farming and off-farm activities. Adoption of agroforestry will be considered in the light of the limited availability of land, labor and capital, and in the context of local market and policy environments that affect the farmer's perception of the risk involved. Initial adoptors of agroforestry practices tend to be individuals or groups that can afford to take a risk, as shown, for example, by the Rwanda and Nigeria case studies. It is generally only when agroforestry activities are already widely practiced by local people, or else when new agroforestry practices are perceived as necessary to maintain subsistence production (i.e. under conditions of severe environmental degradation), that less entrepreneurial farmers will adopt them.

Perceptions of opportunity costs can be distorted by inappropriate macroeconomic policies. For example, fertilizer subsidies in northern Nigeria made this option cheaper for the farmer than mulching crops with cuttings in the alley farming system. Now that subsidies have been removed and fertilizer is not always readily available, the appeal of alley farming should increase. Variations in opportunity costs may also be related to social and ecological factors. In Rwanda and Tanzania, farmers responded to population pressures by intensifying agricultural activities. In the Sahel, farmers responded to similar pressures by diversifying out of agriculture.

3. Supply-led vs. demand-led project designs. Concentration on supply-driven activities such as the establishment of nurseries, woodlots, and plantations, rather than on downstream distribution systems and demand for wood products, often leads to a poor "fit" between project activities and farmers' perceived needs. In Kenya and in Nigeria, the species selected for distribution to farmers were not initially those the farmers wished to plant. If agroforestry activities are to become self-sustaining at the farm level, there must be satisfactory market conditions or institutions in place to stimulate demand for the commodities produced by these activities. These aspects need to be evaluated by project planners with input from the intended beneficiaries.

4. Inadequate understanding of local markets. Local markets are not limited to the formal channels of exchange officially recognized by the state. They include local exchange, barter, and petty trade which may involve several intermediaries before a product reaches its final consumer. The case of the Chagga homegardens illustrates an agroforestry system designed to serve a number of different market demands. Value is added by intermediaries through transportation, bulking or processing activities. In most cases, the products sold or traded are "subsistence" commodities. Markets are used to capitalize a surplus of subsistence goods and to circulate such goods among producers, processors, and consumers.

Knowledge of local markets can help to avoid overly ambitious agroforestry projects, which can result in saturating local markets with agroforestry products such as building poles or fruits and fibers. Local market knowledge can also facilitate project success by introducing new commodities that will meet or complement market demands. Agroforestry interventions should be designed to complement local marketing networks and, to the extent possible, promote increased market coordination. In some cases, agroforestry has been introduced as part of a package developed in collaboration with suppliers who have already identified a market for its products.
5. Connection with off-farm enterprises and employment. Diversification of income sources for rural inhabitants in Africa, involving a variety of enterprise and wage labor activities in addition to farming, has become commonplace. Indeed, few individuals or households could exist in Africa today without recourse to at least one non-farm income-generating activity. Such income diversification implies that agroforestry interventions should be assessed, not only from the viewpoint of crop production, but also in terms of their potential to promote off-farm enterprise and employment opportunities. For example, processing activities may already exist or could be developed that would take advantage of new agroforestry products.

Another implication of this trend relates to the availability of labor. Because of income diversification into nonfarm activity, including seasonal migrant labor by men in many areas, critical labor shortages may occur in agriculture at certain times of the year. Thus, when an agroforestry intervention requires significant labor input, especially if this has to be sustained over a long period of time, it may not be appropriate for such an area. Or, it may be adopted by persons able to hire the necessary labor, but cannot be adopted by the majority of the population.

6. Private returns vs. public objectives. Among the agencies that design and implement agroforestry projects, there is a persistent focus on public (e.g. environmental) benefits rather than private returns to investment. It seems to be felt that farmers should, and therefore will, plant trees because they will provide benefits to the community. In contrast, the case studies found that, although farmers are willing to consider environmental benefits, these aspects alone rarely offer sufficient incentive for small farmers to engage in agroforestry activities. Even when the financial benefit is clear, most farmers cannot afford to invest in such projects if returns are deferred for several years, and especially in new interventions where the return to investment is not guaranteed.

Behind this mistaken belief lies an assumption that smallholders are subsistence oriented and consequently are not responsive to economic incentives. Years of experience with rural development projects have shown the fallacy of this assumption. This experience has been confirmed by the field work for the present study, which clearly demonstrates that farmers do respond to economic incentives and that they will engage in agroforestry activities when these are economically advantageous from their point of view. A project orientation toward the public good, as expressed in purely environmental concerns, tends to obscure issues of appropriate institutional focus and long-term sustainability. It leads to a misunderstanding of the motives of participants and tends to perpetuate project dependence on outside support. The long-term sustainability of agroforestry projects will depend on their degree of market orientation and their ability to respond to changing economic conditions.

Social Issues

1. Differential adoption of agroforestry by gender, age, and socioeconomic level. While an agroforestry intervention may be designed for a given ecological zone, it will be adopted to varying degrees by persons of different income levels, occupations, gender, age, and education. Access to land, labor, and capital further influence the degree to which an intervention will be adopted.

The tree-seedling nurseries in Kenya proved to be appropriate for small, informal women's groups. Risk involved in the activity can be shared by the group as a whole, land of a male relation of a member can be used for the nursery (in exchange for a portion of the seedlings produced), and labor requirements can be shared among the women members. The different seedlings produced by these groups will be appropriate for persons of different standing in the area; for example, men with excess land may purchase seedlings to start a
wood pole lot; landless men and women may want fruit trees to plant in their compound; wealthier farmers may want to purchase fast-growing legume species to plant with their coffee crops in order to increase soil fertility.

Alley cropping in Nigeria, too, has differential acceptance and impact. For farm households with labor constraints, keeping to the prescribed pruning schedule may not be possible. Richer farmers may be able to hire laborers for such tasks, but this approach involves greater risks, unless farm owners are able to provide close personal supervision of the labor force. Similarly, management-intensive activities such as stall feeding of livestock in conjunction with the maintenance of fodder banks, as in Rwanda, may turn out to be appropriate only for a small group of wealthier and more entrepreneurially oriented farmers. For poorer men and women, and for families with limited access to land, labor, or capital, more modest agroforestry interventions are needed.

2. Pastoralists and agroforestry. Government programs designed to involve pastoralists in agroforestry may be based on misleading assumptions about pastoral production systems. Such systems are not necessarily self-contained or subsistence oriented. Relations between nomadic and settled populations are very complex and cannot be reduced to conflicts occasioned by pastoralists travelling through agricultural lands. For example, maintenance of the traditional \textit{Acacia albida} agroforestry system is highly dependent upon continued interaction between the two groups. These relations are by no means ideal, and conflicts do occur. However, the central importance of this symbiotic relationship, in which herder and farmer occupy different niches in the same ecosystem, should not be obscured by these conflicts.

The symbiotic relation between farmer and pastoralist at the individual level is part of a larger, regionally-based exchange relationship which capitalizes on the comparative advantages of different ecological zones. Policies directed at controlling and limiting cross-border trade can result in serious unintended environmental impacts, by forcing farmers and herdsmen alike into inappropriate subsistence production activities. Government strategies that attempt to create top-down delivery systems based upon spatially bounded models such as ranches or cooperatives have generally failed to reach the majority of pastoralists. A better understanding of the economic and ecological importance of pastoralism is needed in order to design more viable projects.

3. Tree tenure, land tenure, and usufruct rights. Ownership or secure use of land is frequently cited as a precondition for farmers to make long term investments in agriculture. This argument appears particularly apt for agroforestry, where several years may elapse before the farmer can expect to receive a return on his investment. But it is important to realize that, in rural Africa, the tenure issue has less to do with formal laws and regulations than with the customary rights of various groups and individual members of these groups to make use of the land and of different products growing on the land. Strategies of land management based on the usufruct rights of lineage members to land or to particular resources on the land are basic features of African hoe agriculture. Elders allocate specific lands for cultivation to adult males of the lineage, who in turn must allocate plots to all of their wives. In this way, land is retained as a corporate resource within the lineage. Land may be rented, but not purchased, by outsiders.

Customary law regulates the usufruct rights and obligations of members of a kin or residential unit to communal lands. In many cases, so-called communal lands would be more correctly described as corporately controlled lineage lands. Access to such lands is not open to everyone. Rather, it is limited to group members and others who have established a formal relationship with the group. Furthermore, equal rights of access are not guaranteed; every community or lineage has its own internal hierarchy based on factors such as age, gender, education, etc. Contrary to popular opinion, the corporate management of lands and other productive resources in Africa is not diminishing in the face of modernization.
In contrast, trees are often individually owned—usually by the person who planted them—while land itself is annually redistributed. However, when land circulates within a limited pool of related people, agroforestry investments benefit the lineage as well as the individual planter. Thus, it has long been possible for smallholders to develop tree crop plantations. Yet, since the management of tree crops and annual crops cannot be separated in this system, it will be more difficult for them to adopt alley farming. In some situations, trees on farm lands, whether planted or protected, belong to the government by formal law and/or to the local chief by customary law. The government or the chiefs may sell the right to harvest the trees to outsiders. Not only do farmers lose the benefits of these trees, they may also experience damage to their crops for which it may be difficult to claim compensation. This situation creates a powerful disincentive to farmers to plant trees even when they are aware of the potential benefits to their farmland.

There is no clear evidence that improved land tenure would provide a greater incentive for farmers to invest in agroforestry. Where agroforestry activities are demonstrably profitable, farmers appear to be willing to invest despite the insecurities of tenure; while farmers, even with secure tenure, will not adopt agroforestry practices that do not show positive returns on their investment of labor or capital. Secure returns are guaranteed not by formal land tenure, but rather by the web of usufruct rights that link members of a group with a variety of productive resources, including both land and trees. Moves to promote individual land tenure may, in fact, tend to disenfranchise large segments of the local population by depriving them of their customary use rights. Formal tenure may be limited to men, providing more incentives for cash cropping than for the mixed farming systems in which women participate. Such moves may well enhance the productivity of particular plots while having a net negative effect on the welfare of the community as a whole.

Institutional Issues

1. Institutional design and project sustainability. Achieving long-term sustainability, including recurrent cost recovery, is a key concern shared by all agroforestry projects. Some difficulties encountered by projects can be related to inadequate institutional design. Agroforestry projects are often expected to function as self-contained units, lacking linkages to local and higher-order economic and institutional systems. Without such linkages, agroforestry activities are not likely to survive in the absence of sustained external support. Agroforestry may in fact be most successfully implemented as a component of a larger agricultural project. Free-standing agroforestry projects will often be too small to interest major donors and governments.

The case studies illustrate three basic options for project management: (1) management by international project staff; (2) management by government agency staff; and (3) management by local communities or indigenous NGOs. The first model provides some short-term advantages because of its ready access to external funding and its ability to secure early quantitative success. However, long-term sustainability may be more difficult to achieve because indigenous institutions, marketing channels, or training and extension facilities that could later take charge of project activities are not systematically identified and strengthened under this model. Token involvement by local counterpart staff or community representatives will not guarantee sustainability, because actual decision making, implementation, resource mobilization, and staff training remain under the control of the international donor.

The second model is intermediate in the sense that it has somewhat greater local legitimacy but does little to reduce local dependency on outside resources and expertise. Government managed projects may, in fact, result in new forms of reliance on subsidized inputs by smallholders. A tendency for government agencies to focus on technical
considerations of nursery design and selection of species may result in critical economic and institutional issues not being adequately addressed. There is also a danger that, instead of strengthening local institutions and markets, project activities may encourage more systematic extension of government patronage and control into rural areas.

The third model for project implementation offers many advantages. First, indigenous NGOs are a product of, and operate effectively within, the local economic, social, political, and institutional context. The danger of their becoming enclave projects is relatively small. Achieving a producer-centered perspective from the inception of project activities will be more likely. Furthermore, since indigenous NGOs are well equipped to mobilize local resources, such organizations will generally be more cost-effective instruments for project implementation. Finally, indigenous NGOs are more likely to be able to continue functioning when external resources are withdrawn from the project.

2. Institutional support for agroforestry interventions. The introduction or expansion of agroforestry activities requires services, whether provided by the government or not, in research, extension, and the supply of seeds and seedlings. The integration of agroforestry activities on the farm requires a comprehensive understanding of the farming system in total. Therefore, research requires close cooperation between forestry, agriculture, and animal husbandry departments. Forestry extension activities should be integrated into the work program of the agricultural extension service, with professional foresters working as subject matter specialists at the central level and with the participation of forestry technicians at the field level.

Since agroforestry interventions are only gradually adopted by farmers, continuous attention from the extension service and a regular annual supply of seeds and seedlings are of great importance. Research and extension work should focus more on species which can be directly sown on the farm and on species which can be raised by farmers themselves.

3. Use of indigenous NGOs. Local associations are embedded in local social structures and are characterized by voluntary, personalistic, face-to-face transactions; hence, they tend to be highly participatory and to reflect well their members' interests. However, there may be inherent weaknesses within such informally organized groups. Such organizations may meet formally only in relation to certain activities and or at certain times of the year. They generally do not have the management capacity of more formal institutions, and are often organized around one or several charismatic figures who dominate decision-making in the group.

Such organizations may collapse under efforts to impose more formalized procedures. This may be due to competing interests, lack of general education, time and labor constraints, and/or an unsupportive policy environment. Where informal, traditional associations have developed the skills to act as intermediaries for their members, they have generally benefited from government support as well as sound politically and economically based reasons for their existence.

The strength of indigenous NGOs—that their informal, decentralized and member-based structure enables them to articulate and address developmental interests of their members—also constitutes a potential weakness. They are not systematically linked to higher order arrangements through which regular inputs of technical assistance can be channeled. Thus, it may be difficult to work with them on a sustained basis. Unless some form of vertical coordination can be achieved, the capacity of indigenous NGOs to implement projects may be limited.
In some areas, indigenous NGOs have historically played key roles in focusing political opposition at the local level. The government may be wary of allowing indigenous NGOs to enter the development arena, or may be willing to do so only in the context of central government control or oversight. Such control may be exercised by insisting that NGOs adopt a given organizational design, such as a cooperative, or that they register with local officials as a precondition for receiving assistance.

A realistic assessment needs to be made of the amount of technical assistance an indigenous NGO will require in order to be able to implement project activities. Technical and financial management skills will need to be transferred to these groups. Project subsidies should be kept to a minimum so that the group's success will not become dependent on outside support. Finally, indigenous NGOs are local interest groups and are not necessarily equitable in their allocation of resources. Thus, careful assessment of an indigenous NGO's character and clientele is necessary in order to plan for its successful involvement in an agroforestry project.

Research Issues

1. **Diagnostic studies and adaptive research.** Diagnostic studies are needed to identify and better understand indigenous agroforestry systems, including both traditional systems and more recent adaptations to changing environmental conditions. Studies should pay attention to environmental, economic, social, and institutional aspects of agroforestry systems, as well as their technical characteristics. There is also a great need for adaptive research focusing on improvement of locally cultivated tree species, on improved product processing and marketing systems, and on improved soil and water conservation measures. Adaptive research should focus first on the products which provide the best economic return to farmers, such as poles, fruit, and stakes. Environmental benefits should be sought as an adjunct to such economic benefits, and not the other way around.

2. **Research delivery systems.** In order for agroforestry research to promote effective change in farmer behavior, it needs to become more responsive to demands from the farm level. At the same time, more effective extension techniques need to be developed in order to transfer new knowledge from research stations to the farm level. The relevance of agroforestry research to farmers, as well as effective marketing of research products to them, will be enhanced by strengthening demand-led linkages with user groups at local, regional, and national levels. Linkages between regional research institutes, national research institutes, and monitoring and evaluation units of projects involving agroforestry practices need to be developed or strengthened, so that they can become effective conduits of user demand from smallholders to higher levels.

3. **Using the "household" as the unit of data collection and analysis.** Previous case studies of African farming systems have demonstrated that focusing on a household as the sole unit of data collection and analysis can be misleading. In Africa, lineages or extended families continue to be important as corporate entities controlling the organization of productive activities. Access to land is generally still tied to lineage or extended family rights of land use and tenure. Often, budgets are not pooled within the household, but are separately controlled by each individual member.

Decisions about engaging in agriculture, agro-forestry, and off-farm activities are not "household" decisions; men will make decisions in one area, women in another. In some instances, agroforestry systems can involve complementary actions by different household members. For example, fruit trees may be owned by men, while usufruct rights to the fruit belong to women. In other cases, there may be a chain of vertically coordinated activities, such as the seedling nurseries operated by women in western Kenya, from which men can obtain seedlings for trees from which women will eventually gather fruit. Still other agroforestry activities, such as alley farming in western Nigeria, are individually oriented,
with owner/managers using both kin and non-kin labor reimbursed either in kind or in cash. These examples illustrate the fact that the organizing principles of lineage and marriage, and not just the layout of households or farm plots, must be taken into account in the design of agroforestry projects.

4. The many meanings of success. The definition of "success" in agroforestry has multiple dimensions. What may be appropriate, and apparently successful, from a technical viewpoint may be less successful from an economic, social, institutional, or management perspective. The criteria used to identify "successful" case studies for this project focused primarily on their technical aspects. For example, the Majjia Valley windbreaks are technically a success. However, the difficulty of defining an appropriate institutional framework and the lack of development of local management skills calls into question the sustainability of the project over time. What is biologically appropriate for dealing with environmental problems may not always be appropriate in terms of local institutional arrangements and the managerial skills of local people.

Similarly, the establishment of community nurseries as part of integrated rural development projects may be intended to stimulate community involvement in agroforestry. But, such nurseries often promote the extension of control by central and regional authorities to the village, rather than strengthening local capabilities. While such nurseries may successfully produce seedlings, the economic and institutional goals of encouraging the direct participation of small farmers in agroforestry activities will not be achieved. In fact, such activities may actually increase local dependency on subsidized inputs, government expertise and/or donor funding.

These findings have important implications for the training of agroforestry researchers and extensionists. Successful and sustainable agroforestry projects obviously depend partly on appropriate technical advice relating to species selection and cultivation techniques. However, many aspects of successful agroforestry projects relate more to the economic, social, and institutional context than to the technology of production. These complex development issues suggest that taking a team approach, involving the skills of specialists in agroforestry, small scale enterprise, credit, and marketing, would produce more sustainable interventions in the future.
V. CONCLUSIONS AND RECOMMENDATIONS

The insights gained from the agroforestry literature, from discussions with key professionals, and from field visits to seven agroforestry sites in Africa lead to the following conclusions and recommendations. These recommendations do not address in detail the merits or disadvantages of particular agroforestry systems or technical packages. Further work on the technical aspects of these systems and packages is, of course, important. This chapter seeks to broaden the range of issues considered in agroforestry project design in order to better incorporate some of the contextual factors which have important implications for project success and sustainability.

General

1. **Agroforestry is found all over Africa.** The concept of combining trees and shrubs with field crops and/or livestock is central to many traditional farming systems in Africa. Until recently, such systems were sustainable at relatively low levels of welfare for the participants. But rapid population growth combined with rising expectations for human welfare have rendered such traditional systems unsustainable in the long run. African farmers need to implement new, more effective farming systems in order to generate productivity increases on a diminishing resource base. Modern agroforestry has a significant part to play in helping to accomplish this transition. Indeed, there appears to be no other viable solution for sustainable agriculture in the humid tropics.

2. **Agroforestry is only one aspect of an integrated farming systems approach to enhanced agricultural productivity.** Promotion of agroforestry should therefore be integrated with the work of the national agricultural extension services in African countries, rather than be done by foresters. Extension services will, of course, require subject matter specialists who are familiar with the characteristics and uses of different trees and shrubs and who understand how they can be effectively combined with crops and/or with grazing. However, for historical reasons, and because of their involvement with the whole farm enterprise, it is likely that agricultural extension agents will be better able than foresters to deliver agroforestry services to the farmer.

3. **Africa's needs for wood cannot be met from her remaining forest resources.** Most of the demand for wood comes from people living in agricultural areas. A large part of the urban wood demand is also for fuelwood and charcoal rather than timber and pulpwood. This demand provides a significant market for products which can be produced economically on small farms. Yet, as long as wood can be collected from common lands at low cost by rural producers, there will be little economic incentive to plant trees on farms to meet fuelwood demands.

4. This leads to the conclusion, reluctantly reached by many, that **agroforestry for fuelwood will not be widely adopted until the "free" wood resources of the commons have virtually disappeared,** and market forces have brought the price of fuelwood more into line with its true social cost. This implies that agroforestry cannot be expected to solve the fuelwood crisis in Africa; other solutions must be actively sought to meet domestic energy needs. In contrast though, **agroforestry has already been widely adopted by farmers for other purposes,** and there is reason to suppose that the present pattern of forest clearing and degradation of natural woodlands can be reversed by a combination of effective protection for the remaining forest resources and active promotion of tree planting on farms.
5. For this reason most, if not all, agricultural projects should contain a tree planting component, providing extension services and seeds or seedlings where needed. Projects should offer a selection of species tailored not only to the ecological conditions of the area but also to the perceived needs of farmers for tree products and services. Projects should conduct research on local agroforestry species, practices, and products with the aim of identifying and disseminating successful systems to other farmers. The following sections provide more specific recommendations concerning the design of agroforestry projects or project components.

Economic Analysis

6. Agroforestry projects should be designed at least partly in response to perceived demand for agroforestry products and services at smallholder, regional, and national levels. Expected long-term benefits to agricultural production should be balanced by short-term returns to the farmer from consumption or sales of agroforestry products. Production, processing, and distribution channels should be identified both upstream and downstream of the project. Off-farm enterprises that can or do utilize agroforestry products should also be identified. Public and private, formal and informal marketing channels should be identified and strengthened.

7. In addition to determining the economic return of the program to society as a whole, project designers should pay attention to the financial returns of agroforestry interventions from the point of view of specific user groups. Short term economic benefits to farmers should be assessed, in addition to an analysis of social benefits due to community participation and environmental benefits due to improved land use. More disaggregated models need to be developed for calculating the economic and financial returns of agroforestry interventions. Where the expected returns to farmers are insufficient to provide a meaningful incentive for farmer participation in the project, there may be a case for subsidies or other incentives to bring farmer costs down to an acceptable level, in light of the environmental benefits of such projects to society at large (watershed protection, soil conservation, etc.).

8. Studies should be conducted on aspects of the rural and national economies that impact on agroforestry practitioners, focusing on linkages between producers and relevant regional and national economic structures. These may include topics such as rural financial markets, land and tree tenure systems, pricing and tariff structures, incentives and subsidies. At the farm level, consideration should also be given to the competing demands of household activities and off-farm employment for the resources needed in agroforestry.

Institutional Support

9. Institutional issues need to be addressed at three levels, corresponding to varying degrees of institutional and managerial complexity, as well as to varying kinds and degrees of return on investment. Micro-level agroforestry interventions, such as fruit trees or alley cropping, should emphasize short-term benefits, relative ease of management, and project implementation at the individual or farm level. Middle-level interventions, such as community nurseries or woodlots, may emphasize short or long-term benefits. Such projects should involve implementation by groups or associations. They are likely to require more specialized and intensive management, and to combine economic returns to the group with social service and/or environmental benefits to the community as a whole. Macro-level interventions, such as windbreaks or forest plantations, emphasize long-term benefits and may be most appropriately implemented through the public sector. These projects are likely to involve the most specialized and intensive management requirements. Social and environmental benefits will be important in such projects, although economic returns may also be sought, especially where cost recovery is a goal.
10. To date, many agroforestry projects have been undertaken as pilot projects at the local level with support from outside groups. Knowledge gained through these activities should be used to refocus donor support on institutional strengthening in order to enhance country capabilities for initiating and managing agroforestry interventions. Implementation through "community" or "self-help" groups may be most useful for one-time or intermittent activities. However, with appropriate institutional support and coordination, such groups can also contribute to the long-term, systematic upkeep and management of some agroforestry interventions.

11. An assessment of local institutions, including their actual and potential capability of providing intermediary services, should be conducted. Local institutions can be analyzed in terms of the three levels described above: i.e., macro, middle and micro level institutions. Appropriate institutions for project implementation should be selected in relation to the project goals, technology, and target group. Strengthening of existing institutions should always be preferred to the development of new institutions.

12. Agroforestry projects should adopt rolling, process type designs, allowing for regular assessment of monitoring data and reformulation of project activities in response to changing conditions and user demands. Project targets must be realistic and linked to a phased implementation scheme. Project monitoring should focus on the processes leading to farmer adoption and replication, rather than on quantitative indicators of service delivery. A reasonable time frame should be allowed before evaluating project success, particularly for projects introducing new technologies and/or new institutions. In many cases this time frame should be ten years or more.

13. Agroforestry training activities should be directed to (a) developing holistic interdisciplinary training courses and materials; and (b) strengthening in-country institutions, both public and private. These institutions may include a variety of intermediaries, particularly at the regional and local levels (schools, local NGOs, religious associations, etc.). Training for foresters should extend beyond agroforestry techniques, to include relevant skills in related disciplines (agriculture, rural markets, off-farm enterprises, credit, etc.). Agricultural extension staff should also be trained to handle interdisciplinary, complex agroforestry interventions.

14. Training materials, courses and seminars should be developed in cooperation with local institutions. Such training should provide a better balance between the conceptual and practical aspects of agroforestry, with a focus on field demonstrations. Some training materials should focus on the role of women, particularly in post-harvest processing technologies and crafts that utilize agroforestry products. Needs for human resource development in the different disciplines that are relevant to agroforestry should be assessed at both national and local levels, and training plans should be prepared as an integral part of policy and project formulation.

Research Priorities

15. ICRAF and other researchers in agroforestry use a procedure for developing agroforestry systems, called "Diagnosis and Design," based on the model of farming systems research. This agroforestry research paradigm involves four kinds of research activities: (1) diagnostic research, including baseline data collection and analysis, emphasizing study of the farm household and community environment as a basis for determining constraints to increased productivity, farmer needs, and the characteristics of potential alternative solutions; (2) applied research, designed to develop a range of agroforestry technological packages; (3) adaptive research, in which alternative technologies are evaluated in light of their suitability for use under specific local conditions; and (4) on-farm adaptive research, through which the process of farmer adoption is monitored and the selected package is modified in response to farmer feedback.
Within this paradigm, two kinds of research should receive greater emphasis: (1) on-farm adaptive research, in which an agroforestry activity is fine-tuned to the ecological, socio-economic and institutional conditions of a particular area, and (2) applied research aimed at improving the productivity of indigenous agroforestry and related activities. There is also a need for basic research to enhance understanding of agroforestry techniques for improving both existing and newly introduced farming systems. The content of this research should be informed by the priorities of smallholders as well as of users in higher-order institutions.

16. Research should be focused at the producer level. Therefore, research programs should actively incorporate local organizations, extensionists, and producers in research activities which they can help identify and supervise. Research should extend beyond biological considerations to include socio-economic, cultural, financial, legal, and policy aspects of agroforestry systems. Research methodology should adopt the farming systems approach, so that activities would be phased and resource allocation priorities established to reflect the farming and off-farm activities of the participating population.

17. Project monitoring activities should be designed to interface with adaptive research. To the extent possible, project-specific monitoring should be integrated with national research and evaluation activities. Methodologies need to be developed for long-term tracking of agroforestry production systems. Such tracking exercises should be systematically conducted within and coordinated across different ecological zones.

Policy Issues

18. Governments should be encouraged to develop action programs of support for agroforestry, generally within agricultural research and extension programs. Cooperative programs should be established to link agroforestry research and extension with the work of forestry agencies. Provision of adequate recurrent budget support to sustain projects over a lengthy time frame is essential. Expectations of cost recovery from beneficiaries should take into account the long gestation period of most agroforestry interventions. The capacity of in-country institutions to identify policy issues and to assist in policy formulation should also be strengthened. Opportunities should be provided for national staff to gain practical experience and to participate in short orientation courses in developed or other developing countries.

19. Studies should be conducted on policy issues related to agroforestry, both from the point of view of smallholders and from that of implementing agencies. Such studies could include the effects of licensing restrictions, subsidy policies, import duties, pricing and marketing structures, import/export restrictions (especially restrictions on interregional trade), and factor and product market distortions. Policy studies related to land tenure should also include issues of tree tenure and usufruct rights under customary and contemporary law.

20. The donor community should support efforts to educate policy makers, planners, extension workers, and the rural population about the importance of agroforestry. The discipline of agroforestry is still relatively unfamiliar to many decision-makers, and many people are not clear about what it involves. It requires work by interdisciplinary teams, including agronomists, foresters, economists, and social scientists, whose efforts should be focused in the field. Farmers should be involved from the very beginning in the design and development of agroforestry activities. The donor community should also support agroforestry research and development, both at the national level and at the international level, through the work of the Consultative Group on International Agricultural Research.
NOTES


(14) CTFT (Centre Technique Forestier Tropical), "Estimations des volumes et de la productivité des formations mixtes forestières et gramineennes tropicales." Nogent-sur-Marne, France, 1982.


(24) Lal, R. "Agroforestry as a possible sustainable farming system in the humid tropics." Department of Agronomy, Ohio State University, Columbus, Ohio, 1988.


**PERSONS CONTACTED FOR THIS STUDY**

**The World Bank**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emmanuel Asibey</td>
<td>Consultant, AFTEN</td>
</tr>
<tr>
<td>Stephen Carr</td>
<td>Principal Agriculturalist, AFTAG</td>
</tr>
<tr>
<td>Michael Cernea</td>
<td>Rural Sociology Adviser, AGRPS</td>
</tr>
<tr>
<td>Leif Christoffersen</td>
<td>Division Chief, AFTEN</td>
</tr>
<tr>
<td>Robert Clement-Jones</td>
<td>Country Officer, AF5CO</td>
</tr>
<tr>
<td>Graeme Donovan</td>
<td>Senior Economist, AF2AG</td>
</tr>
<tr>
<td>Francois Falloux</td>
<td>Senior Environmental Specialist, AFTEN</td>
</tr>
<tr>
<td>Michael Furst</td>
<td>Senior Rural Development Specialist</td>
</tr>
<tr>
<td>Scott Guggenheim</td>
<td>Consultant, AGRPS</td>
</tr>
<tr>
<td>Benjamin Kamugasha</td>
<td>Consultant, AFTEN</td>
</tr>
<tr>
<td>Jeffrey Lewis</td>
<td>Agriculturalist, AF5AG</td>
</tr>
<tr>
<td>William Magrath</td>
<td>Natural Resource Specialist, ENVST</td>
</tr>
<tr>
<td>Kathleen McNamara</td>
<td>Forestry Specialist, AFTAG</td>
</tr>
<tr>
<td>Shem Migot-Adholla</td>
<td>Senior Rural Sociologist, AGRAP</td>
</tr>
<tr>
<td>Hans Mittendorf</td>
<td>Consultant, AFTAG</td>
</tr>
<tr>
<td>Augusta Molnar</td>
<td>Consultant, ASTEN</td>
</tr>
<tr>
<td>Ridley Nelson</td>
<td>Environmental Specialist, ENVST</td>
</tr>
<tr>
<td>Raymond Noronha</td>
<td>Consultant, ENVOS</td>
</tr>
<tr>
<td>Keith Openshaw</td>
<td>Forestry Specialist, IENHE</td>
</tr>
<tr>
<td>Donald Pickering</td>
<td>Senior Agricultural Advisor, AFTAG</td>
</tr>
<tr>
<td>Chandrashekhar Ranade</td>
<td>Economist, AF4AG</td>
</tr>
<tr>
<td>Paul Ryan</td>
<td>Forestry Specialist, IENHE</td>
</tr>
<tr>
<td>Anand Seth</td>
<td>Division Chief, AF4AG</td>
</tr>
<tr>
<td>Alain Seznec</td>
<td>Agriculturalist, AFTAG</td>
</tr>
<tr>
<td>Alfredo Sfeir-Younis</td>
<td>Senior Evaluation Officer, OED</td>
</tr>
<tr>
<td>Poul Sihm</td>
<td>Senior Livestock Specialist, AFTAG</td>
</tr>
<tr>
<td>John Spears</td>
<td>Division Chief, ENVST</td>
</tr>
<tr>
<td>Jon Martin Trolldalen</td>
<td>Research Analyst, ENVST</td>
</tr>
<tr>
<td>Raymond Rowe</td>
<td>Forestry Advisor, AGRPS</td>
</tr>
<tr>
<td>Horst Wagner</td>
<td>Senior Forestry Specialist, ASTAG</td>
</tr>
<tr>
<td>Joseph Wambia</td>
<td>Senior Economist, AF4AG</td>
</tr>
<tr>
<td>Francois Wencelius</td>
<td>Forestry Specialist, AFTAG</td>
</tr>
</tbody>
</table>

**USAID**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dan Deely</td>
<td>Headquarters Staff Forester, S&amp;T/FNR</td>
</tr>
<tr>
<td>Mike Benje</td>
<td>Staff Forester, S&amp;T/FNR</td>
</tr>
<tr>
<td>Dennis Johnson</td>
<td>Agroforester, FSP</td>
</tr>
<tr>
<td>Abdul Wahab</td>
<td>Head, Planning and Analysis Branch, AFR/TR/ARD</td>
</tr>
<tr>
<td>Michael McGahuey</td>
<td>Forester, AFR/TR/ARD</td>
</tr>
</tbody>
</table>

**Oxford Forestry Institute**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.E.M. Arnold</td>
<td>Senior Associate</td>
</tr>
</tbody>
</table>
Energy/Development International

Asif Shaikh, President; Forestry Economist
Amare Getahun

World Resources Institute

Robert Winterbottom, Deputy Director

Associates in Rural Development

James Thomson, Senior Associate

Equity Policy Center

Irene Tinker, President

International Resources Development and Conservation Services

Fred Weber, Forester

FAO, Rome

Philippe Alirol, Forestry Officer
K.-H. Friedrich, Agricultural Economist
Malcolm Hall, Chief, Farm Management and Production Economics Division
Claude Heimo, Forestry Officer, FAO/CP
Marilyn Hoskins, Community Forestry Officer
Robert Kirmse, Forestry Officer, FAO/CP
Lennart Ljungman, Assistant to the ADG, Forestry Department

ICRAF, Nairobi

Bjorn Lundgren, Director
Eva Mueller, Consulting Forester
Fred Owino, Forester
John Raintree, Anthropologist
Sara Scherr, Economist
Michel Baumer
Denis Depommier
Peter Huxley
Bashir Jama
Richard Labelle
P.K.R. Nair
Peter Oduol
Andres Pinney
Mark Sandiford
Gregor Wolf
Peter Wood
CARE/Kenya, Nairobi

Hugh Allen       Regional Technical Advisor
Louise Buck      Regional Technical Advisor
Peter Harz       Education Resource Development Unit
Bill Huth        Country Director (outgoing)
Walter Msimang   Country Director (incoming)

Kenya Rural Enterprise Programs

Fred O'Regan     Managing Director

IDRC, Nairobi

Ron Ayling       Program Officer
Jeffrey Fine     Program Officer
John Nkinyangi   Regional Program Officer

Institute for Development Studies, Nairobi

Urs Herren       Research Fellow
G. M. Ruigu      Senior Research Fellow

World Bank Resident Mission, Nairobi

Michael Mills    Deputy Resident Representative

Ford Foundation, Nairobi

Alan Fowler      Program Officer
Dianne Rocheleau Program Officer

USAID, Nairobi

Patrick Fleuret  Regional Advisor, Behavioral Science
David Gibson     Regional Advisor, Forestry/Agroforestry
Atha Kayoth     Agricultural Economist, USAID/Tanzania

KENGO, Nairobi

Achako Wari      Executive Director

Center for African Studies, Nairobi

Anne Fleuret    Lecturer, Department of Anthropology
CARE/Kenya, Siaya District

Margaret Keseje  National Sector Manager/Water
Pascal Otieno  Assistant Regional Program Coordinator
Robert Osborne  Western Regional Director

Siaya District Government Officers

S. O. Amoko  District Director, Forestry Department
Julius Gicheher  District Forestry Extension Officer
Mr. Okoth  District Grain Marketing Officer
Fred Mukholi  District Animal Production Officer
Gwengi Oudia  District Animal Production Officer
Bernard Wanyama  District Livestock Marketing Officer
District Community Development Officer
District Agricultural Development Officer

Moskhi Town, Tanzania

L. K. Danso  Chief Technical Advisor, FAO/Japan
Community Forestry Project, Arusha
Mr. Mollel  Regional Natural Resources Officer
Daniel Matungwa  Assistant Regional Forestry Officer
P. Kimiti  Regional Commissioner

Hai District, Tanzania

District Natural Resources Officer
District Forest Officer
Kibo and Kikafu Coffee Estates
Chief N.K.C. Shangali  Chairman, Tanganyika Farmers Association

Moshi District, Tanzania

A. V. K. Mmuni  District Executive Director
F. S. Mosha  District Natural Resources Officer
E. J. Kisoli  District Forest Officer
B. A. Mbuya  Division Secretary
Mr. Vunjo  Village Chairman

Rombo District, Tanzania

N. E. Mushi  District Executive Director
J. S. Mawi  District Natural Resources Officer
District Forest Officer

World Bank, Kigali, Rwanda

M. Loewen  Resident Representative
Government of Rwanda

Mr. Kirollo
Donald Mead  
Forestry Officer, Ministry of Agriculture  
Principal Consultant, MINIFINECO

USAID, Rwanda

I. Endoreyaho  
Assistant Agricultural Development Officer  
Edward Robins  
Technical Advisor

GTZ, Nyabisindu and Butari, Rwanda

Dr. Keller  
Project Director  
Mr. Schmidt-Duchardt  
Extension/Training Director  
Emmanuel Nkurunziza  
Director  
M. Georges  
Monitor

World Bank, Lagos, Nigeria

Tariq Husain  
Resident Representative  
Mohsin Alikhan  
Senior Operations Officer

ILCA, Ibadan

Kwesi Atta-Krah  
Agronomist  
Dr. Peters
G. O. Kilawole  
Extensionist  
Len Reynolds  
Animal Scientist/Team Leader

IITA, Ibadan

Mr. Beatty
B. T. Kang  
Senior Research Scientist  
Bede Okigbo  
Assistant Director General

National Livestock Project, Ibadan

H. D. C. Tarlton  
Zonal Supervisor

Government Officers, Ibadan

T. A. Adeniran  
Agricultural Extension, Oyo  
T. A. Alabi  
Ministry of Agriculture  
S. E. Idowu  
Agricultural Extension, Jobele-Oyo  
J. O. Olarewaju  
Agricultural Extension, Oyo  
G. A. Sanusi  
Agricultural Extension, Oyo
Traditional Leaders, Ibadan

Raji Odediran
Village Chief, Owu Ile
Village Chief-Elect, Iwo Ate

Government Officers, Abuja

S. S. O. Akalata
Assistant Director of Livestock
Director of Central Planning

National Livestock Project, Kaduna

J. N. Bincan
M. J. Powell
Director
Chief Land Use Planning Officer

ILCA, Kaduna

R. von Kaughman
M. Saleem
Team Leader
Soil Agronomist

Government Officers, Kano

K. J. Joseph
M. Tiyani Aliyi
S. Bello Harris
Janusz Debski
Dan Yaro
Senior officials
Director, Afforestation Programme
Accountant, Afforestation Programme
Principal Forester
Forest Management Officer
Forestry Consultant
Director, Forestry Department
Kano State Agriculture and Rural Development Authority

Traditional Leaders

Ahmad Muhammad Sani
H.H. the Emir of Gumel

World Bank Resident Mission, Niger

Helmut Sanger
Francis Mody
Resident Representative
Operations Assistant

CARE/Niger

Steven Dennison
Olav Bakken Jensen
Allan Turnbull
Regional Technical Advisor
Agroforestry Program Manager
Country Director
USAID/Niger

James Goggin
Erna Kirst
Michael Kirst Food for Peace Officer
Kevin Mullaly Assistant Agricultural Development Officer

Government of Niger

Senior officials Ministry of Forest and Natural Resources

Government Officers, Zinder

Alhassane Albade Sous-Prefet, Matameye
Attaou Laminou Head, Forestry Service, Zinder
Abdoulaye Mahamane Forestry Officer, Matameye
Forestry Officer, Mirriah
Sous-Prefet, Mirriah
Livestock Officer, Zinder
Bawa Guoh Ousman Agriculture Officer, Zinder
Karamba Bako Director, Integrated Rural Development Project
Maman Sami IRDP Field Director, Baboulwa
Mme. I. H. A. Maiga IRDP Extensionist

Traditional Leaders, Zinder

Sarkin Gaba Abdou Village Chief, Bangaya (Magaria)
Malam Badamassa Guero Director, Mayhari (Mirria)
Sarkin Mahaman Village chief, Baboulwa (Zinder)
Malam Moussou Village chief, Inkouble (Magaria)

Government Officers, Bouza

Mohammadou Attahoudi Livestock Officer, Bouza
Siedou Ohadouba Agricultural Officer, Bouza
Moctar Regional Forester
Agricultural Extensionist, Majjia
Sous-Prefet, Bouza
Dutch volunteer Advisor, Forestry Department

Traditional Leaders, Majjia Valley

Hadj Mahamadou Zoukari Village Chief, Garadoume Kare

CARE/Majjia Valley

Zakari Madougou Project Assistant
CARE/Tanout

Leigh Heart Regional Forester

Agro-Forestry Pilot Project, Dosso

Claes Kjellstrom Agronomist
Forester

SEMESTER -- MARCH 29, 1989

From Department:

Cynthia Cook, AFTEN
Agi Kiss, AFTEN
Mikael Grut, AFTAG
John Peberdy, AFTAG

From elsewhere in the Bank

Ridley Nelson, ENVPR
William Magrath, ENVPR
Mary Dyson, ENVPR
Jon Martin Trolddallen, ENVPR
John English, ENVPR
K. Loganathan, AF2AG
Lewis Campbell, AF4AG
Nwanze Okidegbe, AF6AG
Nicole Glineur, AF5PH
Michael Colby, SPRSP
Ellen Tillier, PREVP
Nadim Khouri, INUWS
Frank Convery, EDI
SEMINAR -- OCTOBER 20, 1988

Leif E. Christoffersen, AFTEN
Francois Falloux, AFTEN
Cynthia Cook, AFTEN
Emmanuel Asibey, AFTEN
Ben Kamugasha, AFTEN Consultant
Raymond H. Rowe, AGRPS
Douglas McGuire, AFTEN Consultant
Diana de Treville, AFTEN Consultant
Tomas Hexner, AFTEN Consultant
Knut Opsal, AFTEN Consultant

Written comments were received from:

From Department:

Francois Falloux, AFTEN
Emmanuel Asibey, AFTEN
Ben Kamugasha, AFTEN
Donald Pickering, AFTAG
Steven Carr, AFTAG
Poul Sihm, AFTAG
Tom Hexner, AFTEN Consultant

From elsewhere in the Bank:

Chris Keil, AF2AA
Jeffrey Lewis, AF5AG
Augusta Molnar, ASTEN
William Magrath, ENVPR
Raymond Rowe, AGRPS

From outside the Bank:

Sharif Harir, University of Khartoum
Fredrick Owino, ICRAF
Robert Winterbottom, WRI
Bede Okigbo, University of Michigan
Faye Benedict, Institute for Environmental Analysis, Bo, Norway

Michael McGahuey, USAID
Bjorn Lundgren, ICRAF
Sara J. Scherr, ICRAF
A.N. Atta-Krah, ILCA
B.T. Kang, IITA
Walter Msimang, CARE/Kenya
Olav Bakker Jensen, CARE/Niger
Allan Turnbull, CARE/New York
Adegboye, R.O. et al
1978 A Socio-economic Study of Fulani Nomads in Kwara State by a Study Team Commissioned by the Federal Livestock Department, Kaduna. Ibadan.

Adeyoluju, S. Kolade

Akachuku, A.E.
1985 Cost-Benefit Analysis of Wood and Food Components of Agri-silviculture in Nigerian Forest Zone. Agroforestry Systems (Netherlands) 3, no. 4:307-16, 1985. Costs and revenue of agri-silviculture in the Nigerian forest zone were estimated, and rates of return two crop combinations were estimated. The author finds agri-silviculture increases the farmer's income in this zone.

Anderson, Dennis
1986 Declining Tree Stocks in African Countries. World Development (U.K.) 14:853-63, July 1986. The paper first discusses evidence of the loss of trees and associated ecological changes taking place then, discusses the economic merits and limitations of two forms of public investment in afforestation: (i) in forestry management and plantation programs, with special reference to watershed and shelterbelt plantings and (ii) in various forms of support -- research, extension and nurseries -- for the development of agro- or farm- forestry.

Anderson, Dennis

Anderson, Dennis and M.W. Leiserson

Arap-Sang, F.K.

Armitage, F.B.

Arnold, J. E. M.
1983 "Economic Considerations in Agroforestry Projects." Agroforestry Systems 1:299-311 This paper reviews the economic benefits the small farmer can realize and the costs he may face by incorporating trees into his farm system.
Arnold, J.E.M., Chipeta, M.E. and Fisseha, Y.

Arnold, J.E.M.


Atta-Krah, Akwasi
1985 Fodder Intervention in the Farming System of Southeastern Nigeria. Ibadan: ILCA.

Atta-Krah, Akwasi

Atta-Krah, Akwasi and L. Reynolds

Atta-Krah, Akwasi and P.A. Francis

Atta-Krah, Akwasi, J.E. Sumburg and L. Reynolds
1985 Leguminous Fodder Trees in the Farming System -- an Overview of Research at the Humid Zone Programme of ILCA in Southwestern Nigeria. Ibadan: ILCA.

Atten, O.D.

Balasubramanian, V. and Egli, A.
1986 Role of Agroforestry in the Farming Systems in Rwanda with Special Reference to the Bugesera-Gisaka-Migongo Region. Agroforestry Systems 4, no. 4: pp. 271-89, 1986 Subjects: Agroforestry; cropping systems; agricultural productivity

Becker, Barbara
This paper discusses the integration of indigenous species with particular value to human nutrition into agroforestry systems in the Ferlo.

Beets, Willem C.
This publication introduces the subject of agroforestry, indicating the role it can play in African tropical farming systems, land use, agricultural development, and woodfuel production. Because agroforestry is a multidisciplinary subject, approaches from the viewpoint of the agriculturalist, economist, sociologist, and institutional specialist are considered. Strategies for the development of agroforestry are discussed, and two appendices on multi-purpose trees are included.
Blair, H., and Olpaldawala, P.

Blandon, Peter.
Portfolio theory (from the field of financial economics) is used to analyze the risk of hypothetical agroforestry systems. It is shown that the relationship of the returns from an agroforestry system is vitally important in correctly defining risk. It is shown that it is impossible to design a "best" system, but rather a set of efficient systems of differing risk and return can be defined.

Boudet, G.C., and Toutain, B.

Bounkoungou, Edouard G.
1987 Monographie de acacia albida dei, espece agroforestiere a usages multiples. Ouagadougou: IRBET/CNRST. Project UNSO/DES BKF/80/X02

Bradley, P.N. and A.W. Ngugi

Buck, Louise and Teel, Wayne.

Buck, Louise, Huxley, P.A., Owino, F., and Ngugi, David, eds.

Bunting, A.H. and Bunting, E. (eds.)

Burgers, T.F.

Burley, J.
Need for international collaboration in exploring, testing, evaluating, and conserving the genetic resources of selected tree species for use in agroforestry and plantation schemes is discussed.
Burley, J.

Burley, J., Saville, P.S.

Buschmann, U.

CAB International and the International Council on Agroforestry
A quarterly publication providing abstracts and reviews of the world's research and technical literature covering the field of agroforestry.

CARE

CARE

Carlson, L.W., Shea, K.R. (Compilers)
Conferences; increasing productivity of multipurpose lands; IUFRO; agroforestry; reclamation; nurseries; fuelwood plantations; research projects; fuel plantations; silvopastoral systems; plant breeding; seed collection; nitrogen fixation.

Casey, John

Cassagne, Bernard
1987 Le Probleme du bois de feu dans les villes d'Afrique tropicale le cas de Banui (RCA): approche d'une solution agroforestiere.

Castro, Noel A.

Center for Research on Economic Development

Centre Technique Forestier Tropical (CTFT)
Centre Technique Forestier Tropical (CTFT)
1988  Faidherbia albida (= Acacia albida). Nogent-sur-Marne, France: Centre Technique
Forestier Tropical.

Cernea, M.M.
1981  Land Tenure Systems and Social Implications of Forestry Development Programs. Staff

Chambers, Robert and Leach, Melissa
228. Institute of Development Studies.

Chandler, Trevor, and David Spurgeon, eds.
    International Council for Research in Agroforestry, Nairobi, Kenya
    The topics addressed include: the ecological aspects of agroforestry in arid
    and savanna, mountain, and humid tropical ecosystems; agroforestry projects
    around the world; documentation, training, and extension for agroforestry;
    agroforestry research; socioeconomics of agroforestry; and the sponsoring
    agencies.

Chavangi, Noel A.
1987  Agroforestry Potentials and Land Tenure Issues in Western Kenya. Land, Trees and
    Tenure, John B. Raintree, ed.. Nairobi/Madison, Wisconsin: ICRAF/the Land Tenure
    Center.

Chavangi, Noel A. Rutger J. Engelhard
1985  Culture as the Basis for Implementing Self-sustaining Woodfuel Development Programmes.
    Nairobi: The Beijer Institute.
    This paper describes the work of the Kenya Woodfuel Development
    Programme towards developing a self-sustaining system of tree planting to
    contribute to fuelwood supplies in Kakamega District of Kenya. The
    programme's approach has been to identify the major factors that have acted
    as constraints on the full acceptance and implementation of many projects.

Chew Siew Tuan
1989  Agroforestry Projects for Small Farmers: a Project Manager's Reference, CDIE Special
    Study (mimeo). A.I.D. Evaluation Study No. 59.

Chidumayo, E.N.
1988  Integration and Role of Planted Trees in A Bush-fallow Cultivation System in Centra
    Subjects: Agroforestry; Agricultural systems.

Chijicke, E.O.
    21, Rome.

Club du Sahel

Cobbina, J., N. Atta-Krah, and B.T. Kang
1987  Leguminous Browse Supplementation Effect on Agronomic Value of Sheep and Goat
    Manure. Ibadan: ILCA.

Combe, J., Jimenez, Saa, H. and Monge, C.
1981  Bibliography on Tropical Agroforestry. Turrialba, Costa Rica: Centro Agronomico
    Tropical de Investigacion y Ensenanza.
Forestry and agriculture cannot be considered separately in the tropics. Since the tropical farmer has traditionally practiced agroforestry, it is possible to take advantage of his experience to achieve a sustained yield agriculture and protect tropical forests. The author proposes a classification of principal agroforestry techniques and describes some traditional practices.

Delahanty, James, M. Hoskins and J.T. Thomson

DiCastri, Francesco, John Celecia, and Hadley Malcolm
Attempts within the Man and Biosphere (MAB) Program of UNESCO to produce research findings and information materials useful for education and training in agroforestry are outlined. Three different field projects are described. Lessons learned about the development of programs in agroforestry education are described.

Djenana, B.

Energy/Development International

Energy/Development International

Energy/Development International

Energy/Development International (E/DI)

Engel, A., et al

Fairburn W.

FAO
FAO

FAO
1978 Forestry for Local Community Development. FAO Forestry Paper No. 7. Rome: FAO.

FAO

FAO

FAO
1987 Small-scale Forest Based Processing Enterprises. FAO Forestry Paper 79.

Felker, P.


Fernandes, Erick

Field, A., Rocheleau, D., and Weber F.

Filius, A.M.
1982 Economic Aspects of Agroforestry. Agroforestry Systems 1:29-39. Agroforestry is analyzed by means of economic concepts. The paper is mainly theoretical. Complementary and supplementary relationships (resulting from biological factors) that make agroforestry an efficient system are identified. Agroforestry can be an appropriate technology in areas with fragile ecosystems and subsistence farming.

Foley, Gerald and Barnard, Geoffrey

Ford Foundation

Fortmann, Louise

Fortmann, Louise
The involvement of women in agroforestry projects and activities is examined in case studies from the Dominican Republic, India and Kenya. Considerations for including women in agroforestry projects are discussed.

Fortmann, Louise.
1985 "The Tree Tenure Factor in Agroforestry with Particular Reference to Africa." Agroforestry Systems 2:229-251
Rights over trees, which are often distinct from rights over land, are discussed. These rights include the right to own or inherit trees, the right to plant trees, the right to use trees and tree products, the right to dispose of trees and the right to exclude others from use of trees and tree products. The implications of tree tenure issues for the design of agroforestry projects are explored.

Fortmann, Louise, and James Riddell
1985 Trees and Tree Tenure. Land Tenure Center, University of Wisconsin, Madison and International Center for Research in Agroforestry, Nairobi.
This bibliography reviews the interrelations among trees, land tenure, and agroforestry.

Fortmann, Louise and John W. Bruce, eds.

Fowler, Alan et al.

Francis, P.A.

Francis, Paul and Getachew, Bulfeta

French, David

Friendrich, K.H.

Gabel M. and Heiland
Getahun, Amare, Bashir Jama, and Jackson Ndung’u

This bulletin reports the research conducted with *Gliricidia sepium* at the Mtwapa Agroforestry/Energy Centre on the Kenya coast. *Gliricidia sepium* is a leguminous multipurpose tree that is easy to establish both from seeds and cuttings. It is adaptable to the coastal climate of Kenya and grows quickly. Because of weed problems and reduced soil fertility -- caused by high rainfall and humid conditions -- in this coastal region, *Gliricidia*’s benefits are significant.

Getahun, Amare, Kedir Reshid, Bashir Jama, and Jackson Ndung’u

This report describes the agroforestry experimental designs being used by the Kenya Renewable Energy Development Project (KREDP). It explains the objectives of KREDP agroforestry research, the experimental designs being used, parallel systematic design, split plot design, randomized block design, seed orchard screening trials, and future research needs.

Gibson, David C. and Muller, Eva

Giffard, P.L.

Giffard, P.L.

Gorse, Jean.

Interactions between droughts and human abuse of the environment are the primary cause of the current crisis in the Sahel. The author offers a number of specific prescriptions to help alleviate the crisis, including improved management systems and reducing demand on wood and land resources. He suggests actions for government, financiers, and forest researchers. Agroforestry enters into much of this discussion.

Grandin, B.E.

Gregersen, H., Draper, S., and Elz, D.

Grut, Mikael

Grut, Mikael
Gulick, Frances A.  
1984 Increasing Agricultural Food Production through Selected Tree Planting Techniques.  
Washington, D.C.: USAID.  

Haggblade, Steve, Peter Hazell and James Brown  

Hama, Kadri  

Harrison, Paul  

Havnevick, K.J.  

Hill, Jeff  

Hoagland, Sara H.  

Hoekstra, D.A.  

Hoekstra, D.A.  

Hoekstra, D.A.  
This paper uses MULBUD, a micro computer program for agroforestry systems, for simulations and analysis of economic utility of alley cropping systems.  

Hoekstra, D.A.  
This paper highlights the economic aspects of the diagnosis and design exercise. It also discusses issues, methods, and tools to be considered when looking for agroforestry solutions to land-use problems or exploiting other agroforestry potentials.  

Hoekstra, D.A. and Van Gelder, A.  
Hoekstra, D.A., Torres, Filemon, Darnhofer, T. and Kariuki, E.
Case studies in Agroforestry Diagnosis and Design no. 3. ICRAF working paper no. 19. In collaboration with the Kenya Agricultural Research Institute, the National Dryland Farming Station, Katumani, and the Machakos Integrated Development Program, Ministry of Agriculture.

Hoskins, Marilyn W.

Hoskins, Marilyn W.

Houerou, H.N.,

Huxley, Peter A. and P.J. Wood
Examines the use of the "Diagnosis and Design" (D & D) methodology for the completion of research programs. Emphasis is placed on the research design stage. The authors link the design stage to the implementation of research projects.

Huxley, Peter
1985 The Tree/crop Interface -- or simplifying the Biological/environmental Systems. Agroforestry Systems 3:251-266.
Proposes a method for studying agroforestry systems by separating their growth and yield characteristics into three basic sets of variables: 1) the agricultural crop, 2) the effects of tree/crop interface on both crop and tree, and 3) the growth of the tree as a whole crop.

Huxley, Peter A.
This working paper identifies key issues in selecting, managing, and evaluating multipurpose tree species, including genotype consideration, land sustainability, and tree management. Multipurpose trees as crops and in managed mixtures of species are discussed. From this discussion, research priorities are identified.

Huxley, Peter

Huxley, Peter A.
Some special problems relevant to experimenting with multipurpose trees are noted. The International Council on Research in Agroforestry (ICRAF) in Nairobi has available a set of source materials and guidelines on "Research Methodology for the Exploration and Assessment of Multipurpose Trees," which are listed. The establishment of an informal experimental agroforestry network is also mentioned.
Huxley, Peter A.
Systematic field layouts are especially useful with multiple purpose tree species for examining plant responses, e.g. to density, stress, and where a wide range of treatment levels are needed because of lack of previous data. Examples of "fan" and "parallel-row" layouts are given and the development of parallel-row designs for management trials and mixed cropping is illustrated.

Huxley, Peter A.
This note presents a "first generation" model for estimating the potential productivity of the land for agroforestry systems. The model is based on soil and plant factors. Conceptual predictions are made for changes in soil fertility and plant production over time.

Huxley, Peter A., Mead, Roger, Ngugi, David

Hyman, Eric
1983 The Monitoring and Evaluation of Forestry Projects for Local Community Development. Rome: FAO

ICRAF/CFI (International Council for Research in Agroforestry/Commonwealth (now Oxford) Forestry Institute
1983 Methodology for the Exploration and Assessment of Multipurpose Trees.

International Council for Research in Agroforestry

International Council for Research in Agroforestry

International Council for Research in Agroforestry (ICRAF)
Intended for agroforestry workers, this handbook provides a detailed explanation ICRAF's D & D methodology. Step-by-step guidelines explain the pre-diagnostic, the diagnostic, and the design stages.

An international journal published in cooperation with ICRAF. Volume 1 appeared in 1982. Managing editors: H.J. von Maydell, Hamburg, Germany; B. Budowski, Turrialba, Costa Rica; H. n. Le Houerou, Montpelier-Cedex, France; B. Lundgren, Nairobi, Kenya; H.A. Steppler, Quebec, Canada.
International Institute of Tropical Agriculture
A series of brief reports on recent research and developments in crop and
farming technology. The section on farming systems contains two reports
relevant to agroforestry: "Alley Cropping: Six years of Experiments and
Farmer Use of the System," and "Effects of Deforestation and Land Use on
Soil, Microclimate, and Productivity: First Phase of a Long-term Study."

International Institute of Tropical Agriculture and International Livestock Centre for Africa
1987 Alley Farming Network for Tropical Africa: a Proposal to Support Collaborative Research
Network in Tropical Africa. Ibadan: IITA; ILCA.

International Livestock Centre for Africa

Issa, Aboubacar
1-Agroforesterie au Sahel, Niamey, 23 mai – 8 juin.

Johnson, Dennis U.
1986 An Abstract Bibliography of Agroforestry: Articles from Agroforestry Systems and the
One hundred and forty annotated citations. Subject, plant name, and
geographic indices are included.

Jouve, Philippe
1987 Rapport de Mission sur l’avancement du Programme de Recherche-Developpement de
MARADI. Republique du Niger/CIRAD

Kang, B.T. and G.F. Wilson
1987 The Development of Alley Cropping as a Promising Agroforestry Technology. Ibadan:
IITA Reprint Series.

Kang, B.T., G.F. Wilson, and T.L. Lawson
1984 Alley Cropping: A Stable Alternative to Shifting Cultivation. Ibadan: International
Institute of Tropical Agriculture.
This IITA publication presents alley cropping as an agroforestry system in
which food crops are grown in alleys formed by hedgerows of trees or shrubs.
Techniques, species, system management, and ecological character of such
systems are discussed.

Kapp, Gerald
1987 Agroforstliche Landnutzung in der Sahel-Sudanzone: traditionelle Bewirtschaftung,
Nutzungsprobleme, Losungsansatze durch Projekte und Forschung. Munchen: Weltforum
Summary in English and French. At head of title: Originally presented as
the author’s thesis (Universitat Freiburg, 1983). Subjects: Agroforestry --
Sahel. Land use -- Sahel. Agricultural development projects -- Sahel. Sahel
-- Economic conditions. Bibliography. ill., maps.

Kilander, K.

Kirmse, Robert D. and B.E. Norton
1984 The Potential of acacia albida for Desertification Control and Increased Productivity in
Chad. Biological Conservation 29:121-141.
Kjenstad, V.M.
1988 Land Tenure in the Subhumid Zone of Nigeria: Implications for Agricultural Innovations, a Literature Review. Ibadan: ILCA.

Kornick, Jay
Temporal analysis is introduced as a method to assess the suitability of agroforestry projects for meeting rural development objectives. This form of analysis provides a common base for examining social, economic, ecological, and managerial aspects of agroforestry systems.

Lagemann, J.

Lai, Chun K.

Lal, R.
1988 Agroforestry as a Possible Sustainable Farming System in the Humid Tropics. Department of Agronomy, Ohio State University, Columbus, Ohio.

Lamprey, H.G.

Leach, Gerald & Mearns, Robin
In many place in Africa, people, with the help of governments and aid agencies, are putting the land into good shape, growing more food and recreating a healthy cover of trees. Drawing on a wide range of case histories, the authors describe the gains in farming, forestry, and woodfuel supply that have come through a broader people-centered approach.

Lundgren, B.
1982 The Use of Agroforestry to Improve the Productivity of Converted Tropical Land. Report for the Office of Technology Assessment, Congress of the United States, Washington, D.C.

Lundgren, B. and Raintree, J.B.
1983 Sustained Agroforestry. Nairobi: ICRAF.

MacDonald, L.H., ed.

Magee, Tim
Mathu, Winston

Matthews, Peter J. and Dan M. Etherington.

The economics of agroforestry systems are usually approached in a purely analytical/mathematical fashion. This paper posits that such an approach has little practical relevance and that there is an urgent need for a practical tool with which multi-disciplinary teams can assess agroforestry systems.

Mbonye, Arsen and K. Kiambi, ed.

McGahuey, Michael

McGuire, Douglas

McGuire, Douglas

Miambiti, M.E. et al

Miehe, S.

Describes the traditional agroforestry systems based on *Acacia Albida* and other multipurpose trees as practiced by the sedentary Fur people on the lower slopes and highlands of the Jebel Marra Massif.

Mnzava, E.M.

Once the need to plant trees -- whether for fuelwood, food, fodder, shelter, or environmental protection -- is accepted and made a part of government planning, methods must be found to make the effort successful. The Tanzanian experience teaches one thing: listen to the villagers.

Molnar, Augusta

Munene, Mathenge
Nair, P.K.R.

This manual is arranged in three parts. Section one addresses the general principles and concepts of agroforestry in the context of tropical land-use patterns. Part two contains the crop sheets of 40 selected species which are widely cultivated and whose production potentials have been relatively well exploited. Part three addresses some underexploited and localized species with agroforestry potentials.

Nair, P.K.R.
Classification of agroforestry systems is necessary in order to provide a framework for evaluating systems and developing action plans for their improvement. Several criteria can be used to classify and group agroforestry systems: 1) the system's structure; 2) the system's function; and 3) the system's ecological basis. Each has merits, but no one classification can be universally acceptable.

Nair, P.K.R.

Nair, P.K.R. and Fernandes, E.C.M.
The authors describe how the International Council for Research in Agroforestry (ICRAF) has assembled several multipurpose leguminous trees and shrubs of agroforestry potential at the Council's recently established field station in Machakos, Kenya for demonstration and training. Initial results from these trials are presented.

National Academy of Science

National Academy of Sciences

National Academy of Sciences

National Academy of Sciences (NAS)

National Research Council

National Research Council

Neumann, I.F. and Peitrowicz
Ngambeki, D.S.

Nkaonja, R.S.W.

Norman, David
1977 The Rationalization of Intercropping. *African Environment* 2/3:3-21

Noronha, Raymond

O'Kting'Ati, A. and Maghembe, J.A., C.M. Fernandes, and G.H. Weaver

An inventory of plant species was conducted on farms, farm boundaries and homesteads in the Kilimanjaro agroforestry system. The survey covered 30 farms in six village in the Hai District on the slopes of Mount Kilimanjaro, Tanzania. The food crops, trees, and other economically useful plants were found to be carefully chosen by the local farmers and intimately intercropped on the same unit of land.

Oduol, Peter Allan

Ojeniyi, S.O., O.O. Agbede, and J.A. Fagbenro

Chemical analyses were performed on 240 soil samples collected from various plots, some of which were interplanted with trees alone, and others which were interplanted with trees and multiple food crops. Intercropping was found to increase soil N and P in two of three ecological zones.

Okafor, Francis C.

Some farmers in southeastern Nigeria have adopted a multicropping system to maximize returns from every land unit. Crop choice is concentrated on those lands which involve less expense in materials and labor input but promise higher productivity. Although these farmers improved their condition, they have not found a lasting solution to food shortages. This paper suggests that technical innovations introduced into multicropping systems will ensure adequate food supply.

Okafor, J.C.
Okigbo, B.N.

Okigbo, B.N.

Okigbo, B. N.

Okigbo, B. N. and D.J. Greenland
1977 Intercropping Systems in Tropical Africa. Special Publication no. 27. Ibadan: IITA.

Openshaw, K. and Moris, J.

Osemeobo, G.J.

Subjects: Tree planting; afforestation; shifting cultivation; small farms.

Panos Institute

Pickering, Donald, ed.

Poschen, Peter

Poulsen, G.

Poulsen, G.

Poulsen, G.

Poynton, R.J.

Projet Agro-Pastoral de Nyabisindu
Pryor, L.D.

Raintree, J.B.
1983 Preliminary Diagnosis of Land Use Problems and Agroforestry Potentials in Northern Mbere Division, Embu District, Kenya. ICRAF Working Paper no. 1. Nairobi: ICRAF. Case studies in agroforestry diagnosis and design: no:1

Raintree, J.B.
1983 Strategies for Enhancing the Adoptability of Agroforestry Innovations. Agroforestry Systems 1:173-187. Adoption and diffusion of innovations will improve research strategies and design tactics in agroforestry. Research and development teams may then increase their ability to generate relevant and adoptable technologies, thus having a practical impact on land-use systems.

Raintree, J.B.

Raintree, J.B.

Raintree, J.B. and F. Torres.
1986 Agroforestry Research in Farming Systems Perspective: the ICRAF Approach (ICRAF Working Paper no. 39). Nairobi: ICRAF This report links research in agroforestry with research in farming systems. The authors explain the objectives of agroforestry systems research at the International Council for Research in Agroforestry. Topics include: a multipurpose tree inventory, systems research, diagnosis and design of agroforestry systems, demonstration project research, and linkages with national research programs. Future topics include institutional organization, land-use planning and technology generation.

Raintree, J.B. and Young, A.
1983 Guidelines for Agroforestry Diagnosis and Design. Nairobi: ICRAF.

Raintree, J.B. ed.
1986 An Introduction to Agroforestry Diagnosis and Design. Nairobi: ICRAF A succinct explanation of ICRAF's diagnosis and design methodology. Basic principles and procedures are explained, followed by a case study example - the Kathama Agroforestry Project in Kenya.

Raintree, J.B., Thomson, J. and Von Maydell, H-J.
1984 Agroforestry in the West African Sahel. Board of Science and Technology for International Development. Washington, D.C.: National Academy Press. Provides an overview of traditional Sahelian production systems and explores approaches by which modern science and technology can complement the knowledge and experience of rural Sahelian populations in developing more dependable, resilient, and socially acceptable agricultural systems.
Raintree, John B.

Raintree, John and Kathleen

Raintree, John B. ed.

Reshid, Kedir

Reynolds, J. Eric
1987 Choosing Priorities for Agroforestry Research. Nairobi: ICRAF

Roberts, Nigel, ed.
1989 Agricultural Extension in Africa: A World Bank Symposium
Papers from workshops held at Eldoret, Kenya in June 1984 and at Yamoussoukro, Cote d'Ivoire, February 1985.

Rocheleau, D. & Raintree, J.B.

Rocheleau, Dianne E.

Rocheleau, Dianne E.

Rocheleau, Dianne E.

Rocheleau, Dianne, and Annet van den Hoek
An extension of the Kathama Agroforestry Project, a field test of ICRAF's D & D methodology. Landscape analysis focused on roadsides, property lines, gullies, and degraded hillslope grazing lands. This analysis was integrated with the larger agroforestry project.
Rocheleau, M.

Rorison, Kathleen and Steven E. Dennison

Ruthenberg, H.

Scherr, S.J.

Scherr, Sara

Seip, H.K.
1987 Improving Land Use in Sierra Leone by Means of Agroforestry.

Sene, El Hadji.

The author argues for the utilization of natural vegetation, including a great diversity of woody shrubs and trees, as a means of meeting basic food needs in many African countries. Native tree species, often exploited successfully for centuries, have been neglected, abandoned, or destroyed, even though they could play a major role today in relieving the crisis in many African countries, as well as in assisting in the whole process of development.

Shaikh, Asif and Patricia Larson

Skutsch, M.

Spears, John

Spiro, Heather

Ssekabembi, Charles K.

Hedgerow intercropping (alley cropping) is relatively new technology involving growing agricultural crops between rows of planted tree species. This paper attempts to put together and discuss some of the recent advances on management aspects concerning hedgerow intercropping.

Staudt, Kathleen A.

Sumberg, J.E., J. McIntire, C. Okali and A. Atta-Krah 1985 An Economic Analysis of Alley Farming with Small Ruminants. Ibadan: ILCA.


Torres, Filemon 1983 Role of Woody Perennials in Animal Agroforestry. Agroforestry Systems 1:131-163. This paper identifies and explores two main roles of woody perennials: the productive role, where woody perennials yield a material output (fuel, fodder, etc.), and the "service" role (shelter nutrient recycling, etc.) where no tangible product is produced.


Van Gelder, B., Enyola, M.K.L., and Mung’ala, P.M.
   Describes the first phases of the implementation of the Kenya Woodfuel Development Programme (KWDP) in Kakamega District in the western highlands of Kenya. The principal objective of the KWDP is to encourage people living in densely populated, high potential agricultural areas to become self-sufficient in their domestic energy requirements by planting trees for fuelwood on individual farms.

Verinumbe, I. and Knipscheer, H.C.
   An economic evaluation of zero-tillage farming system against the background of small-scale farmers in Southwest Nigeria was undertaken using the linear programming method. The results suggested a promising future for the combined production of agricultural and forestry crops under an integrated land management system by small-scale farmers in the humid tropics.

Von Carlowitz, Peter G.
1984 Multipurpose Trees and Shrubs; Opportunities and Limitations; the Establishment of a Multipurpose Tree Data Base. Nairobi: ICRAF.

Von Carlowitz, P.G.

Von Maydell, H.J.

Von Maydell, H.J.
   Discusses the environmental, social, and political conditions of the Sahel. Agroforestry is presented as a means to approach food and energy problems and concomitant social problems.

Wang’ati, F.J.

Weinstock, Joseph A.
   Agroforestry research and design has heavily favored integral systems -- production of tree crops on the same land and at the same time as production of food crop annuals. In this paper, alternate cycle agroforestry, in the form of modified forest swidden systems, is discussed and compared to integral agroforestry systems.
Wiersum, K.F.
Evaluates the soil protective value of different agroforestry systems; examines the effect of trees grown in combination with agriculture crops on rainfall erosivity; looks at soil erosion and surface production. Concludes that the key to erosion control in agroforestry lies not in trees but in good management practices.

Wiersum, K.F., Anspach, P.C.L. et al

Winterbottom, Robert

Winterbottom, Robert and Hazlewood, Peter

Wood, P.J.

World Bank

World Bank

World Bank

World Bank

World Bank

Young, Anthony
Outlines two objectives and procedures of land evaluation and their results. Reviews the present state of evaluation methodology for land-use related to agroforestry. Describes the stages in the development of methodology: an environmental data base, formulation of appropriate agroforestry land-use requirements, construction of bio-physical models, assessment of environmental impact and sustainability, method for comparison between agroforestry and non-agroforestry land utilization types, and testing through case studies.
This paper describes eight examples of agroforestry in sloping areas and gives two examples of economic analysis of agroforestry systems. The author outlines the ICRAF D & D method and compares it with land evaluation procedures. He concludes that sloping areas should be a priority environment for the application of research and development in agroforestry.

Young, Anthony

Young, Anthony

Young, Anthony and Muraya, P.

Zulberti, E. ed.

B. SOURCES USED IN PREPARING CASE STUDIES

KENYA

Akunda, Elijah and Peter A. Oduol

CARE International/Kenya

Ford Foundation

Fowler, Alan et al.

International Council for Research in Agroforestry

Rocheleau, Dianne

Scherr, Sara J.
Scherr, Sara J.
1987 Choosing Priorities for Agroforestry Research. Nairobi: ICRAF.

Scherr, Sara J.

Vonk, Remko B.

TANZANIA

Fernandes, E.C.M, A. Oktingati, and J. Maghembe

Friendrich, K.H.

Gabel, M. and A. Heiland

Humpal, D.S.
1980 Arusha Regional Agriculture Sector Review. Arusha Region: Regional Commissioner's Office (mimeo).

Kasembe, J.N.R. et al.

International Council for Research in Agroforestry

Marhatta, Hari P. et al.

Miambiti, M.E. et al.
1985 Economic Analysis of the Traditional Farming Systems of the Kilimanjaro Region - Tanzania. IAF Publication no. 85. West Virginia Agricultural and Forestry Experiment Station, Division of International Agriculture and Forestry, West Virginia University, Morgantown, West Virginia.

O'ktin'ati, A. et al.
Tibaijuka, Anna K.  

Tibaijuka, Anna K.  

Tibaijuka, Anna K.  

RWANDA

Projet Agro-pastoral de Nyabisindu  

Projet Agro-pastoral de Nyabisindu  

Projet Agro-pastoral de Nyabisindu  

Projet Agro-pastoral de Nyabisindu  

Projet Agro-pastoral de Nyabisindu  

Projet Agro-pastoral de Nyabisindu  

Project Agro-pastoral de Nyabisindu  

Buschmann, U.  

Dressler, J.  

Dressler, J. and I. Neumann  
Egger, K. and T.H. Zeuner

Kruger, W.D.

Kruger, W.D.

Neumann, I.F.

Zeuner, Tim H.

SOUTHERN NIGERIA

Atta-Krah, Akwasi
1985 The Relevance of Alley Farming to the Forester. Paper presented at Agroforestry Workshop on Alternative Production Methods to Shifting Cultivation. Ibadan: IITA.

Atta-Krah, Akwasi
1985 Fodder Intervention in the Farming System of Southeastern Nigeria. Ibadan: ILCA.

Atta-Krah, Akwasi
1988 Final Report to International Development Research Center (IDRC), Ottawa, Canada. Ibadan: ILCA.

Atta-Krah, Akwasi and P.A. Francis

Atta-Krah, Akwasi and L. Reynolds

Atta-Krah, Akwasi, J.E. Sumberg and L. Reynolds

Atten, O.D.
Cobbina, J. and A.N. Atta-Krah
1988 Effect of Variability in Soil Fertility on Growth and NPK Nutrition of Leucaena and Gliricidia in Alley Farms. Ibadan: ILCA.

Cobbina, J. et al.
1987 Leguminous Browse Supplementation Effect on Agronomic Value of Sheep and Goat Manure. Ibadan: ILCA.

Francis, P.A.

Francis, P.A.

Francis, P.A.

Francis, P.A.

Francis, P.A.

Francis, P.A. and A.N. Atta-Krah

Francis, P.A. and A.N. Atta-Krah

Francis, P.A. and A.N. Atta-Krah

Francis, P.A. and G. Bulpheta

Francis, P.A. et al.

International Institute of Tropical Agriculture (IITA)
1983 IITA Research Highlights. Ibadan: IITA.

---- and International Livestock Centre for Africa (ILCA)
Kjenstad, V.M.
1988 Land Tenure in the Subhumid Zone of Nigeria: Implications for Agricultural Innovations, a Literature Review. Ibadan: ILCA.

Kjenstad, V.M. and P.A. Francis

Ngambeki, D.S.

Ngambeki, D.S. and G.F. Wilson

Okafor, F.L.

Okali, C.

Okali, C. and K. Cassaday

Okali, C. and J.E. Sumberg

Okali, C. and K. Sumberg

Okali, C. and P.A. Sumberg

Osuntogun, A. et al.

Reynolds, L., A.N. Attah-Krah and P.A. Francis

Sumberg, J.E.

Sumberg, J.E. and C. Okali
Sumberg, J.E. et al.  
1985 An Economic Analysis of Alley Farming with Small Ruminants. Ibadan: ILCA.

Vogel, Wolfgang O.  
1985 Socio-economic Considerations for Alley Farming. Lecture presented at the workshop Alley Farming as an Alternative Production System to Shifting Cultivation, 9-10 December. Ibadan, Nigeria: IITA.

CENTRAL AND NORTHERN NIGERIA

Hill, Jeff  

Kano State Agricultural and Rural Development Authority (KNARDA)  

KNARDA  
1986 Kano ADP Fertilizer Study Results. Kano: KNARDA.


1986 Manpower Planning and Development for KNARDA by Barry Challens, Manpower Development Advisor. Kano: KNARDA.


Saleem, M.A. et al.  

Saleem, M.A. et al.  

Saleem, M.A. et al.  

Saleem, M.A. et al.  

World Bank  
World Bank

1986 Nigeria: Second Livestock Development Project: Report and Recommendations of the

NIGER

CARE

Delehanty, James, M. Hoskins and J.T. Thomson

Hama, Kadri
1985 Report on the Wood Distribution Schemes Associated with the Majjia Windbreak Cutting
Studies. 1985 Campaign.

Jouve, Philippe
1987 Rapport de Mission sur l'avancement du Programme de Recherche-Developpement de
MARADI. Republique du Niger/CIRAD.

Rorison, Kathleen M. and Steven E. Dennison
1986 Windbreak and Windbreak Harvesting Influences on Crop Production: 1985 Growing
Season. Niger: CARE.

Thomson, James
1987 Synthese Provisoire Concernant la Gestion des Brise Vent de la Maggia et la Rehabilitation
des Versants.

Thomson, James

Thomson, James
1987 Majjia Valley: Rules Underlying Participatory Management Systems for Majjia
Windbreaks and Watersheds (mimeo).

United States Agency for International Development
1987 Windbreak and Shelterbelt Technology for Increasing Agricultural Production. Agro-
forestation Series #6, S&T/FENR. Washington, D.C.: USAID.
Argentina
Carlos Frenich, SRL
Calleta Guzmán
Florida 165, 4th Floor-Of 450/465
1330 Buenos Aires

Australia, Papua New Guinea, Fiji, Solomon Islands, Vanuatu, and Western Samoa
D.A. Books & Journals
11-13 Station Street
Melbourne 3012

Austria
Gemdell and Co.
Graben 37
A-1011 Vienna

Bahrain
Bahrain Research and Consultancy
Association Ltd.
P.O. Box 7285
Manama Town 317

Bangladesh
Micro Industries Development Assistance Society (MIDAS)
House 56, Road 7/A
Dhaka 1000

Belgium
Publications des Nations Unies
Av. du Rat 202
1060 Brussels

Brazil
Publicaciones Tecnicas Internacionales Ltda.
Rua Pinheiros-Conrado, 209
06300 San Paolo

Canada
Le Diffamateur
C.P. 61, 1513 rue Amherst
Boucherville, Quebec
J4B 5L6

China
China Financial & Economic Publishing House
8, D. Pei Dong Jing
Beijing

Colombia
Infra Ltda.
Apartado Aereo 3227
Bogota D.C.

Costa Rica
Liberia Typos
Calle 11-13
Av. Fernandez Guad
San Jose

Cote d'Ivoire
Centre d'Édition et de Diffusion Afrikan (CÉDA)
04 B.P. 341
Abidjan 04 Fleurant

Cyprus
MECO information Services
P.O. Box 2096
Nicosia

Denmark
Sammiland Literatur
Rosenlund Afd. 11
DK-1970 Frederiksberg C

Dominican Republic
Editors Tallen, C. por A.
Reestación a la Cartelita Colón 309
Apartado Postal 2190
Santo Domingo

El Salvador
Fasida
Avendaña Manuel Enrique Arano 3500
Edificio BSA, 4th Piso
San Salvador

Egypt, Arab Republic Of
Al Ahram
Al Galaa Street
Cairo

The Middle East Observer
8 Cherballi Street
Cairo

Finland
Axelmann-Kirikuopa
P.O. Box 128
SF-00100
Helsinki 10

France
World Bank Publications
66, avenue d’Iéna
75116 Paris

Germany, Federal Republic Of
UNO-Verlag
Pappelallee Allee 165
D-6032 Bonn 1

Greece
KEIM
24, Ippodromou Street Plaka Patras
Athens-11655

Guatemala
Liberne y Pintores Santa
Centro Cultural Pedro Santa
11 calle 6-9 entre 1
Guatemala City

Hong Kong, Macao
Asia 2000 Ltd.
3 Fl. 146 Prince Edward Road, W.
Kowloon
Hong Kong

Hungary
Kultura
P.O. Box 139
1389 Budapest 62

India
Allied Publishers Private Ltd.
751 Motilal Road
Madrass-600 002

Branch offices:
131 J. Nuernberg Meng
Ballard Estate
Bombay-40 008

13/14 Ash All Road
New Delhi 110002

17 Chitramani Avenue
Colombo-7072

Javaye Hand Building
5th Main Road Chennai
Bangalore 560 009

3-5-1139 Kapikadal Cross Road
Hyderabad- 500 007

Parthasarathi Plaza
2nd Floor
Near Thakare Baag, Nallagghara
Amarapalada 370030

Patila House
16-A Ashok Meng
Locknow-226 001

Indonesia
P. L. Indra Limited
Jl. Sem Randang 37
Jl. Marta Paste
P.O. Box 115

Ireland
TDC Publishers
12 North Frederick Street
Dublin 1

Italy
Unione Commerciante Japan SPA
Via Benedetto Pastur 120/10
Castello Frumolo 022
50125 Florence

Japan
Eastern Bank Service
2-3, Hongo 3-Chome, Bunkyo-ku 110
Tokyo

Kenya
Afric Bank Service (E.A.) Ltd.
P.O. Box 6245
Nairobi

Korea, Republic Of
Pan Kukse Bank Corporation
P.O. Box 320. Kwangyang-si, Jeonnam

Kuwait
IMES Information Services
P.O. Box 2665

Malaysia
University of Malaya Cooperative Bookshop, Limited
P.O. Box 1317
Jalan Pandan Besar
Kuala Lumpur

Mexico
Intecomp
Apartado Postal 22-460
14000 Toluca, Mexico D.F.

Morocco
Societe d'Etudes Marketing Marocain
12 rue Morlat, 8e. d'Ars
Casablane

Netherlands
Inco-Publication b.v.
P.O. Box 14
7240 BA Lelend

New Zealand
Hills Library and Information Service
Private Bag
Newmarket
Auckland

Nigeria
University Press Limited
Three Cenatra Building, Ijegho
Private Mall Bag 8935
Ibadan

Norway
Narvesen Information Center
Berndt Nærvesen vei 2
P.O. Box No. 729
Lerum 3

Peru
Editorial Desarrollo SA
Apartado 3634
Lima

Philippines
National Book Store
701 Rizal Avenue
P.O. Box 1954
Metro Manila

Poland
OFAAP
Panski ulicy i Nauci
00-501 Warszawa,

Portugal
Livraria Portugal
Rue Da Cunha 70-74
1200 Lisbon

Qatar
Saud Araabi Qatar
Jetty Bank Street
P.O. Box 2006
Riyadh 11471

Tunisia
IMES Information Services
French office:
Al Alaseh Center
Al Dehia, Center
First Floor
P.O. Box 718
Riyadh

Saudi Arabia, Qatar
Jasir Bank Street
P.O. Box 2006
Riyadh 11471

IMES Information Services

Spanish

Spain
Mundo-Prensa Libros, S.A.
Castellana 37
28001 Madrid

Liberetia Internacional AEDES
Calle de Can, 591
08029 Barcelona

Sri Lanka and the Maldives
Lake House Bookshop
P.O. Box 246
100, Sir Chittampalam A. Gardiner
Mawella
Colombo 2

Sweden
For subscription orders
Pristina Book Importing
Registratgeslag 12, Box 1656
S-103 23 Stockholm

For subscription orders
World Books International AB
Box 9004
S-120 23 Stockholm

Switzerland
For single title
Librarie Payot
6, route de Gex
Case postal 381
CH-1211 Geneva 11

For subscription orders
Librarie Payot
Service des Abonnements
Case postal 5212
CH-1102 Lausanne

Tanzania
Oxford University Press
P.O. Box 2299
Dar es Salaam

Thailand
Central Department Store
306 Stadium Road
Bangkok

Trinidad & Tobago, Antigua, Barbuda, Barbados, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts & Nevis, St. Lucia, St. Vincent & The Grenadines
Systematic Sales Unit
All White Street
Corpus Christi
Texas, West Indies

Turkey
Hemen Kütuphane A.Ş.
Küçük Kapi Sok 43/1
Konya 42000

Uganda
Uganda Bookshop
P.O. Box 7143
Kampala

United Arab Emirates
MBIR Golf Co.
P.O. Box 6097
Sharjah

United Kingdom
Microtrade Ltd.
P.O. Box 9
Alton, Hampshire GU3 2LG

Uruguay
Instituto Nacional de Libro
San Jose 1114
Montevideo

Venecuela
Libreria del Tanc
Av. López 40320
Caracas 1000A

Yugoslavia
Novi Sad

Zimbabwe
Langsford Zimundo
P.O. Box 5125
Southbank
Harare
RECENT WORLD BANK TECHNICAL PAPERS (continued)

No. 85. Ernst & Whinney, Proposals for Monitoring the Performance of Electric Utilities
No. 86. Munasinghe, Integrated National Energy Planning and Management: Methodology and Application to Sri Lanka
No. 87. Baxter, Slade, and Howell, Aid and Agricultural Extension: Evidence from the World Bank and Other Donors
No. 91. Reij, Mulder, and Begemann, Water Harvesting for Plant Production: A Comprehensive Review of the Literature
No. 94. Le Moigne, Barghouti, and Plusquellec, Technological and Institutional Innovation in Irrigation
No. 95. Swanson and Wolde-Semait, Africa’s Public Enterprise Sector and Evidence of Reforms
No. 96. Razavi, The New Era of Petroleum Trading: Spot Oil, Spot-Related Contracts, and Futures Markets
No. 97. Asia Technical Department and Europe, Middle East, and North Africa Technical Department, Improving the Supply of Fertilizers to Developing Countries: A Summary of the World Bank’s Experience
No. 98. Moreno and Fallen Bailey, Alternative Transport Fuels from Natural Gas
No. 100. Veldkamp, Recommended Practices for Testing Water-Pumping Windmills
No. 101. van Meel and Smulders, Wind Pumping: A Handbook
No. 102. Berg and Brems, A Case for Promoting Breastfeeding in Projects to Limit Fertility
No. 103. Banerjee, Shrubs in Tropical Forest Ecosystems: Examples from India
No. 105. Pasha and McGarry, Rural Water Supply and Sanitation in Pakistan: Lessons from Experience
No. 106. Pinto and Besant-Jones, Demand and Netback Values for Gas in Electricity
No. 108. Falloux, Land Information and Remote Sensing for Renewable Resource Management in Sub-Saharan Africa: A Demand-Driven Approach
No. 109. Carr, Technology for Small-Scale Farmers in Sub-Saharan Africa: Experience with Food Crop Production in Five Major Ecological Zones
No. 110. Dixon, Talbot, and Le Moigne, Dams and the Environment: Considerations in World Bank Projects