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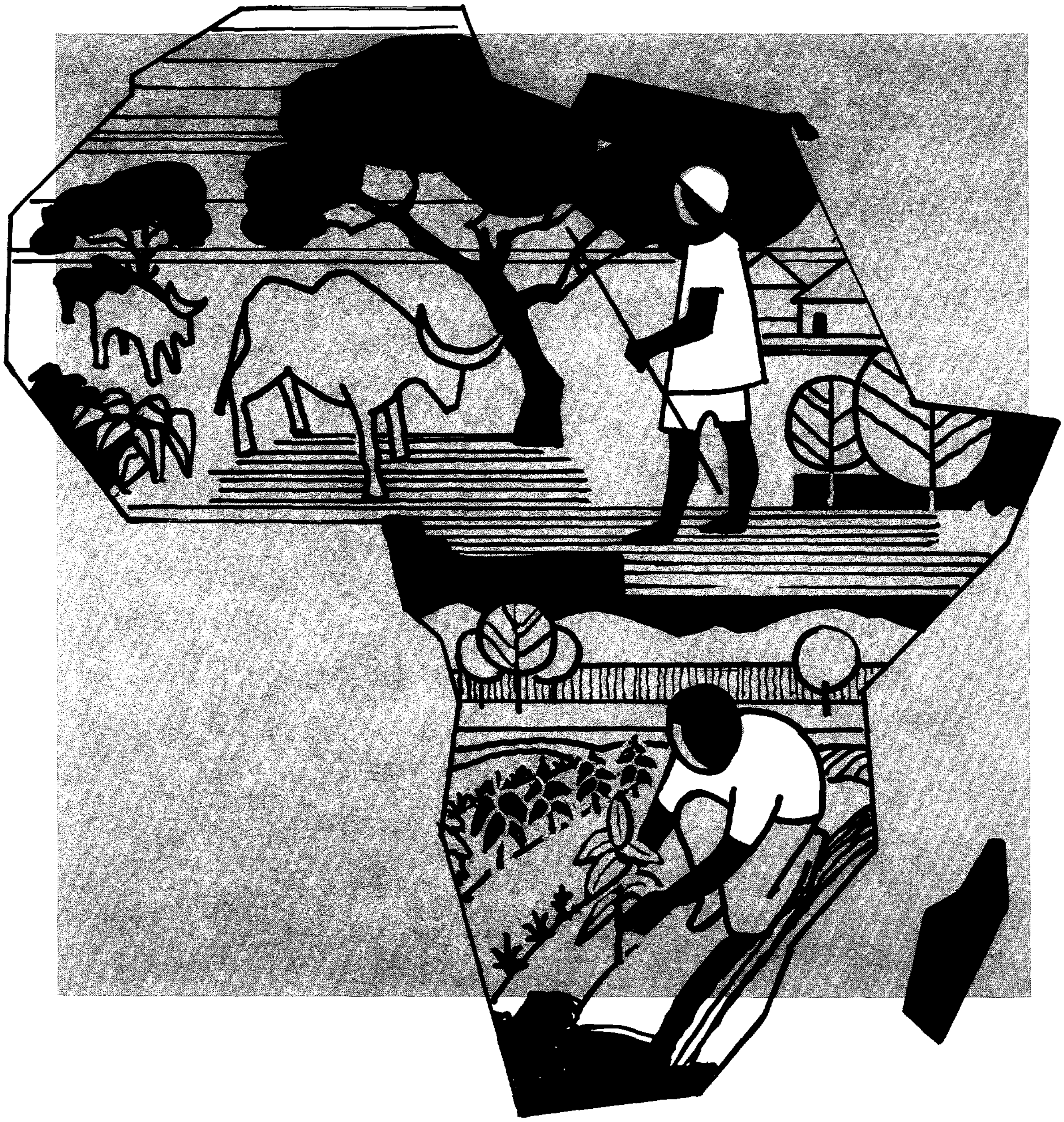
Agroforestry in Sub-Saharan Africa

A Farmer's Perspective

Cynthia C. Cook and Mikael Grut



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Cynthia C. Cook and Mikael Grut

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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

PREFACE

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.(1) 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.(2) Soon afterward, the Food and Agriculture Organization (FAO) carried out a review of worldwide experience with agroforestry.(3) The International Center for Research in Agroforestry (ICRAF), founded in Nairobi in 1977, has developed a typology of agroforestry activities.(4) 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.(5) 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.(6)

Experience has shown, however, that agroforestry projects in Africa have had only limited success in mobilizing farmer participation.(7) 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.(8) 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.(9)**

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-sylvo-pastoral 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

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

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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.(13)

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 m3/ha/year, has been estimated with the equation $0.05 + 1.08R^2$, where R is the mean annual rainfall in meters.(14) For example, where the mean annual rainfall is 800 mm, the MAY would be 0.7 m3/ha on the average. Where mean annual rainfall is 1,200 mm, MAY = 1.6 m3/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.(15)

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 chiefs 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.

Forested 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.(17)

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.(18) 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.(19) 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.(20) 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.(21) 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:(22)

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

***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.