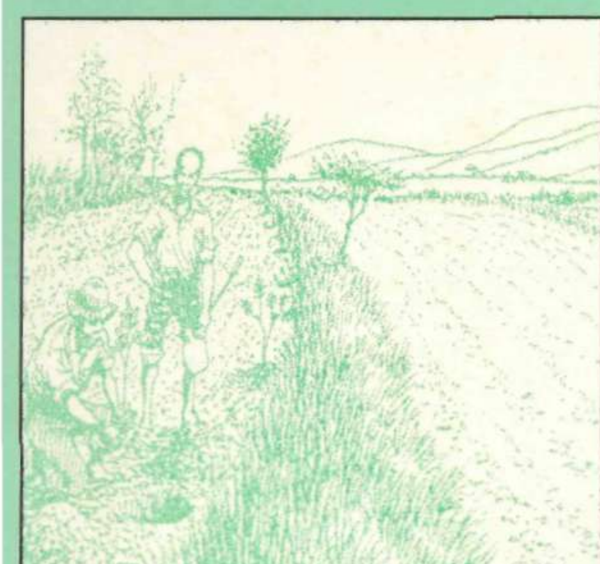
Bo Tengnäs

Agroforestry extension manual for Kenya



The International Centre for Research in Agroforestry (ICRAF), established in 1978, is an autonomous, non-profit organization whose purpose is to help mitigate tropical deforestation, land depletion and rural poverty through improved agroforestry systems. ICRAF's objectives focus on conducting strategic and applied research, in partnership with national institutions, aimed at developing appropriate agroforestry technologies for more sustainable and productive land use. The Centre seeks to strengthen national capacities to conduct agroforestry research by encouraging inter-institutional collaboration and promoting the dissemination of information through training, education, documentation and communication activities.

ICRAF is governed by a board of trustees, which has equal representation from developed and developing countries. Since May 1991, ICRAF has become a full member of the Consultative Group on International Agricultural Research (CGIAR). Established in 1971, the CGIAR is an association of about 50 countries, international and regional organizations, and private foundations working together to support agricultural and forestry research around the world. The World Bank, the Food and Agricultural Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP) are co-sponsors of this effort.

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AGROFORESTRY EXTENSION MANUAL FOR KENYA

Bo Tengnas

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LIST OF CASE REPORTS

PREFACE

Agroforestry has received much attention in recent development efforts in rural Kenya. This has been reflected in numerous projects during the last decade that were aimed at supporting the tree-growing efforts of local people. Several ministries have been involved, notably the Ministry of Agriculture (MoA), the Ministry of Energy (MoE), and the Ministry of Environment and Natural Resources (MoENR). The efforts of the various government extension services have been complemented by the non-governmental organization (NGO) community.

Two National Agroforestry Seminars were organized during the 1980s and at these occasions, as well as at numerous other workshops and seminars, the need for training and extension materials was stressed. The Second National Agroforestry Seminar, which was held in 1988, was co-organized by ICRAF within the framework of the Kenya Agroforestry for Development in Kenya project. This two and a half year project aimed at synthesizing experiences gained in agroforestry extension in Kenya and to develop relevant training materials for extension workers. An experienced project leader, Dr Amare Getahun, was hired and worked in close collaboration with representatives from the Ministry of Agriculture, the Ministry of Environment and Natural Resources, the Kenya Forestry Research Institute (KEFRI), and the Regional Soil Conservation Unit (RSCU) which is part of the Swedish International Development Authority (SIDA) office in Nairobi.

The main materials that resulted from the project are:

- *A Selection of Useful Trees and Shrubs for Kenya: Notes on Their Propagation and Management for Use by Agricultural and Pastoral Communities,* ICRAF, 1992.
- *Agroforestry for Development in Kenya: An Annotated Bibliography,* ICRAF, 1991.

Further efforts made by the ministries and KEFRI, in collaboration with RSCU, resulted in two other books published by RSCU:

- *Curriculum for In-Service Training in Agroforestry and Related Subjects in Kenya,* RSCU 1992.
- *Guidelines for Agroforestry Extension Planning in Kenya,* RSCU, 1993.

All the publications mentioned above are complementary to each other.

With the completion of this extension guide it is hoped that extension officers, both in government service and in the NGO sector, will now have access to a set of books that covers the field of agroforestry in Kenya. We hope that the books will prove useful to all extension officers in their vital work of helping the farmers and pastoralists who manage Kenya's land and vegetation resources.

At the time of writing (mid-1992), the US dollar was worth approximately KSh 30.

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Mr F.W. Mbote of the Soil and Water Conservation Branch (SWCB), Ministry of Agriculture, played a key role in collecting the data for the Case Reports. He has made useful suggestions on how to improve the earlier drafts. Mrs K. Fahlstrom of SWCB also reviewed an earlier draft and made a significant contribution to the final book.

The manuscript was technically reviewed by several ICRAF researchers, namely:

Dr Habib Ibrahim, ICRAF, Nairobi
Mr J. Beniest, ICRAF, Nairobi
Dr F. Place, ICRAF, Nairobi
Dr S. Minae, ICRAF, Malawi
Dr A. Temu, ICRAF, Nairobi
Dr D. Ngugi, ICRAF, Malawi
Dr F. Owino, ICRAF, Nairobi

Various other people have reviewed or contributed to different sections of the text. Among those I would like to mention are:

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Mr L.I. Mwarasomba, SWCB, MoA
Mr B. Hansson, ICRAF, later SIDA/RSCU
Staff of the Bellerive Foundation, Nairobi
Mrs N.A. Chavangi, Changwe Consultants, Nairobi
Mr P. Maundu, The Herbarium, Museums of Kenya
Dr M. Nicholson, Consultant, Nairobi
Mr Wangwe Baraza, FESD, MoENR, Nairobi

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Mr E.N. Oluoch, SWCB, MoA (reports from Turkana and West Pokot)
Mrs M.W. Murithi (on energy conservation in Embu District)
Mr P. Maundu (on nutritious trees)
Staff of the Bellerive Foundation (on energy conservation at the coast)
Dr H.P. Liniger, Laikipia Research Programme (on root pruning to minimize competition).

Under the project "Agroforestry for Development in Kenya", implemented by ICRAF and funded by SIDA, attempts were made to produce an agroforestry manual for Kenya. Ideas generated during that project have proved useful in the current work. Main discussion partners at that time were Mrs Loice Omoro and Mrs Alice Kaudia.

Basic data on current agroforestry research in Kenya were collected by Mrs M. Berlekom, consultant, Nairobi.

Copy editing, design, layout and typesetting were done by Caroline Agola. The cover was designed and prepared by Damary Odanga.

A few illustrations were drawn specially for this book by Boniface Agar. However, most of the illustrations have been taken from the other sources listed on page xii.

Some sections of the text are based on other publications: these sources are indicated at the appropriate places.

Without the contributions of farmers and other people who were interviewed and who willingly shared their experiences for inclusion in the Case Reports this publication could not have been developed.

I am grateful for all these contributions.

Finally I am most grateful to Dr Habib Ibrahim and Dr Ester Zulberti of ICRAF for their support and encouragement.

B. *Tengnas*

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1. INTRODUCTION

1.1 The concepts of agroforestry and extension

Agroforestry

Agroforestry, social forestry, community forestry, village forestry and farm forestry are all terms used to describe tree growing that is undertaken mainly outside gazetted forest areas. These terms are often used to describe very similar activities, but in theory they have slightly different meanings.

Agroforestry is the term most often used in the extension context in Kenya. Agroforestry is a land-use system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock. This integration of trees and shrubs in the land-use system can be either a spatial arrangement, e.g. trees growing in a field at the same time as the crop, or in a time sequence, e.g. shrubs grown on a fallow for restoration of soil fertility.

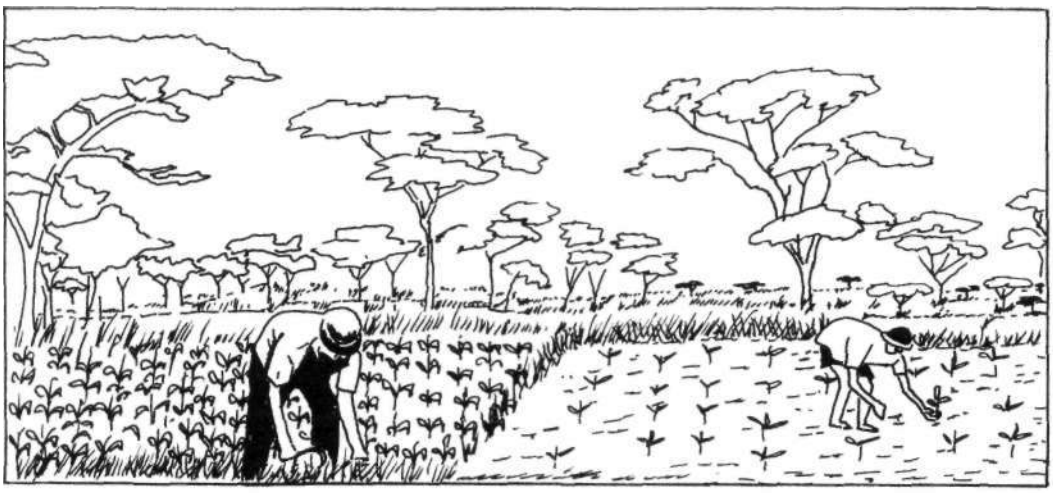


Figure 1.1 *Agroforestry provides opportunities for people to meet local needs for both food crops and forest products*

Sometimes the phrase woody perennials is used instead of trees and shrubs. Of course, woody perennials include all trees and shrubs with a lifespan of more than a year, but they also cover bamboos and palms.

The trees in an agroforestry system are not necessarily planted. Instead natural regeneration of trees may be protected, or mature trees may be deliberately left in the fields or pastures. Hence agroforestry is a much wider concept than tree planting.

Agroforestry systems often involve management of trees and shrubs and utilization of their products. The trees and shrubs will have an impact on the other components in the land-use system. Hence, agroforestry systems are normally characterized by ecological and economic interactions between woody perennials and crops or livestock.

Woody perennials are sometimes referred to as multipurpose trees and shrubs or MPTS. Almost all trees and shrubs can be said to be MPTS, but the concept was introduced to distinguish the multiple role often played by trees and shrubs in an agroforestry system from the single purpose of wood production in pure forest plantations. Tree growing in such forest areas normally aims at meeting demands for wood for industrial purposes, and is often called industrial forestry.

Social forestry is a slightly wider concept as it includes tree growing for ornamental purposes in urban areas and in avenues. Farm forestry can be regarded as almost synonymous to agroforestry, but it may also include large-scale forest production on private farms, an activity that would fall outside the definition of agroforestry. Finally, the term community forestry has been used to stress the involvement of people in tree-growing efforts, although people are, of course, much involved in all agroforestry activity. In many countries the concept of community forestry has now been replaced by those of farm forestry or agroforestry. This change is the result of the de-emphasis of communal efforts which have often proven less fruitful than was predicted some years ago. What has been said here about community forestry largely applies to village forestry as well.

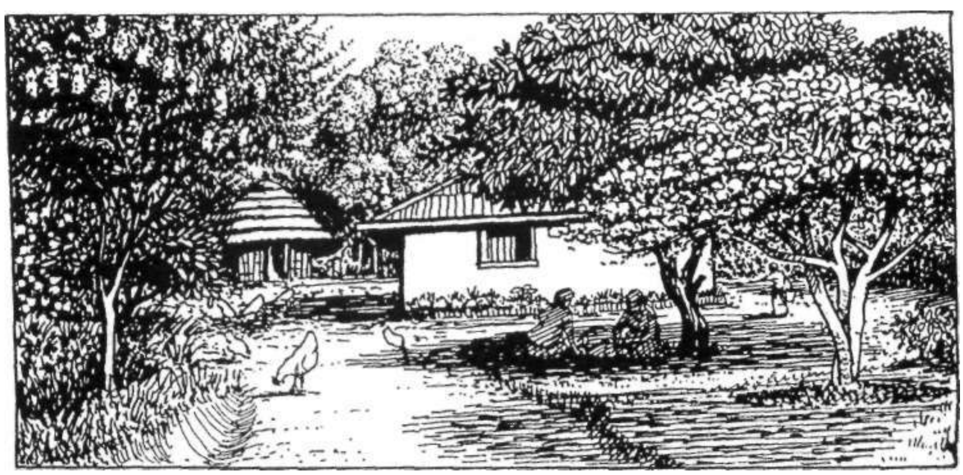


Figure 1.2 Carefully chosen and nurtured trees add beauty to a homestead

In this book the term agroforestry will be used in its widest sense with no attempt being made to distinguish it from any of the other concepts discussed above. Instead of the cumbersome "woody perennials" or "multipurpose trees and shrubs" we will simply use "trees and shrubs" or just "trees". Whenever we talk of trees or trees and shrubs these terms should be understood as equivalent to woody perennials.

Extension

Extension is a term that has long been used to describe a non-formal educational system aimed at improving the livelihood of farmers and their communities. Sometimes extension efforts aimed at increasing the growing of trees have involved provision of considerable physical or financial resources such as free tree seedlings, cash payments in relation to the number of surviving trees, etc. Although such incentives may be part of an agroforestry extension system, the core activities in extension are education and training.

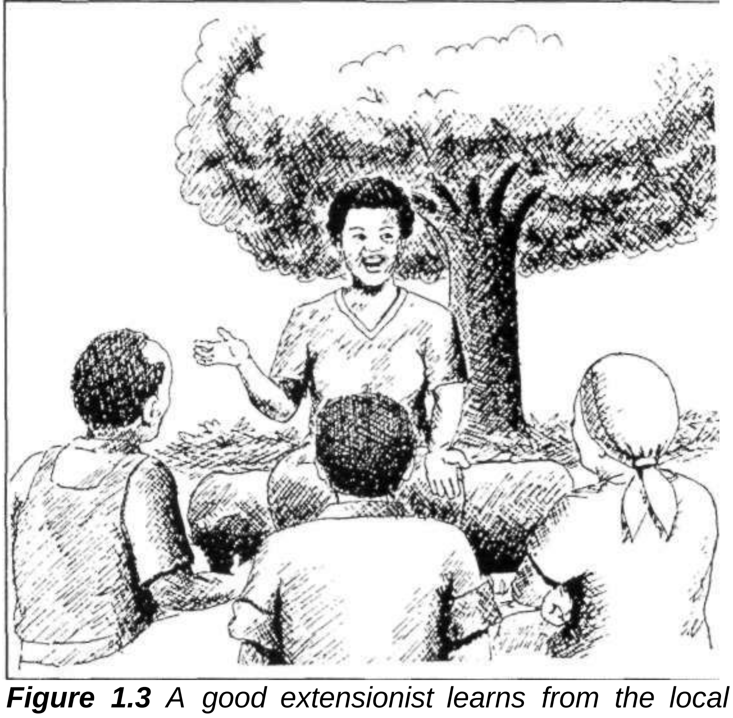


Figure 1.3 *A good extensionist learns from the local farmers*

Sim and Hilmi (1987) used the term forestry extension to cover any situation in which local people are directly and willingly involved in forestry activities and from which they will derive some recognizable benefit within a reasonable period of time. These authors felt that too often in the past

> extension has been regarded as a means of passing down to fanners techniques which, it was believed, would be beneficial to them without taking into account sufficiently the particular social or environmental conditions of the area. In particular, too often, the indigenous skills, social structure and detailed local knowledge of the people have been ignored in trying to transfer new skills or techniques to them.
>
> Fortunately, extension is now being regarded as a much wider task of integrating indigenous and new skills and techniques, derived from study or research, into an overall framework of discussion and co-operation between the people and the extension organisation.

It is in this wider sense that the term extension is used in this book.

1.2 Introduction to this book

This book aims to explain the factors that need to be considered in agroforestry and the nomenclature that is used. It is complementary to *A Selection of Useful Trees and Shrubs for Kenya* (ICRAF, 1992), which gives detailed information on a large number of tree species that are important in Kenya. These two publications are core materials for in-service training in agroforestry conducted by MoA, MoENR and KEFRI that follow the *Curriculum for In-service Training in Agroforestry and Related Subjects* (RSCU, 1992). This book is related mainly to the course called Block No. 1 in the curriculum, but it will also be used as core training material in courses for international participants organized by ICRAF in Kenya.

Participants who have attended such in-service training and familiarized themselves with the content of both those books will be expected to be able to carry out local-level planning of extension activities following the *Guidelines for Agroforestry Extension Planning in Kenya* (Tengnas, 1993).

A basic philosophy of all these publications is that agroforestry technologies for extension cannot be designed at the central level but have to be worked out jointly by extension officers and actual land users at the local level. One of the major aims of the in-service training course is to impart the knowledge and skills necessary for someone to initiate and participate in such planning. Consequently, no detailed technologies for specific environments are suggested in this book: such detailed designs will have to be based on specific local conditions and needs.

Figure 1.4 A farmer discusses his plans with the exfensionist

The interested reader who may want to read further is referred to two other recent publications: *Agroforestry for Development in Kenya: An Annotated Bibliography* (ICRAF, 1991), and *Soil and Water Conservation in ASAL: Field Manual No. 3* (MoA, 1992).

Certain aspects of agroforestry have not been covered in detail in this book since they are covered in the other training materials mentioned above. Some of these areas are local-level planning, communication, agroforestry in ASAL, and information on individual tree species. Neither are tree-nursery techniques given in any detail since these aspects are covered in *Fruit Tree Nurseries* (MoA, 1990), *Tree Nurseries* (ILO, 1989), and *On-Farm Nurseries* (Mung'ala *et al.*, 1988).

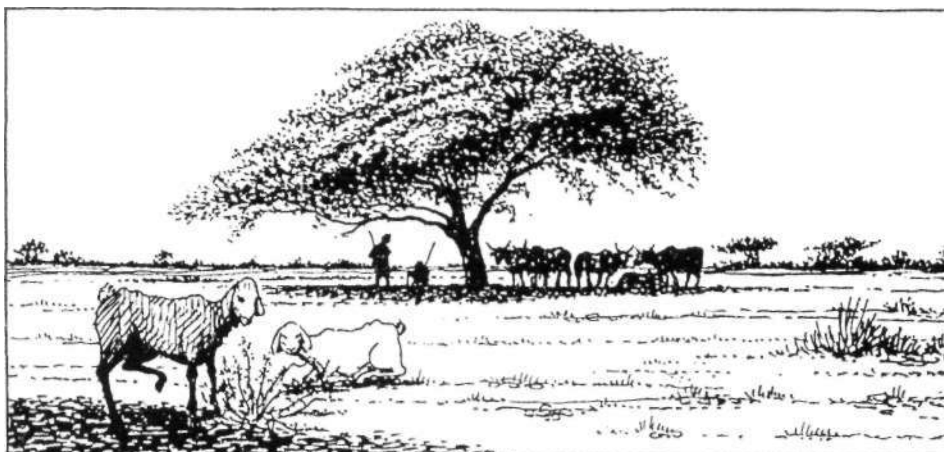


Figure 1.5 Valued as fodder and browse, Acacia tortilis *also provides welcome shade in the dry season*

2. THE HISTORICAL SETTING

2.1 The history of land use in Kenya

A brief review of the history of land use in Kenya may help us to better understand the present situation with regard to tree cover in the country.

African agriculture before the colonial period

Reports from earlier days indicate that before the land area of present-day Kenya was penetrated by the Europeans the land use was a combination of pastoralism and subsistence agriculture (Cone and Lipscomb, 1972). This subsistence-agriculture system was based on shifting cultivation, and since the population density was low, fallow periods were long. It was an extensive land-use system, with vast areas being under grazing. In the farming areas only small patches were cultivated each year and the rest was fallow.

A large number of crops such as bananas, yams, sweet potatoes, Colocasia, vegetable marrow, millet, Eleusine, sugar cane, tobacco and a little cassava were grown (Linton, 1904). The variety of crops grown on one plot ensured that different kinds of food were available over a long period of time.

From early reports it is clear that the agricultural system was a sustainable one. It is also clear that the production was diverse, which made for a varied diet, and the rich flora of crops must have contributed to maintenance of soil fertility and control of pests and diseases.

In spite of the fact that agricultural development over the last hundred years or so has been well documented, little has been written about changes in tree cover. With the sparse population, however, it is obvious that there was little need to plant many trees. Indeed, there were too many trees in some areas and these had to be cleared for agriculture. Fire was an important tool for such clearing.

The white settlers

The early white settlers tended to believe that the fertility of the soil in the highlands was inexhaustible and that the only problem was to find the right crop varieties for each area (Cone and Lipscomb). This approach was in sharp contrast to the diversified traditional African agriculture.

But by the 1930s it became obvious that unless more careful land management was practised, the fertility of the soils would become exhausted. Mixed farming and crop rotation were called for. After the Second World War settler agriculture was intensified. Crop rotation and soil conservation became common practices.

After independence

Radical changes occurred after independence in 1963. The majority of the white settlers gradually left, and more development efforts were directed towards small-scale African agriculture. Many large-scale farms were sub-divided, although a few remain to the present time.

Agricultural development in relation to tree cover during the colonial period

The influx of white settlers into the highlands in the early years of the century had both a direct and an indirect impact on the tree cover.

Some of the areas that were opened up for large-scale agriculture had been grassland with only scattered trees. These grasslands had been used as seasonal grazing by the local pastoral communities and also by the wild fauna which had a significant impact on the ecology. Trees were often left in the fields when new land was opened up for cultivation, so the cultivation of such areas did not bring about deforestation on any large scale. On the contrary, the settlers brought a knowledge of tree planting with them and woodlots and windbreaks were commonly established in the highlands.

Other areas that were covered with dense forests were, however, taken over for other land use. Those areas are mainly the present tea zones and the upper coffee zone. The opening up of these areas for cultivation obviously caused deforestation.

But it was the indirect effect of the settlers' agriculture that contributed most severely to deforestation. The entire area of the fertile "White Highlands" was reserved for white settlers and the Africans became restricted to the various tribal "reserve" areas designated by the colonial government. Thus indigenous agriculture was confined to an insufficient area of relatively poor soils. With increasing populations, land became even scarcer and it was no longer possible to practise traditional shifting cultivation with fallow periods that allowed the soil to regain fertility. Fire remained an important tool for land clearing and the consumption of firewood and building materials increased. This pressure on the land eventually resulted in deforestation and a shortage of tree products.

The pastoral communities lost their most important dry-season grazing areas to the settlers. This resulted in increased pressure on the more marginal semi-arid areas and hardship for the pastoralists.

With the gradual introduction of more intense tree growing, both before and after independence, indigenous trees were to a large extent replaced by exotics. Many exotic species originally brought to Kenya by the settlers at the turn of the century found their way into the small-scale farming systems. Cypress was originally brought from Mexico in 1908 as a promising timber tree, wattle was introduced for tannin in 1903, eucalypts were planted to provide train fuel for the railway and to drain swamps around the growing town of Nairobi, and Grevillea was brought in as a shade tree for coffee. Later these and other exotics were found to be suitable for a wide range of other uses.

In most areas the spread of exotic trees has taken place at the expense of indigenous trees. With the increase in the area of cultivated land, the shortage of tree products has become increasingly severe in many areas.

2.2 Increased pressure on land

The population of Kenya was approximately 7 million at the time of the 1962 census. It is estimated that in the 30 years since then the population has increased more than three-fold to about 24 million in the early 1990s. In spite of this population increase, the country has been largely self-sufficient in food and agriculture has remained one of the major export earners.

The increase in population was followed by an increase in agricultural production made possible both by increasing the area cultivated and by intensifying the use of each unit of cultivated land. The shifting cultivation of earlier days has disappeared from most areas and the "land mining" type of farming practised by the white settlers is also a thing of the past. Most land suitable for rainfed agriculture is now utilized, and in addition marginal lands have been put under cultivation. Subdivision of land over several generations has resulted in very small holdings in many high-potential areas. The population in urban centres has grown more rapidly than that in the rural areas and an ever-increasing proportion of the population needs to be fed without being actively involved in farming themselves.

In spite of achievements in intensifying production, there are significant problems in agricultural production. Major efforts are required to maintain soil fertility, prices of inorganic fertilizers are on the increase, and new ways of achieving sustainable production are being sought. In the arid and semi-arid (ASAL) areas the livestock, population has increased and parallel to this pastoralists have lost their best dry-season grazing lands to agricultural production.

From the late 1970s onwards, researchers and extension workers have concentrated on determining the role that trees can play in sustaining or even increasing overall production in various farming systems. Trees have two major functions in farming areas: firstly in supplying useful products and secondly in service functions that support other activities such as growing of crops or rearing livestock. Recently awareness has grown of the important role trees can play in solving some of the serious problems in tropical land use. The role of trees in land-use systems will be discussed in detail in Chapter 4.

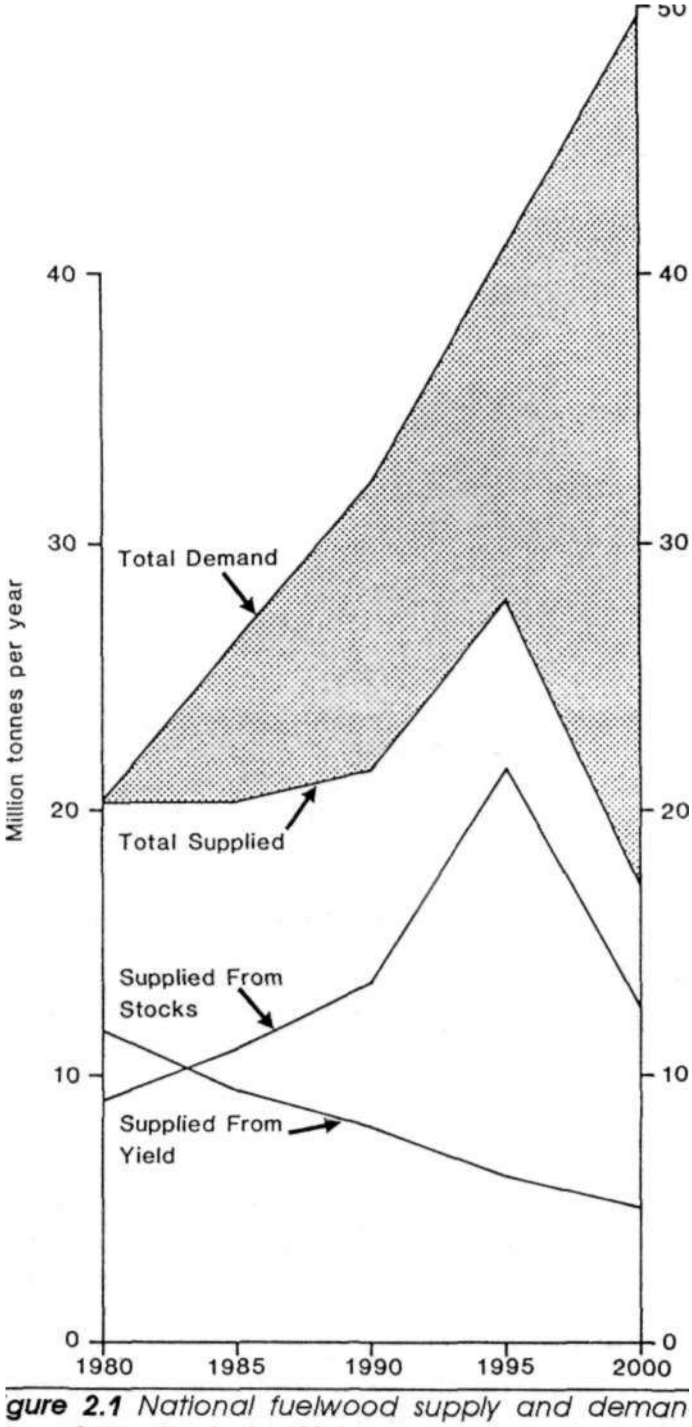
With the shift from monocropping agriculture and intensive use of chemical fertilizers and pesticides towards a more sustainable system based on tropical ecosystems, support for farmers' tree-growing efforts has become essential.

2.3 Trends in tree growing outside gazetted forests

In the early 1980s a comprehensive study of energy demand and supply in Kenya was carried out under a project called the Kenyan Woodfuel Project. The Beijer Institute was instrumental in implementing the project in collaboration with various national institutions and foreign donors. A summary of the study was published under the title "Energy and Development in Kenya: Opportunities and Constraints" (O'Keefe *et al.*, 1984). The findings of the study were alarming. Stocks of wood were found to be depleting rapidly since the consumption of wood for energy purposes far exceeded yields. Further, demand was projected to increase from 20 million tonnes per year in 1980 to 50 million tonnes per year in 2000. If tree growing was not intensified, the annual increment in yield was expected to decrease from 11 million tonnes in 1980 to only 5 million tonnes in

2000 due to over-exploitation. As a whole, there was a large and increasing gap between demand and supply of fuel, and the standing stock, of wood was projected to decline by about 30% in the period 1980-2000.

After this alarming report, serious efforts were made to intensify tree growing on farm land. Numerous tree-planting projects were started and general awareness of the importance of trees increased.



gure 2.1 National fuelwood supply and deman
rom O'Keefe et al., 1984)

Another study carried out in the early 1990s (Holmgren, 1992a) presents a more encouraging picture. Preliminary results from this study indicate that the standing stock of woody biomass outside forests is increasing in most parts of the country. According to the study more than half of the planted tree volume in the country is on farmland, and hence farmers in Kenya are now managing a larger resource of planted trees than the Government Forest Department.

In ASAL areas, only three Districts, Baringo, Samburu and Turkana, show a negative trend. In high-potential areas the preliminary results from the survey indicate that the standing planted volume is increasing by 4—5% annually, i.e. faster than population growth of about 3.8%.

It is also interesting to note that in high-potential areas the volume of planted trees is higher where the population is dense and lower where people are fewer. This may be the result of more intensive land use and tree growing to meet people's needs for fuel and other commodities. In fact, if this preliminary finding is correct, the high population density in the highlands may have contributed to better tree cover in those areas.

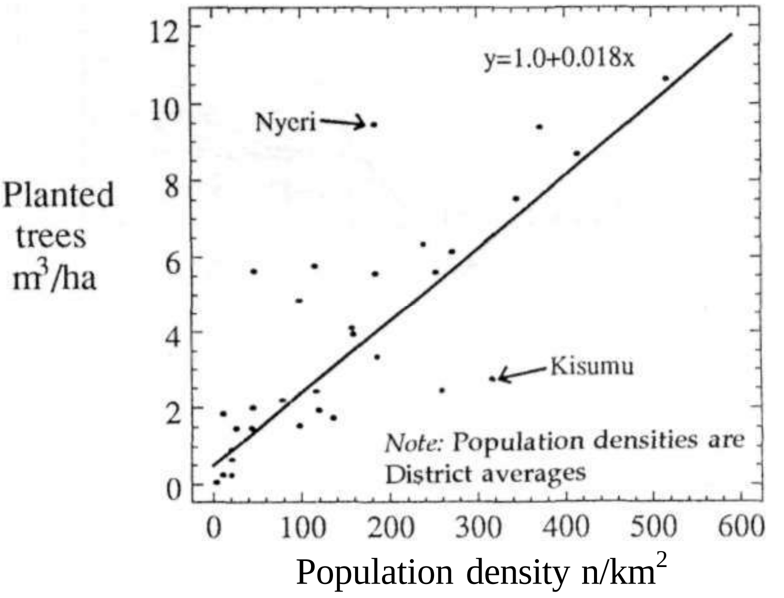


Figure 2.2 *Planted tree volume outside forests compared to population density by District in high-potential areas (after Holmgren, 1992a).*

The reasons for the discrepancies in the results of these two studies are not clear. Either the studies themselves have had certain weaknesses leading to these conflicting results, or perhaps these are real signs that farmers in Kenya, with support from extension workers, have managed to increase the woody biomass on the land they control.

But even if the picture is encouraging at this macro level, it is clear that there are still serious problems to be addressed in agroforestry extension. In most areas there is a shortfall in fuel, building materials and other commodities. Women still have to use crop residues as fuel, or to walk considerable distances to obtain fuelwood. Prices for poles are high, and the trees that are important for human food and medicine are rapidly disappearing in many areas. Agricultural productivity is on the decline due to increased prices of fertilizers and declining quality of the soils. In recent years, per capita food production has gone down and the country has been forced to import food to meet domestic needs. Income levels in the rural areas are far from satisfactory.

The growing of trees has the potential to alleviate many land-use problems and uplift the people's standard of living, as we shall see in the following chapters.

Figure 2.3 The trees and shrubs in an agroforestry system have many uses

3. FARMING SYSTEMS IN KENYA AND THEIR AGROFORESTRY POTENTIAL

3.1 Kenya's ecological diversity

Kenya's land area covers a very wide range of ecological zones. Based on moisture and temperature regimes, the country has been divided into seven main agroclimatic zones, and attempts have been made to further sub-divide these seven zones. Jaetzold and Schmidt (1982/83) divided the country into agro-ecological zones mainly on the basis of altitude and rainfall.

The agro-ecological zones can be said to give an indication of what may be grown in a particular area. Within each zone, local communities may opt for various land-use systems. Their choice will depend on socio-economic factors such as population density, access to markets, level of education, infrastructure and support services, farming practices, the tenure situation, culture and traditions, and also on Government policies. Depending on such factors, therefore, the land-use pattern may evolve differently in different areas even if the ecological conditions are similar.

When discussing the agroforestry potential of various parts of Kenya, both ecological and socio-economic factors need to be taken into account. Hence, it is most appropriate to tie the discussion to actual land-use systems. Such analysis can help us to judge which agroforestry technologies and which tree species are appropriate and the potential that improved agroforestry practices have for solving the particular land-use problems experienced by farmers in each area.

Land-use systems vary from place to place, however. For example, the management of the coffee-based system in the central highlands is different from that in western Kenya. It is obvious that any division of this nature cannot be made with rigid boundaries—and the change from one zone to another is usually gradual. Transitional systems incorporating aspects of two adjoining systems are often recognizable. An example is the tea/coffee zone where farmers grow both crops.

The following presentation is based largely on the findings from two land-use studies that ICRAF participated in during 1987 and 1988. Both studies were based on the "Diagnosis and Design" (D&D) methodology. The first one was under a regional agroforestry programme covering the bimodal highlands of eastern and central Africa (Minae and Akyeampong, 1988). The second study was specifically planned to cover the rest of Kenya, particularly the coastal and ASAL areas (Minae *et al,* 1988). The results of both studies were presented at the Second Kenya National Seminar on Agroforestry.

These studies involved analysing land use by describing the main activities and components of the system in terms of organizational structure, farm resources, socio-economic situation (including land-tenure system), and physical

This chapter is based largely on Minae, Kamau and Jama, 1988, with additions and modifications by Fahlstrom, Getahun and Tengnas.

and environmental factors. The performance of each system was also analysed in terms of levels of inputs, outputs and efficiency in utilizing farm resources. Finally, the constraints of the system were identified, including production potentials that are not fully exploited. In so doing, the major causes of the constraints were also identified.

In the second phase of the analysis, proposals were made for agroforestry interventions by matching agroforestry technologies with land-use requirements.

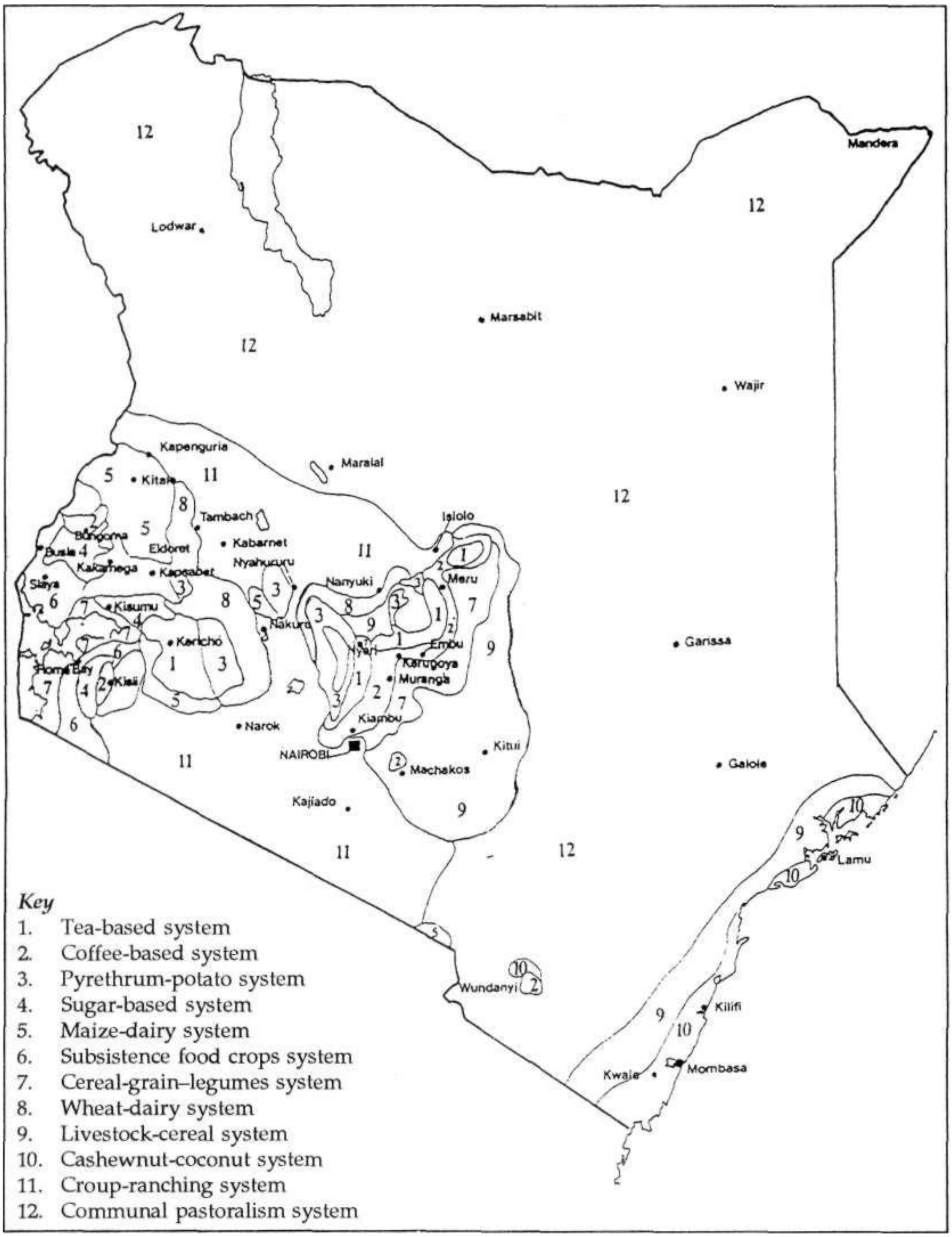


Figure 3.1 The major land-use systems in Kenya

There was extensive use of secondary data in the studies, notably the *Farm Management Handbook of Kenya* (Jaetzold and Schmidt, 1982/83).

The land-use systems identified in these studies were based on what were considered the main or most important components. In most cases, the names coincided with the names of the agro-ecological zones in the *Farm Management Handbook.*

There are major differences between small-scale subsistence-oriented production systems and large-scale commercial production. For these reasons, the two are recognized as separate systems despite similarities in the components. The focus here is on the small-scale systems.

In the following sections 12 major land-use systems will be described and their agroforestry potential discussed. These land-use systems are:

- The tea-based system
- The coffee-based system
- The pyrethrum-potato system
- The sugar-based system
- The maize-dairy system
- The subsistence food crops system
- The cereal-grain-legumes system
- The wheat-dairy system
- The livestock-cereal system
- The cashewnut-coconut system
- The group-ranching system
- The communal pastoralism system.

3.2 The farming systems and their agroforestry potential

The tea-based system

Tea-based systems are located on the higher slopes of the highlands in Kiambu, Nyeri, Muranga, Kirinyaga, Embu and Meru in the central highlands and in Kericho, Nandi, Kakamega and Kisii in the western highlands. This land-use system has the highest capacity for generating income from tea growing and dairy production, which are the main commercial activities. Temperate fruits and vegetables also do well in this system. Maize is the main food crop, but due to the high altitude there is only one growing season per year. Soils are of volcanic origin and tend to be acidic. Some areas have very steep slopes and V-shaped valleys.

Constraints in the system are acidic soils, low temperature and erosion problems.

Agroforestry considerations: Both land and labour have high opportunity costs. Therefore any agroforestry intervention must use little space and its management must not take time off the labour required for agriculture. Since dairy production could expand with increased fodder production, growing of fodder trees would be a viable option, but due to the high altitude and acidic soils the choice of species is limited. *Calliandra calothyrsus* is one of the few promising species for fodder production in this zone. Other promising interventions are boundary planting, windbreaks, woodlots, fruit orchards and live fences. Again, the low temperatures limit the choice of species. In addition to Calliandra, *Morus alba* can also be grown for fodder and fruit up to about 2,000 m.a.s.l. Temperate fruits such as pears, peaches and plums do well, and *Croton megalocarpus* can be grown on boundaries for live fencing and /or fuel wood production. It can be combined well with *Grevillea robusta* for timber. *Casuarina cunninghamiana, Millettia dura* and *Hakea saligna* can be planted as windbreaks, and good wood lot trees for this zone are *Eucalyptus globulus* and *Acacia mearnsii.*

The coffee-based system

Coffee-based systems are found on the lower slopes of Mt Kenya (Kirinyaga, Embu, Meru), the Aberdares (Nyeri, Muranga, Kiambu) and Mt Elgon (Bungoma). Marginal coffee zones are also found in Siaya, Machakos and the Taita Hills. These are the most intensive systems and the areas concerned have the highest population densities in the country. Coffee is important for income generation and the main food crops are maize, beans, bananas and potatoes. Dairy farming is also important and most farmers have planted fodder in small plots or as grass strips along contours. Fruit trees are intercropped with food crops, and many farmers have planted trees for fuelwood, timber and poles along boundaries, dispersed in cropland or occasionally in woodlots. Due to the intensity of land use, woodlots with competitive trees are gradually being phased out and replaced with trees that grow well with crops in other spatial arrangements, notably Grevillea. Several studies have indicated that the woody biomass in this system has increased in recent years and tree growing is an important commercial enterprise.

Constraints in the system are declining soil fertility due to continuous cropping, soil erosion, shortage of fodder and wood.

Agroforestry considerations: Agroforestry is already extensively practised in this zone. Land and labour have high opportunity costs, so agroforestry extension must be geared towards technologies that intensify the system. Boundary planting, trees along soil-conservation structures, trees dispersed in cropland, woodlots on land that is unsuitable for cropping, live fences, fodder banks, and fruit orchards are all current practices in this system, but there is still scope for more tree growing based on such technologies. Moisture is seldom a severe constraint, hence hedgerows of nitrogen-fixing shrubs could also have potential. Due to the high altitude, however, there are few species to consider. *Calliandra calothyrsus, Leucaena diversifolia* and *Chamaecytisus palmensis* (tree lucern, tagasaste) may be good options, but experience with these species is still limited. Other important species in this system are *Jacaranda mimosifolia* on boundaries, and *Syzygium* spp. producing good wood and fruit along water courses and as windbreaks. *Cyphomandra betacea* (tree tomato), *Persea americana* (avocado), *Macadamia tetraphylla, Passiflora edulis* (passion fruit), *Casimiroa edulis* (white sapota), *Annona senegalensis* (custard apple), *Psidium guajava* (guava), *Eriobotrya japonica* (loquat), pawpaw, peaches and bananas are also useful for fruits or nuts. Some trees that commonly grow in cropland are *Grevillea robusta, Albizia* spp., *Erythrina abyssinica, Cordia abyssinica, Croton* spp., *Markhamia lutea* and *Bridelia micrantha. Eucalyptus* spp., *Acrocarpus fraxinifolius* and *Acacia mearnsii* are good trees for woodlots on sites where they will not interfere with more valuable production. Calliandra, Morus *alba*, Grevillea and *Markhamia lutea* are good options for planting on soil-conservation structures.

The pyrethrum-potato system

Pyrethrum-potato systems are high-altitude systems found in Meru, Nyandarua, Kiambu, Narok, Kericho, Nakuru and Uasin Gishu. Pyrethrum is produced as a cash crop and vegetables such as carrots, peas, cabbage, kale, potatoes and temperate fruits are important. Dairy production and rearing of sheep are also important activities. Part of this system consists of new settlements formed from the sub-division of former large-scale farms. Thus farmers have also introduced maize, although it does not do very well. These areas are mostly open plains or gently sloping land and trees are scarce.

Apart from the poor supply of wood products, *constraints* are crop damage by low temperatures and wind and the slow growth of trees.

Agroforestry considerations: Windbreaks are important both for crop protection and as one way of increasing the supply of wood products. Woodlots, boundary planting, trees on soil-conservation structures, live fences and intensified fruit production are other technologies that could be further promoted. Some suitable species for this system are *Eucalyptus globulus, Acacia mearnsii, Grevillea robusta, Hakea saligna, Croton macrostachyus, Dombeya* spp., *Dodonaea angustifolia, Casuarina cunningharniana*, and *Dovyalis caffra.* Fruit trees such as pears, peaches and plums can also do well.

The maize-and-dairy system

Maize-and-dairy systems are found mainly in or near the Rift Valley: Trans Nzoia, West Pokot, Nandi, Uasin Gishu, Nakuru, Kericho, Narok and around Loitokitok. Although maize is grown throughout Kenya, in this system it is produced as a cash crop, occupying about 60% of the cropland. Dairy production is well integrated into the system, sometimes as a commercial enterprise. A significant area of this system consists of small farms sub-divided from former large-scale farms.

Constraints: The lack of trees in the newly settled areas has led to crop damage from wind and a shortage of wood products. Small-scale farmers also experience shortage of fodder, and with the increasing prices of inorganic fertilizers the maintenance of soil fertility is becoming increasingly difficult. Soil-conservation structures are often damaged by contractors ploughing across them. Post-harvest grazing is common, and burning of crop residues also occurs. Such practices are constraints to tree growing in cropland.

Agroforestry considerations: Small woodlots are already common. Some windbreaks remain from the large-scale farming era, but they are insufficient and overgrown. Wind damage can be reduced by establishing new windbreaks, but often boundary planting is more practical in small-scale farming areas and it serves the same purpose. Live fences can contribute to improved grazing practices (paddocking, etc.) on large-scale farms and they help protect homesteads and control post-harvest grazing in small-scale farming areas. Since maize is sensitive to shade, there is only scope for trees in cropland if they are intensively managed. Hence small woodlots are likely to continue to be used for intensive wood production. Trees may be used on soil-conservation structures to make them more permanent, but with due consideration to the risks of reducing crop yields because of the effects of shade. More fruit trees and vegetables could be grown both for domestic use and for sale. Some suitable species are *Grevillea robusta*, *Sesbania* spp., *Croton macrostachyus, Croton megalocarpus, Acacia abyssinica, Eucalyptus* spp., *Acacia mearnsii, Casuarina cunninghamiana, Dovyalis caffra, Markhamia lutea, Cordia abyssinica, Calliandra calothyrsus, Combretum* spp., *Terminalia* spp., and a large variety of fruit trees.

The wheat-dairy system

Wheat-dairy systems are located in Meru, Laikipia, Nyandarua, Samburu, Narok, Nakuru, Baringo, Uasin Gishu and Trans Nzoia. Wheat and dairy production are the two main commercial activities. Sheep also play an important role in some areas. Most small-scale farmers also grow maize, beans and vegetables for subsistence although these crops do not do very well. Sub-division of land is continuing and this will further reduce the area under wheat.

The constraints in this system are similar to the ones in the maize-dairy system.

Agroforestry considerations: Windbreaks, trees on boundaries, woodlots, live fences, fodder trees, trees on soil-conservation structures and fruit trees are all viable options for further extension in this zone. Some suitable species are *Acacia abyssinica, Eucalyptus* spp., *Grevillea robusta, Casuarina* spp., *Morus alba, Calliandra calothyrsus* and a large variety of fruit trees.

The subsistence food crops systems

These systems are found mainly in western Kenya in Kakamega, Bungoma, Busia, Siaya, Kisumu, Nandi, South Nyanza and Kisii, but also around Marsabit. These are high-potential areas, but due to poor infrastructure, especially poor access to markets, production for sale is not well developed. The main crops grown at present are maize, beans, bananas, cassava, sorghum, sweet potato and millet. The majority of farmers have some livestock.

Constraints are shortage of cash income and low crop yields due to low levels of management.

Agroforestry considerations: Technologies to improve soil fertility would be important and labour is not as much of a constraint as it is in the more commercially oriented systems. Fruit and fodder trees should be promoted. Some suitable species are *Leucaena leucocephala, Calliandra calothyrsus, Sesbania* spp., *Grevillea robusta, Casuarina* spp., *Markhamia lutea, Albizia* spp., *Cajanus cajan, Erythrina abyssinica, Ficus sycomorus, Morus alba, Psidium guajava, Tipuana tipu, Syzygium* spp., *Maesopsis eminii* and fruit trees such as citrus, pawpaw, mango and others.

The sugarcane-based system

Sugarcane-based systems are found in the Lake Basin plateau at medium altitudes (Siaya, Busia, Bungoma, Kakamega, Kisumu, Nandi, Kisii, and South Nyanza). Production of crops other than sugar is still at subsistence level. A significant land area previously devoted to other crops has now been converted to sugar production. The land has the potential for intensified livestock production, but infestation by tsetse fly is a major constraint.

Other *constraints* are declining soil fertility due to continuous cropping and, in some parts, soil erosion problems aggravated by tractor ploughing. Wood products are in short supply.

Agroforestry considerations: Wood production is important and could be intensified through trees on boundaries, woodlots and tree fallows with *Sesbania sesban.* The latter practice would also help improve soil fertility. Fruit trees could diversify the system. Some suitable species are *Leucaena leucocephala, Sesbania sesban, Flemingia macrophylla, Gliricidia sepium, Albizia* spp., *Cajanus cajan, Ziziphus* spp., *Citrus* spp., *Mangifera indica, Annona senegalensis, Carica papaya, Pithecellobium dulce, Euphorbia tirucalli, Cassia siamea* and *Psidium guajava.*

The cereal-grain-legume system

Cereal-grain-legume systems are found on the lower slopes of Mt Kenya adjacent to the coffee-based system (Kiambu, Muranga, Embu, Meru), and in Machakos, Kitui, Taita-Taveta, Nyeri and in the Lake Victoria basin. Production is mainly for subsistence, although surplus food crops are sold for cash. Cotton, sunflower and sisal have potential as cash crops, but marketing is still poor. Many farmers from the coffee-based system are moving to these areas.

The main constraints are low crop yields due to poor management and crop failure due to unreliable rainfall. Grazing lands are degraded due to overgrazing and poor management, and soil erosion is a problem on sloping land. There is a decline in fuelwood supply due to clearing of bushland for cultivation.

Agroforestry considerations: Trees along soil-conservation structures to make them more permanent, trees on boundaries and scattered trees in cropland are potential technologies for increased wood production and as a support to agricultural production. Hedgerows of leguminous shrubs may be less feasible due to the risk of moisture competition with crops. Woodlots have a role to play in wood production, and fodder trees are needed as a supplement for young stock and draught animals. More fruit trees of improved varieties could also be grown, both for domestic consumption and for sale. Some suitable species are *Leucaena leucocephala, Flemingia macrophylla, Gliricidia sepium, Sesbania* spp., *Faidherbia (Acacia) albida, Grevillea robusta, Casuarina eauisetifolia, Prosopis* spp., *Cajanus cajan, Acacia* spp., *Combretum* spp., *Terminalia* spp., *Faurea saligna, Cassia* spp. (both exotic and indigenous), *Piliostigma thonningii, Parkinsonia aculeata, Balanites* spp., *Cordia sinensis, Ziziphus* spp., *Anacardium occidentale, Citrus* spp., *Mangifera indica, Carica papaya, Annona* spp., and *Euphorbia tirucalli.*

The livestock-cereal system

Livestock-cereal systems are found in Eastern Province (Meru, Embu, Machakos, Kitui), in Kajiado, and in the coastal hinterlands (Kwale, Kilifi, Tana River, Lamu). Ideally, only drought-tolerant crops should be grown in this system, but due to subsistence requirements the main food crops are still maize and beans. Other crops are pigeonpeas, cowpeas, sorghum and millet. Livestock are an important component.

Constraints to crop production are moisture limitations and little use of manure or fertilizers which results in poor soil fertility. Serious degradation of grazing land due to overstocking and poor land management is common throughout these areas. There is also a shortage of poles and timber. It can be noted that in Kwale and Kilifi Districts child mortality is high and nutritional status is among the poorest in Kenya.

Agroforestry considerations: Improvement of soil fertility is much needed, and trees and shrubs could play a role if combined with water harvesting. But consideration must be given to the risk of moisture competition with crops. Planting of more fodder trees, the establishment of fodderlots and better management of grazing areas would increase fodder availability, which would benefit both livestock and crop production (through draught animals being in better condition). Woodlots could be established mainly for production of poles, and more fruit trees could improve nutrition. The species that are suitable for this area are the same as for the cereal-grain-legume system.

The cashew-coconut system

The cashew-coconut system is found along the coast. This system has a low cropping intensity and low levels of management. Coconut, cashew and mango are the main cash crops. Some farmers in Lamu District grow cotton. The main food crops are maize, cassava and cowpeas.

Constraints are related to increased population pressure due to an influx of people from the hinterland. Shifting cultivation is practised but fallow periods are too short Intensification of land use is to some extent hindered by the tenure situation which is characterized by absentee landlords. Crop yields are low not only because of low soil fertility but also due to weed competition and a high incidence of pests and diseases. A poorly developed livestock component is the result of tsetse infestation, and shortage of wood products is another constraint

Agroforestry considerations: Improvement of soil fertility and reduction of weed populations can be achieved through hedgerow intercropping or trees dispersed in cropland. Due to high humidity, moisture competition is not a major problem. Other viable options are intensified growing of trees for shade and fruit around homesteads and woodlots for pole production. In some places more trees are needed to act as windbreaks, and where tenure is secure timber production could also be intensified. Growing of tree products for sale also has a good potential. Some suitable species are *Leucaena leucocephala, Gliricidia sepium, Casuarina equisetifolia, Conocarpus lancifolius, Moringa oleifera, Azadirachta indica, Sesbania grandiflora, Prosopis* spp., *Acacia* spp., *Parkinsonia aculeata, Ziziphus* spp., *Ximenia americana, Cocos nucifera* (coconut), *Anacardium occidental* (cashew), *Citrus* spp., *Mangifera indica, Pithecellobium dulce,* and *Artocarpus heterophyllus* (jackfruit).

Group-ranching systems

Group-ranching systems are found in West Pokot, Elgeyo Marakwet, Baringo, Samburu, Narok and Kajiado areas of the Rift Valley Province. Livestock keeping in this system is still mainly for subsistence. User rights to grazing lands are communal, but in some parts group ranches are rapidly being sub-divided. The importance of crop production varies from one area to another, and livestock normally serve as a form of saving to cover for poor crop years. Trees for browse are an important source of fodder. In some areas, sub-divided ranch plots are sold to people from other areas who tend to be more oriented towards farming than the original inhabitants.

Constraints are erratic and insufficient rainfall resulting in inadequate soil moisture. The tenure situation constrains grazing management and production and results in land degradation and shortage of feed. The erratic and scarce rainfall and high termite populations are constraints to tree propagation.

Agroforestry considerations: Most important is protection of the existing vegetation, either individual useful trees or on preservation of trees in protected plots. Tree planting is possible, but obstacles are tenure, scarcity of water for seedling production and erratic rains during the planting season. Direct seeding can also be done but it carries the risk of failure in poor-rainfall years. Active planting or seeding of trees should normally focus on trees for fodder, shade or fruit. When the tenure changes from communal to private ownership the scope for active propagation of trees increases. Live fences then also become important. This area also has the highest potential for development of beekeeping in the country. Some suitable species are *Acacia* spp., *Azadirachta indica, Prosopis* spp., *Parkinsonia aculeata, Balanites aegyptiaca, Cordia sinensis, Piliostigma thonningii, Psidium guajava, Tamarindus indica, Ziziphus mauritiana, Phoenix dactylifera* and, where termites allow, *Eucalyptus camaldulensis, Casuarina equisetifolia* and *Grevillea robusta.*

The communal pastoral system

Communal pastoral systems occupy a major part of Kenya's land area: Turkana, Samburu, large areas in Eastern and North-Eastern Provinces and the interior of Coast Province. Production is for subsistence and the infrastructure is very poorly developed. Communal user rights extend over large areas. Water is the most limiting factor.

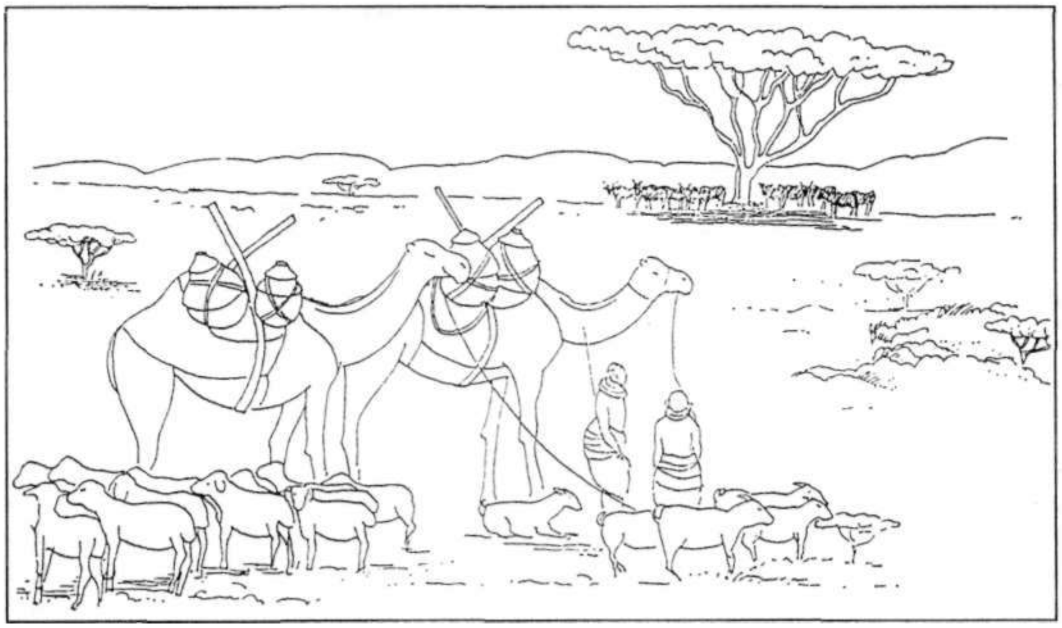


Figure 3.2 The communal pastoral system

Apart from the lack of water, *constraints* are fodder shortage and land degradation, especially near water points and around towns. Possible range-management measures are hampered by the tenure system and overstocking:

social and environmental conditions are such that these factors are not easy to change quickly.

Agroforestry considerations: Good management of existing vegetation in grazing areas and near rivers is essential since active tree propagation is difficult. Along rivers and close to bomas, individual trees for fodder, fruit or shade may be planted or protected for young livestock, or milking herds. Fruit trees can be grown in irrigated areas and nitrogen-fixing trees can also play a role in increasing soil fertility in irrigation schemes. A shortage of wood that may occur near irrigation schemes can be alleviated by growing trees such as *Prosopis* spp. or *Leucaena leucocephala,* but with due consideration to the risk that they might become weeds. This tendency can be controlled to some extent by intensive management Some suitable species are *Acacia* spp., *Prosopis* spp., *Balanites* spp., *Cordia sinensis, Cordeauxia edulis* (ye-eb), *Conocarpus lancifolius, Dalbergia melanoxylon, Lawsonia inermis, Tamarindus indica, Azadirachta indica, Phoenix dactylifera,* and *Hyphaene compressa.*

Other observations

The areas where small-scale farmers were resettled after the mid-1960s pose special problems regardless of the agro-ecological zones in which they occur. In the higher potential areas, settlements were based on the former large-scale foreign-owned farms which, for reasons dealt with in Chapter 2, had their tree cover removed or confined to certain areas. The incoming farmers found themselves in areas that had very few trees.

People migrating into previous ranching areas initially found themselves in a different situation compared to those moving into large-scale farming areas. Their first need was to open up land for cultivation. Later, the need for tree products and services arose. In both situations, the in-coming settlers would, in most cases, have migrated from high-potential areas where tree planting is a common practice. It does not, therefore, require a lot of effort to convince these farmers of the need to plant trees. In most cases, they have already started doing this and the woody biomass is on the increase. The problem is, however, similar to that encountered with agricultural crops in that people tend to grow what they were used to growing in the areas from which they migrated regardless of the suitability of such crops for the new sites. Similarly, various tree species may be planted in the wrong environment partly because of lack, of information on suitable alternatives.

4. THE ROLE OF TREES IN LAND USE

4.1 Products and services derived from agroforestry systems

Agroforestry practices contribute a wide range of products and services. Trees may provide food, shelter, energy, medicine, cash income, raw materials for crafts, fodder and forage and resources to meet social obligations. Trees used in agroforestry systems can also provide a variety of services such as being a form of saving and investment and contributing to the improvement of soil fertility for crop production. These products and services can be summarized as follows:

Food

- Increased amounts of food
- A year-round supply of food
- Better-quality food

Energy

- Increased fuelwood supply
- Better-quality fuelwood
- Cheaper and more convenient fuelwood sources

Shelter, structures

- Building materials
- Shade
- Protection from wind
- Protection from animals
- Marking of boundaries

Medicine

- Preventive (to maintain health)
- Curative (to treat diseases or injuries)
- Veterinary medicine

Raw materials for craft and cottage industry

- An increased supply of materials
- New types of material

Section 4.1 is based on Rocheleau, 1988, pp. 32-33.

Cash income, savings and investment

- Employment (cash earnings)
- Sale of products (cash earnings)
- Substitution of own products for purchased items (less cash spent)
- Exchange of products for other goods (less cash spent)
- New forms of saving and investment
- Greater profitability or security of existing savings and investment

Fodder and forage

- Primary feed
- Supplementary feed

Resources to meet social obligations

- New or improved source of support for social obligations

Conservation of soil water and plant resources

- Increased amounts of water for plant growth, domestic use and livestock.
- Improved seasonal availability of water
- Improved amount, quality or timing of water delivery to dams and large-scale waterworks
- Protection of soil from erosion and loss of nutrients
- Restoration of degraded soils
- Improvement of soil moisture and fertility
- Maintenance or increase in species and habitat diversity
- Substitution of farm tree products for over-use of woodlands for fuel and other items
- Improved conditions for natural regeneration of most desirable species

In the following sections some of the roles trees can play in land-use systems will be discussed in more detail.

4.2 Food and nutrition

Traditional African agriculture was designed in such a way that the various systems offered a variety of food, although mostly with a low output per unit area of land. Fallow lands, savannah grasslands and forests offered a further variety of fruits and other edible products. Children used to eat these naturally occurring fruit, nuts, etc., while they were herding cattle, but nowadays they depend almost entirely on food from the home. This variety of indigenous fruits, many of which were children's favourites, are no longer readily available to children or adults.

Some of the information in Section 4.2 is based on *Forestry and Nutrition: A Reference Manual,* FAO, 1989.

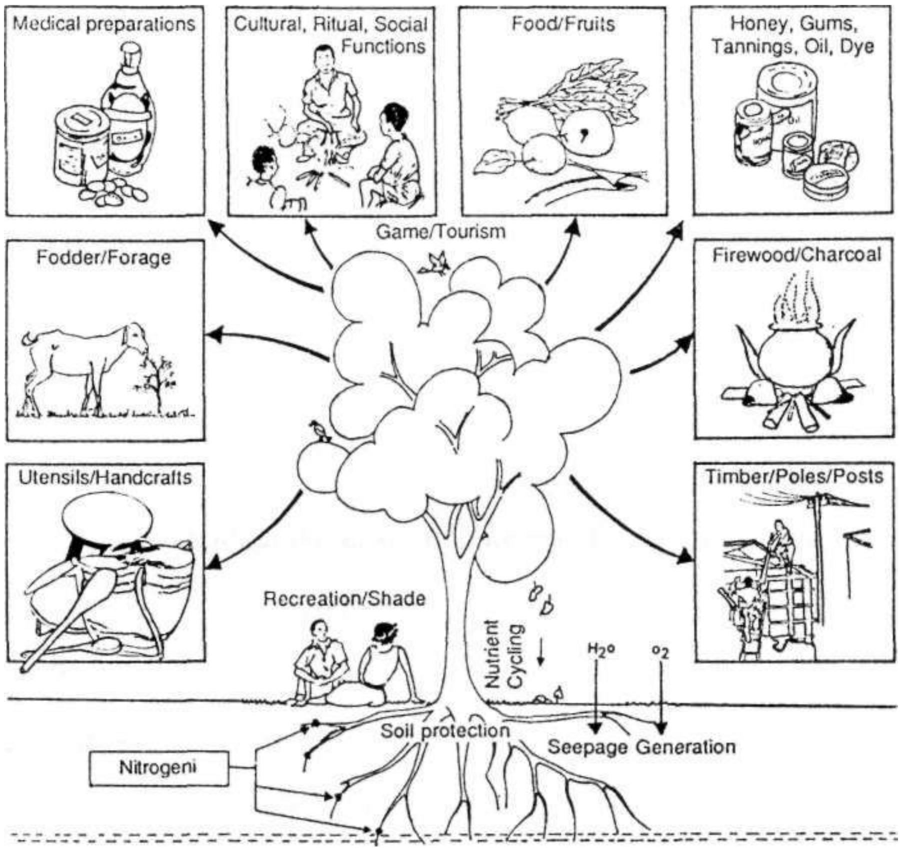


Figure 4.1 Trees provide many products and services

Although undoubtedly malnutrition did exist under traditional agricultural systems, the nutritional benefits that resulted from the availability of a wide variety of trees and crops have been lost in modern times.

This negative impact of "development" has to some extent been compensated for by the introduction of exotic fruits, but there is still a need to give more emphasis to the nutritional aspects in agroforestry extension.

Malnutrition

The main nutritional problems can be summarized as follows:

Low energy and protein intake

People do not eat *enough* food of all kinds. In many areas food shortages are seasonal, being most severe at the end of the dry season and at the beginning of the rains. With the exception of oil-rich seeds and fruit, food from trees can do relatively little to address the energy needs of rural populations on a large scale. A possible exception is the avocado which is high in fat and micronutrients and apart from being eaten as a fruit can be used as a substitute for margarine on bread.

Lack of variety in the diet

A varied diet is likely to be a well-balanced one. More important, the use of different foods, even in small quantities, improves the flavour of the staple food and thus tends to increase the overall consumption of the staple foods *(Forestry and Nutrition,* FAO, 1989). Dietary deficiencies and food insecurity are strongly related to the decreasing diversity of traditional diets.

Lack of vitamin A

Low levels of vitamin A can lead to partial or complete blindness, and children who lack, vitamin A are more likely than healthy children to die from infectious diseases. Yellow fruit and vegetables, as well as dark green leaves, are good sources of this vitamin. Fats, protein and zinc help the body to absorb and use vitamin A, thus a diet low in these nutrients can contribute to vitamin A deficiency. Nuts and oil seeds, in addition to fruit and vegetables, help to meet this nutritional shortfall.

Low levels of riboflavin (vitamin B)

Riboflavin deficiency is another nutrient-related problem which is responsible for eye and skin disorders. Many tree foods, especially leaves, are good sources of this vitamin, and wild leafy vegetables have sometimes been found to have significantly higher riboflavin contents than cultivated varieties. This deficiency is not usually a significant health problem in Kenya.

Iron and iodine deficiency

Iron is essential for the manufacture of haemoglobin. Low levels of iron intake lead to anaemia which is a major health problem in many parts of eastern Africa. Many forest foods supply iron.

In some areas in the region soils are deficient in iodine and therefore the diet is also deficient in this mineral. Iodine deficiency can cause serious disease. The deficiency can be prevented by importation of foodstuffs grown in areas where there is no iodine deficiency and by iodization of salt supplies.

In addition, supplies of medicine and energy are of course important for the health and general well-being of the people, and these factors are discussed in Sections 4.3 and 4.5 in this manual. The service functions that trees can have in sustaining agricultural and livestock production are discussed in Sections 4.4 and 4.8-4.10.

Edible parts of trees

Wild leaves, either fresh or dried, frequently accompany staple grain dishes. They add flavour, minerals and vitamins to the staples. Some leaves also have a high protein content. Seeds and nuts are also used in side dishes and sauces. Fruits are a seasonal food supply and are often eaten as snack food. In some cases, fruit may provide a very substantial part of the diet, e.g. coconuts. Roots and tubers provide energy, carbohydrates and minerals. They are especially valuable dry-season and famine-period foods. Some may be eaten raw as snacks, while others require complicated processing and thus are only used in times of food scarcity. Some Acacia species yield edible gum, and the sap from other trees is used in various ways. The bark of some trees can also be eaten. All these types of food provide essential elements in the human diet.

Case Report No. 1: Nutritious trees

The National Museums of Kenya are implementing an Indigenous Food Plants Programme (IFPP) which aims at widening and documenting current knowledge on indigenous food plants. Mr Patrick. Maundu, a botanist working with the Programme, has compiled the following examples of indigenous trees and shrubs with edible parts that are rich in vitamins, minerals, energy, protein or fat:

Vitamin A: *Vangueria infausta, Vangueria madagascariensis, Grewia* spp., *Mangifera indica, Carica papaya.*

Vitamin B (Riboflavin): *Adansonia digitata* (fruit pulp and seed), *Balanites aegyptiaca* (kernel), *Cajanus cajan.*

Vitamin C: *Adansonia digitata, Berchemia discolor, Grewia tembensis, Sclerocarya birrea* (fruit), *Ximenia americana.*

Iron: *Berchemia discolor, Greivia tembensis, Grewia bicolor.*

Phosphorus: *Adansonia digitata, Cordia sinensis, Berchemia discolor, Tamarindus indica* (fruit pulp), *Salvadora persica, Sclerocarya birrea* (nut).

Calcium: *Adansonia digitata, Grewia* spp., *Salvadora persica.*

Energy: *Tamarindus indica, Adansonia digitata* (pulp and seed), *Persea americana, Greivia* spp., *Vangueria* spp., *Cocos nucifera, Azanza garckeana, Balanites aegyptiaca, Sclerocarya birrea, Ximenia americana, Vitex doniana, Vitex payos.*

Protein: *Adansonia digitata, Balanites aegyptiaca, Carissa edulis, Grewia bicolor, Cordia sinensis, Salvadora persica* (if the whole fruit including the seed is eaten)

Fat: *Balanites aegyptiaca* (kernel), *Sclerocarya birrea, Hyphaene compressa* (kernel), *Persea americana, Cocos nucifera.*

Figure 4.2 Fruit and leaves of the baobab, Adansonia digitata

The role of food from frees in fhe diet

Food from trees makes supplemental, seasonal and emergency contributions to household food supplies.

Supplements to the staple food add taste which enhances the appetite. Some foods increase the absorption of vitamins, e.g. gum arabic (from *Acacia Senegal)* increases the intensity of vitamin synthesis and may help maintain the normal intestinal flora.

Perhaps the most common use of food from trees is as snacks. Traditionally, people ate fruit between meals while herding cattle or working in the fields. Snack foods are especially important for children since they need to eat more often than adults. In addition, these wild fruit may supply micronutrients that are very important for the healthy growth of children but that may be deficient in the cereal-based diet in the home.

Trees and forests can provide crucially important food and fodder during hunger periods, and such foods may often be more important during periods when people have less time for food preparation such as during the peak agricultural seasons. This use of tree foods is especially important in arid regions where seasonal food-supply fluctuations may be acute.

Traditionally, food from trees provided a buffer during emergency periods, especially during drought, famines and wars. Trees provide food for consumption as well as products that can be gathered and sold. These foods are characteristically energy rich, but may require complicated processing. Food aid, transport of food and increased commercialization have diminished the importance of the emergency role of such foods in some areas. In addition, the decline of forest resources has led to a decline in availability of these emergency foods as well as in knowledge about them.

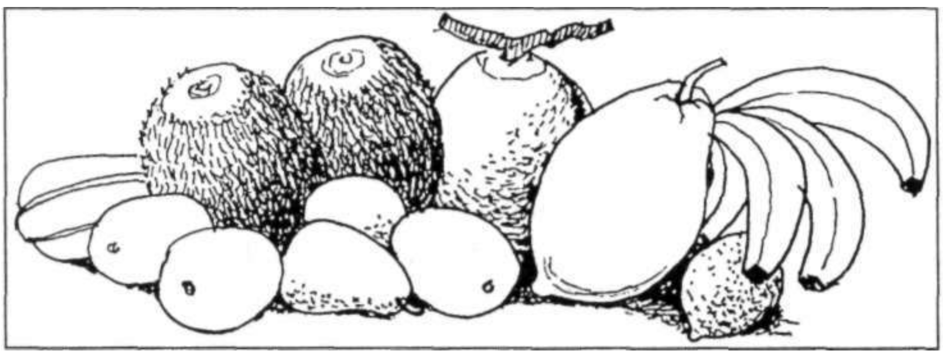


Figure 4.3 A variety of nutritious fruits

Case Report No. 2. Trees for food in a semi-arid area of Turkana

Mr Adekei Louwoto is the leader of **a** group of more than 500 people in Turkwell Division, Turkana District. The group are cultivating crops on an area of approximately 40 hectares and also using an unlimited area for grazing. Mr Louwoto reports that the people of the area know a wide variety of trees that can be used as food. Some fruits that are eaten raw as snacks both by adults and children are (Turkana names in parentheses):
Salvador a persica (esokoni)
Cordia sinensis (edome)
Hyphaene compressa (eengol)
Dobera glabra (edapal)
Boscia coriacea (edung)
Tamarindus indica (epederu)
Zizyphus mauritiana (ekalale)
Balanites pedicellaris (elamash)
Acacia Senegal (ekunoit)
Acacia nubica (epetet)
Balanites orbicularis (ebei)
Maerua subcordata (eerut)
Grewia tenax (eng'omo)
Grewia bicolor (epat)
Ficus sp. *(echoke)*

There are many more; they cannot all be listed.

Numerous species produce fruits that can be cooked and used for food:
Balanites pedicellaris (elamash)
Boscia coriacea (edung)
Dobera glabra (edapal)
Balanites aegyptiaca (ebeyi)
Maerua subcordata (eerut)
Zizyphus mauritiana (ekalale)
Acacia tortilis (exvoi)

Trees that are particularly important during periods of drought include:
Hyphaene compressa (eengol)
Boscia coriacea (edung)
Dobera glabra (edapal)
Cordia sinensis (edome)
Maerua subcordata (eerut)
Balanites pedicellaris (elamach)
Zizyphus mauritiana (ekalale)
Grewia bicolor (epat)

Many of these tree species have uses other than as food. Trees are harvested for these other uses in such a way that they are not killed.

Agroforestry extension and research in relation to nutrition

Figure 4.4 Fruit trees in the school compound can improve children's nutrition

Extension efforts aimed at maintaining a wide range of species accessible to people can go a long way in improving nutrition. Children often have long school days with little to eat, and a rich flora of trees providing a variety of snack food in the school compound could contribute much to improving their health.

Trees that provide edible parts ought to be left standing whenever possible, and there is scope for planting more of these trees, both exotic and indigenous, in homesteads, along boundaries and in places less suitable for agriculture. We should promote fruit trees of different species so that there will be some fruit to eat all the year round.

So far little or no research has been done on improving indigenous fruit trees. There would be scope for the development of larger and better-tasting varieties of many of them in the same way that the common domesticated fruits were developed. A necessary precondition for such work, is that the genetic resources be preserved.

Case Report No. 3: Fruit production in a high-potential area

Mr and Mrs Kabaiko are more than 80 years old but still hard working. They have 12 children, six girls and six boys, all married. The two have worked together to establish about six hectares of avocados, pears, plums and peaches in Lari Division of Kiambu District. Originally they came from Githunguri Division, also in Kiambu. Mr Kabaiko and his wife established the orchard mainly for commercial purposes, but he advises all farmers to plant fruit trees at least on a small scale because children like the fruits very much. Fruit trees can be planted along boundaries, in homesteads or along soil-conservation structures. In many areas temperate fruits are not grown, although they could do well. Mr Kabaiko feels that many farmers have not been active enough in growing fruit trees.

Case Report No. **4:** Trees for food **in a semi-arid area of West Pokot**

Ptokou Group Ranch covers an area of 120 hectares in Sigor Division, West Pokot District. Mr Logeding'ole is the leader of the group and he cultivates **a** 1-hectare plot within the ranch. The population of the area is high and the people farm as well as rear livestock. Mr Logeding'ole reports that the Pokot are also much dependent on trees for their nutritional well-being. There are numerous fruit trees that are important to both children and adults (Pokot names in parentheses):

Tamarindus indica (axon)
Ziziphus mauritiana (tilomo; important during dry seasons)
Acacia sp. *(tingrvo)*
Berchemia discolor (muchukwa)
Grewia bicolor (sitet)
Ficus sycomorus (mokongivo)
Mimusops fruticosa (mugau).

The gum from another local tree known as *panyer* is eaten, and the leaves of *Balanites aegyptiaca* are important for relish. There are also some important fruits that can be used for food after some preparation:

Dobera glabra (krasion)
Balanites orbicularis (lomnyon)
Maerua subcordata (chebliswo)

Another farmer in West Pokot, Mr Lokodo of Chepareria Division, has carefully protected indigenous trees that have edible fruit. He now has more than 10 such species on his plot. According to Mr Lokodo, *Balanites aegyptiaca* is a useful fodder tree with fruits that can be eaten raw or cooked. Its very tender leaves are also good as a vegetable. Goats and cattle like the leaves and fruits of the tree, and when the seeds pass through the animals they will automatically have been pre-treated and germinate easily. Hence Balanites is common near settlements. The people living in semi-arid areas depend on wild fruits when they are herding cattle. Some of the fruits can be dried and stored for a long time, in some cases up to three years. Others are ground and mixed with milk or blood and stored in calabashes for future use as emergency food. Other trees bear fruit during drought and provide fresh fruit for the pastoralist, e.g. *Ficus sycomorus.* Mr Lokodo laments only one thing: most of these trees bear fruit when there is a lot of other food available and only a few come into fruit during the dry season.

4.3 Wood fuel and efforts to reduce consumption

In the early 1980s the importance of wood, charcoal and crop residues for energy supply in Kenya became fully recognized. The Beijer Institute study mentioned earlier (O'Keefe *et al*, 1984) concluded that as much as three quarters of the country's energy requirements were met by biomass. The energy needs of the rural people are almost entirely met from these sources. Among the conclusions of the study were that agroforestry practices have more potential for alleviating the shortage of fuel than any other form of tree and forest management. One important advantage of agroforestry in this respect is that the wood production happens where people live. Another conclusion was that there is a need to encourage people to use improved stoves in order to reduce consumption of wood. Considerable work, has been done since then both on supporting increased production of biomass and on reducing consumption of fuelwood, and, as has already been mentioned, there are signs that these efforts are beginning to bear fruit.

Case Report No. 5: Food from coconuts

Mr Stephen Safari is a farmer in Utange, Mombasa District. Stephen and his wife have six sons and two daughters. The family has three pieces of land, 2 ha at Utange where they live, and two other bits, of 4.8 ha and 1.6 ha respectively, in Kaloleni. All three pieces are registered and Mr Safari has the title deeds.

Mr Safari grows coconut, maize, mangoes and some cucumber. He also keeps cattle and goats. On the Utange farm Mr Safari grows mangoes, pawpaws, coconut, and cashewnuts in a random mixture. The 4.8 ha piece of land at Kaloleni is under coconut. A hired labourer who taps palm wine and harvests immature fruits *(madafu)* for sale is stationed on the farm.

Coconut is a tree whose parts are all useful. The stem can be sawn into timber, and farmers also split the stem to get roof purlins. If treated with engine oil the stem can be used for fence posts. The fronds (leaves) are used for making thatch material *(makuti)* and also as firewood. The immature flower-bearing shoot makes good firewood, while the leaf covering the flower shoot is made into toy boats for sale to tourists as well as for roofing tiles. The immature flower shoot is cut and palm wine tapped.

It is the fruit that has the most uses, however. The coir is used as filler material in oratresses and chairs and also as a medium for growing tree cuttings. Oil is extracted from the copra and the coconut shell is used in the carving industry to make hair clips and other products. The fibrous net-like covering is used to make table mats. The *madafu* are harvested for the liquid contents which make a cool refreshing drink.

The mature nuts are very important in the local cuisine. The white flesh inside the shell is grated and the "milk" squeezed out. Mr Safari says that the coastal people use this coconut milk in almost every dish except *ugali* (stiff maize-flour porridge) and *uji* (thin porridge). In the morning breakfast will often consist of pigeonpeas and *maandazi* (doughnuts), both of which are prepared with coconut milk. A large family requires one coconut for this purpose. At lunch time, rice is cooked in coconut milk and another coconut is needed for a family for that purpose. In the evening, the *mboga* (the relish, whether vegetable, fish or meat) to be eaten with the staple *ugali* is also cooked with coconut milk and half a nut is then needed. On average, two to three nuts are required each day by a family of five. Thus, over a whole year a family will require 750-1,000 nuts. This requirement will be met if a family can harvest the production from about 20 coconut trees for subsistence only.

The importance of a good supply of fuel

The vast majority of rural households in Kenya depend on wood or farm residues as fuel for cooking and heating. Fuelwood collection in rural Kenya is women's work. The majority of rural women are already overworked and the further away the source of fuel the greater their workload becomes. As a result women have less time and energy to spend on other activities such as caring for children or engaging in income-generating activities. This will have a direct impact on the family's nutrition as food supply at the household level is often strongly linked with the woman's income. The dwindling supply of food from wild trees will also have a negative effect on family nutrition and particularly that of children.

Fuelwood scarcity may influence both the amount of food cooked and its type. Women may be forced to choose foods that do not require a long time to cook although they may not be the best from the nutritional point of view. Collection of fuelwood from common land may also be a factor contributing to degradation of the vegetation in such areas, although it is not usually the most important factor.

Figure 4.5 A rural woman bent under a heavy load of fuelwood

Although, for all these reasons, a good supply of fuelwood is extremely important for rural households, extension efforts have shown that farmers are rarely interested in planting trees if the only objective is to produce fuelwood. Fuelwood is often regarded as a by-product, and if extension is to be successful the needs and priorities of the farm family must be the basis for the intervention that is suggested. It should be noted that if the household head is a man, the needs of women and children may not always be addressed. Therefore, it is important to involve the whole family in discussions about tree growing.

Most tree species can be used for fuel, but the quality may vary greatly. Some species burn very fast and have a low calorific value. Other species may produce a lot of irritating smoke or be very difficult to dry sufficiently well. Most appreciated for cooking are those species that have a heavy wood that burns slowly with a lot of heat and little smoke. A wood that is easy to light is preferred for lighting the fire and charcoal should be made from species that yield charcoal which produces a lot of heat. Some species burn even if they are not dried first, and though the convenience of this may be appreciated use of wet or moist fuelwood is always inefficient and should be discouraged.

There are many possibilities for growing trees on farms to meet fuelwood needs. Specific recommendations should be developed together with the people of the localities concerned.

Case Report No. 6: Fuelwood production from Grevillea planted along boundaries

Eliphas Karuguti is a farmer in Mufu Sublocation, Runyenjes Division, Embu District. He lives on his farm with his wife and seven children, five of whom are currently at school. His farm is 500 m from the Embu-Meru road. On the 2-hectare farm, Mr Karuguti has 700 coffee bushes, maize, beans, bananas and potatoes.

In 1961 he planted Grevillea trees along the entire boundary of the farm. The trees are now large and he pollards them regularly to reduce shade on the crops and to harvest fuel, building poles, *fito*[1] for fencing and banana props. All these products can be harvested from the pollarded branches and meanwhile the boles are growing and will eventually provide timber. The family is self-sufficient in fuel from the Grevillea trees.

Efforts to reduce consumption of wood for fuel

Metal charcoal-burning stoves have featured in urban Kenyan kitchens ever since they were introduced by the Indian railway builders at the turn of the century. In rural areas, the traditional open three-stone fire is still common. During the last two decades much effort has been devoted to developing and disseminating improved types of fuel-saving stove as well as practices that reduce consumption of woodfuel.

Case Report No. 7: Fuelwood production from *Sesbania* *sesban*

In Nambale Division of Busia District, Julius Lukoye has a 9.5 ha farm. There are 11 people in the family. The farm is well planned and terraced. On the terraces, Mr Lukoye has planted *Sesbania sesban* with a spacing of about 10 m. He normally uses wildings to establish the Sesbania trees.

The family gets its supply of fuelwood from the trees. According to Mrs Lukoye, the fuelwood from Sesbania is good. It dries quickly after being cut and burns without a lot of smoke. In addition to producing fuelwood, the Sesbania trees also improve the soil. According to the local customs, women can plant or cut the tree in consultation with men.

Thin poles often used in roof construction.

Case Report No. 8: Woodlots of *Acacia mearnsii*

David Maina, a farmer in Sergoit Location, Moiben Division, Uasin Gishu District, has chosen to establish a woodlot of *Acacia mearnsii.* His 8 ha farm is located next to the Eldoret-Iten road before Chepkanga shopping centre. In this area there are no off-farm sources of trees and the only other source of fuelwood is a sawmill 2 km away. The quarter hectare woodlot established by Mr Maina and his two wives is now three years old and the trees are already 5 m high. The main aims of the woodlot are to solve the fuel shortage and to produce wood for farm construction (e.g. *boma* (livestock enclosures), fences, etc.).

Mr Maina has selected a site which has mufram soil and therefore is poor for crop production. The site is conveniently near the home compound with regard to transport of the fuelwood and wood for construction. There are plans to extend the woodlot up to a hectare.

A large-scale farmer in Uasin Gishu, Mr Gitau of Lenges Location, Central Division, has a woodlot of *Acacia mearnsii* covering 4 ha. This woodlot was established mainly for commercial purposes such as production of bark for tannin and poles for direct sale, or for charcoal production. When the trees mature at seven years, the area is clear felled, the bark is peeled off and the wood is used for making charcoal. Normally the task of clear felling is contracted out, the owner paying the contractor Sh 1 per bale of wattle bark and Sh 14 per bag of charcoal.

Case Report No. 9: Kenya Woodfuel and Agroforestry Project (KWAP)

As a follow-up to the energy study conducted by the Beijer Institute, several projects were started under the auspices of the Ministry of Energy and Regional Development. One of these was the Kenya Woodfuel Development Project (KWDP), later renamed KWAP. Initially, projects were carried out in Kakamega and Kisii Districts, but later also in Uasin Gishu, Kericho and Busia. Both in Kisii and Kakamega cultural surveys were carried out. The surveys found important gender-related issues that can affect tree planting by households. These issues hinge on tree tenure within the household, taboos against women planting trees and division of labour within the family.

Tree tenure is complicated by several issues. Usually the man owns the land and everything on it. Any decision to plant or harvest a tree must be made by him, and the women cannot carry out such work without consulting him. There may be exceptions for certain tree species which are of little commercial interest, e.g. Sesbania.

The division of labour within the family is another issue that can seriously hamper tree growing. Tree growing is a man's affair. The man makes decisions on which trees are to be planted, where they will be planted and when they will be harvested. Men mostly prefer trees for timber or poles which can eventually bring in cash. The collection of firewood and water and cooking are the woman's domain but unfortunately she has little say in resource allocation with regard to trees on the farm.

Cathrine Wituka of KWAP says that the husband and wife who head a household have to come to talking terms on these issues. The KWAP project has tried to involve both men and women by using the "mirror" technique (making people see themselves by watching and hearing role plays, films, etc.).

Figure 4.6 *The traditional three-stone fire with use of wet wood*

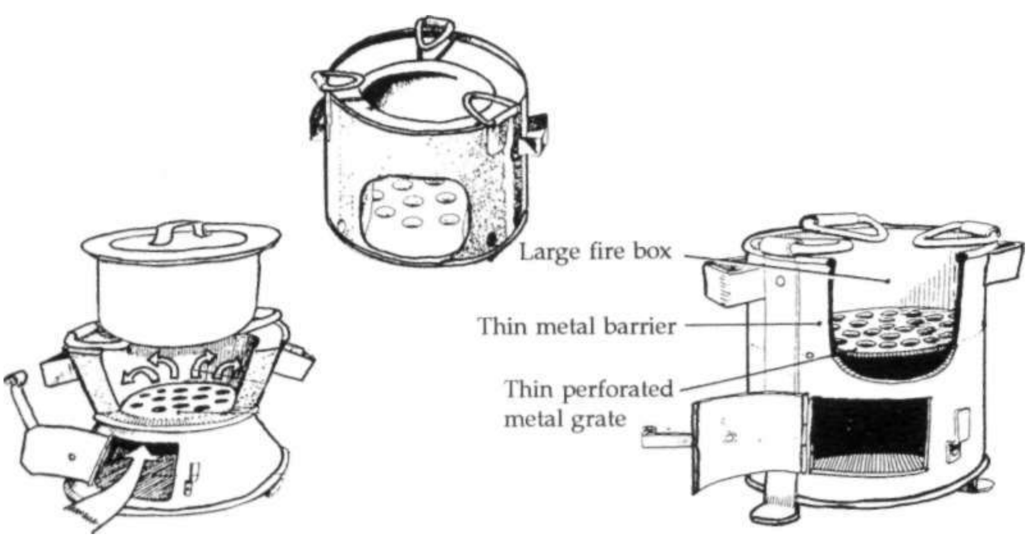


Figure 4.7 *Different types of improved stove*

Conservation practices include soaking food, cutting it up into small pieces, covering cooking utensils with tight-fitting lids, use of dry fuelwood, simmering food instead of boiling it strongly, and use of a good type of stove, possibly complemented by one or more "fireless cookers".

Use of a lid prevents energy loss to the air, so cooking is completed in a shorter time if utensils are closely covered. The efficency of the lid is greatest if it is tight fitting and a stone is put on top of it. Dry wood always burns better, and less will be required than if wet wood is used. With dry wood the kitchen will also be less smoky and more comfortable. A smaller fire is required to simmer food than if the water is kept boiling strongly. Soaking food as well as cutting it into small pieces will reduce the cooking time required and thus also the amount of fuelwood required.

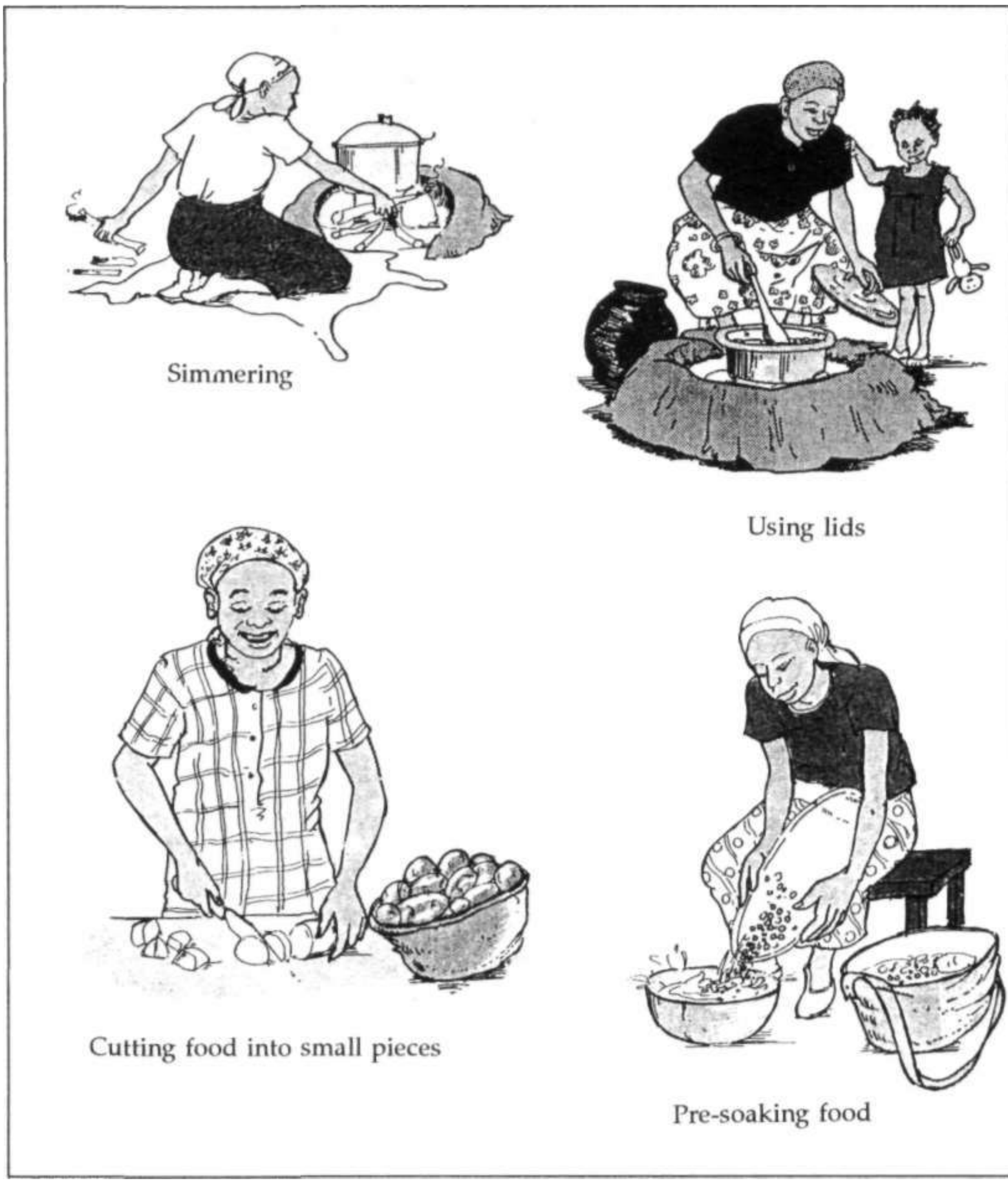


Figure 4.8 The three-stone fire can be made a lot more efficient using dry wood and good cooking methods

The Kenya ceramic *jiko*[1] has been widely accepted in urban areas. The stove was developed as the result of collaboration between many institutions and with the involvement of local artisans who now manufacture it. It has been estimated that the Kenya ceramic *jiko* reduces charcoal consumption by 30-50 % and that the cost of the stove is completely recovered within a few months. No wonder that this model of stove has become popular: it has been estimated that more than 10,000 are produced every month in Nairobi.

Improved stoves have also been designed for households using fuelwood. The "Kuni Mbili" or the "Maendeleo Stove" is based on the same principles as the Kenya ceramic *jiko* but has a larger firebox designed to facilitate the combustion of wood. The Kuni Mbili stove has been field tested in various Districts but is still not widely used.

"Fireless cooking" has been introduced to the Ministry of Agriculture through the Bellerive Foundation. This method is now being disseminated through the Home Economics Officers of the Ministry. Using this technique, food is brought to the boil or allowed to boil for a short while and then removed from the stove and put in a basket filled with insulating material. The heat is preserved in the basket and the food continues to cook until it is ready without the use of any additional energy.

Figure 4.9 The fireless cooker

[1] Traditional stove.

Case Report No. 10: Interview with a fuelwood saver

Mrs Felista Gicuku Nyaga was delighted to be interviewed on her efforts to save fuelwood. Felista lives in Mbeti North Location, Gachoka Division in Embu District. Her family consists of eight people.

She has been using a Maendeleo stove since 1990, and in 1992 she also bought fireless cookers. When she used to cook on an open three-stone fire, she used to need two ox-cart loads of fuelwood each week. After buying the Maendeleo stove her consumption was reduced to one ox-cart load per week, and after adding two fireless cookers she now needs only slightly more than one ox-cart load per month.

Mrs Nyaga bought the Maendeleo stove from the Home Economics staff at KSh 50, and they gave her instructions on how to use it. Felista, who is a member of Furaha Women's Group, has learnt from other members that, if well cared for, a stove can last for 5-7 years.The Home Economics staff also taught her how to make a fireless cooker. Felista describes the fireless cooker as a basket or a carton with insulating material stuffed into it to form a nest for a cooking pot. A cushion is used to cover the pot. Felista's cookers are made of baskets, one insulated with with dry banana leaves and the other one with grass.the fireless cookers cost her Sh 300 each.

With this equipment, Felista starts her cooking on the Maendeleo stove. Soft foods are just brought to the boil, and then she transfers the pot to the fireless cooker. Harder food is boiled for about 25 minutes before being transferred. Before transferring the covered cooking pot it is wrapped in a cotton cloth and then in polythene sheeting. Hard foods should also be soaked overnight before cooking, and other food may need to be chopped into smaller pieces to reduce cooking time. The food/water ratio is also important.

Felista reported the following advantages to these new methods of cooking:

- Much less than half the amount of fuelwood is required
- She has more time for other work since less time is needed both for fuelwood collection and for cooking
- There is less smoke in the kitchen since only a small amount of dry firewood is used
- Food does not get burnt
- No fire accidents occur since the fire is shielded by the Maendeleo stove
- The family can have hot food even when Felista is not at home through use of her baskets
- Tough meat is made tender in the fireless cooker
- The food tastes better as all the flavour is retained
- The stoves are cheap and easy to handle.

There are few if any disadvantages. However, if the Maendeleo stove is badly handled it can break, and the polythene sheet in the fireless cooker can get burnt when hot food is being transferred to the basket, e.g. if this task is left to a child. The polythene sheet is, however, optional.

Felista and the other members of her women's group are very pleased with their stoves. They can now obtain all the firewood they need from trees planted on their small pieces of land.

In 1984 a survey was carried out in several Kenyan institutions (boarding schools, hospitals, prisons, colleges, etc.) to establish the patterns of wood-energy use in their kitchens. The survey showed that these institutions depend largely on wood and charcoal for their cooking. Most institutions used inefficient cooking devices and had poorly designed kitchens (Kinyanjui, 1984). Since then, several organizations, notably KENGO and the Bellerive Foundation, have been involved in technology development and dissemination of improved stoves for institutions.

Case Report No. 11: Use of an improved institutional stove at Kubukubu Memorial Boarding School

Mrs P. Njeru is the Headmistress of Kubukubu Memorial Boarding School in Runyenjes Division, Embu District. The pupils at the school are served breakfast, 10 o'clock tea, lunch and Supper. To facilitate the cooking, the school currently has three institutional stoves. Two have a capacity of 200 litres each and were purchased by the school for Sh 18,000 in 1988. The third, which was bought in 1989 for Sh 10,000, has a capacity of 100 litres. The stoves were sold by the Bellerive Foundation, Embu, and the price included not only the stoves but also training of the cooks, transportation, installation and some future maintenance. Four cooks were trained, and they are now comfortably using the stoves.

Mr Njeru, one of the cooks, reports that nowadays they use 15 lorry loads of fuelwood annually compared with the 30 lorries that they had needed earlier. A lorry load of firewood costs Sh 2,000.

The Headmistress reported that firewood is purchased in bulk at the beginning of each year. The school owns a powersaw which is used to cut the wood into 8-inch lengths. The cooks then split the firewood into pieces about the size of a hand. This wood is then stacked in the fuelwood store to dry.

The Headmistress and the cook reported the following advantages of the new stoves:

- They keep the kitchen smokeless since there is a chimney
- The kitchen remains cool and comfortable to work in
- The food cooks quickly
- The stoves are built to a convenient height for stirring when food is being cooked
- The stoves save 50% on firewood
- There is no risk of scalding and burning and less risk of accidental fires
- The cooking is faster due to minimal heat loss since the stove gate can be locked
- The food is kept hot for a longer time after the fire has been extinguished.

Disavantages are:

- The chimney requires regular cleaning
- The grate occasionally needs replacement
- Labour is required for splitting the firewood.

Use of wet firewood at the school once resulted in the chimney being completely blocked, and the stoves could not be used until the chimney was cleaned.

Case Report No. 12: Tree growing at Murray Hill Secondary School

Murray Hill School in Taita Taveta District is an institution that is self-sufficient in fuelwood due to a sustained programme of tree planting within the school compound.

Initially the school used gas supplemented by old and inefficient wood stoves, but the supply of gas was erratic and the cost prohibitive. So in 1989 the school changed from these systems to the Bellerive cooking system.

In this area a lorry load of firewood costs over Sh 3,500, so the members of the school board decided to use trees grown in the school compound and also to construct a wood store. The school obtained seedlings from the Forest Department free of charge. Some of the largest trees are now being cut and used to supply the school kitchen and expenditure there has been reduced tremendously. Other trees which are suitable for timber are being pruned and the side branches cut, dried and prepared for firewood.

Another area that has received attention is the possible introduction of improved technologies for charcoal production. GTZ supported trials in this area under their Special Energy Programme carried out mainly in Machakos District. Out of the technologies tested, the so-called half-orange brick kilns were found to be the best type of kiln. The possibility of using coconut shells to make charcoal is also being looked into.

Figure 4.10 A typical charcoal farmer who makes charcoal during less labour-intensive periods

4.4 Trees for shelter and other structures

Construction

The need for timber and poles for construction purposes is one of the most common reasons for people to plant and grow trees in Kenya. Few indigenous tree species grow as straight as some of the exotics, and hence these exotic species have become very popular for building materials.

Eucalypts are commonly grown for poles since they are fast growing, straight, easily split and the wood is reasonably durable. In some areas, where the pressure on land is very high, farmers have, however, started to phase out the Eucalyptus since the trees are regarded as too competitive with crops. In such cases Grevillea is often found to be a good substitute. Grevillea has the advantage of not being very competitive and has timber that is well suited to sawing, hence it has more uses than Eucalyptus.

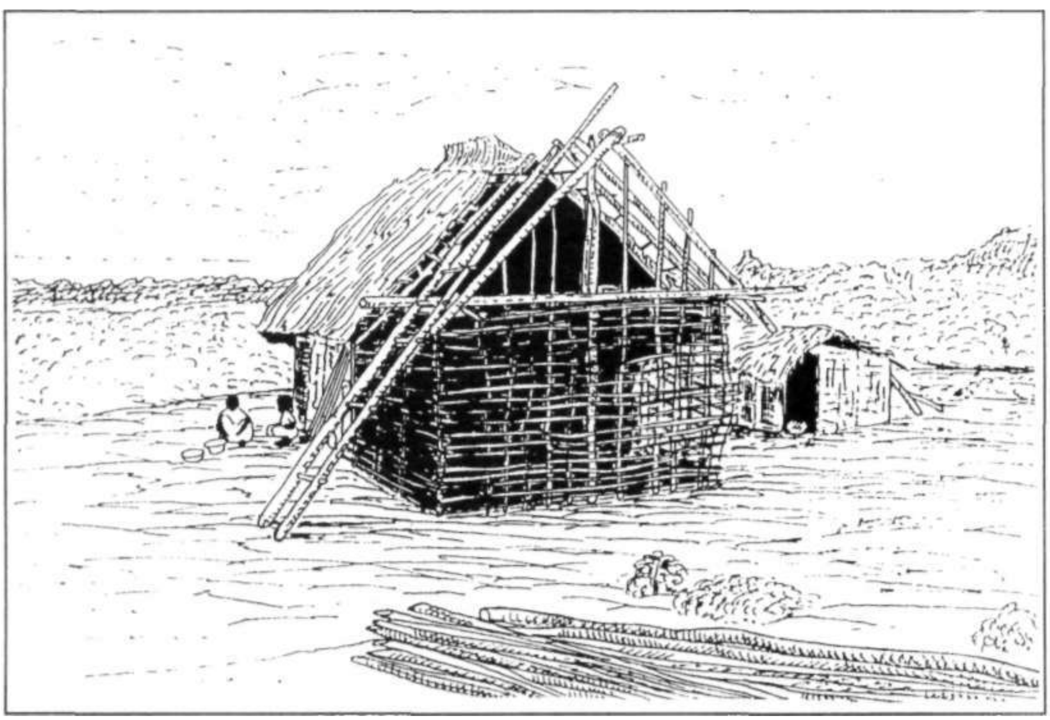


Figure 4.11 House construction

But with regard to resistance to decay and termite attack the best species are indigenous ones. Many indigenous trees produce wood that can last for many years without treatment with preservatives. Many exotic trees are also problematic in areas where termites are common. Seedlings of Eucalyptus and *Casuarina* spp. are very susceptible to termite attack, and Grevillea may also be attacked. In such areas it is still recommended to promote the use of indigenous trees for construction, but continuous efforts have to be made to ensure regeneration for a sustainable supply.

Figure 4.12 Pitsawyers at work

Case Report No. 13: Pole production from Markhamia

Mr Ogola Ooro lives on his farm in Boro Division of Siaya District. He has a large family: four wives and a total of 22 family members.

Mr Ooro values *Markhamia lutea* (called *siala* in Dholuo) highly and he has more than 50 Markhamia stools scattered in his cropland which he coppices for poles. The poles are mainly used within the farm for house construction. The wood is hard and resistant to termites and beetles. Occasionally, neighbours come to buy poles, but he does not sell them on a regular basis. The price per pole may be up to Sh 25.

Apart from poles, other useful products obtained from the Markhamia are:

- Wood for tool handles
- Wood for weaving and traditional chairs (the wood is easily bent to different shapes if heated)
- Wood for carving traditional three-legged stools
- Timber for doors
- Good-quality firewood that can be used immediately after cutting and burns with little smoke
- Leaves to wrap herbal medicine in.

According to Mr Ooro, Markhamia does not compete with crops but improves soil fertility.

Propagation of Markhamia is easy. One can either protect wildings that come up; or if they are not in the desired place they can be transplanted. Initially, transplanted seedlings will not grow as fast as undisturbed ones. In Mr Ooro's area the main flowering of Markhamia occurs in August, and most seeds mature in September-December. Markhamia can also grow from cuttings.

Case Report No. 14: Grevillea for timber production

Mr Muthike, his brother and his parents live on a 5 ha farm in Ngiriambu Sub-location, Gichugu Division of Kirinyaga District. The farm slopes gently towards a river.

Mr Muthike, who has been very active, has planted Grevillea along the boundary and in four rows along the contours across the farm. Along the river bank he has established permanent grass cover and a stand of Grevillea and Eucalyptus trees. The first Grevillea trees were planted in the 1970s and some of these are still standing.

Mr Muthike planted his trees for timber and firewood production. To obtain good timber, Mr Muthike says that the trees should be pollarded for the first time after eight years. If there is a pressing need for wood, they can be pollarded after five years, but not earlier. To improve the quality of the timber, side pruning should also be done. When side pruning, the branches should be cut near the main stem to reduce the occurrence of knots in the timber. The first side pruning should be done when the Grevillea trees are four years old, but then roughly 75% of the crown should be left.

When pollarding for the first time, an important consideration is where to cut the top off the tree. According to Mr Muthike the top is normally cut where either:

It becomes too thin,

- The tree produces two or more branches at the same height, or
- At a height that will yield acceptable lengths of timber.

Most timber trees will be ready for harvest after 20 years. The first good harvest of fuelwood is obtained with the first pollarding at eight years, and thereafter pollarding can be carried out every second year for good-quality fuelwood. If low-quality fuelwood is acceptable, pollarding can be done every year.

When selling trees for timber, the main factors that determine the price are:

- Length of stem that will give good lengths of timber
- The diameter of each log, and its uniformity
- Quality, as a result of how close to the stem and how timely the side pruning has been.

A tree with a diameter of 60 cm which can give three logs of 3.6 m, 3.6 m and 3.0 m may sell for Sh 200. Most of Mr Muthike's trees, however, sell for Sh 80-150, depending on the factors mentioned above.

The market for tree products is good. People come to look for trees for their sawmills, and people building houses also buy trees and call in pitsawyers to saw up the timber for them.

Shade

Trees provide shade, both for human beings and livestock. The shading characteristics of different tree species are very important in determining their suitability for different sites. In certain situations trees with a dense shade all the year round are desirable, e.g. in homesteads and at meeting places. In other situations a tree with less dense shade or a deciduous one might be preferable.

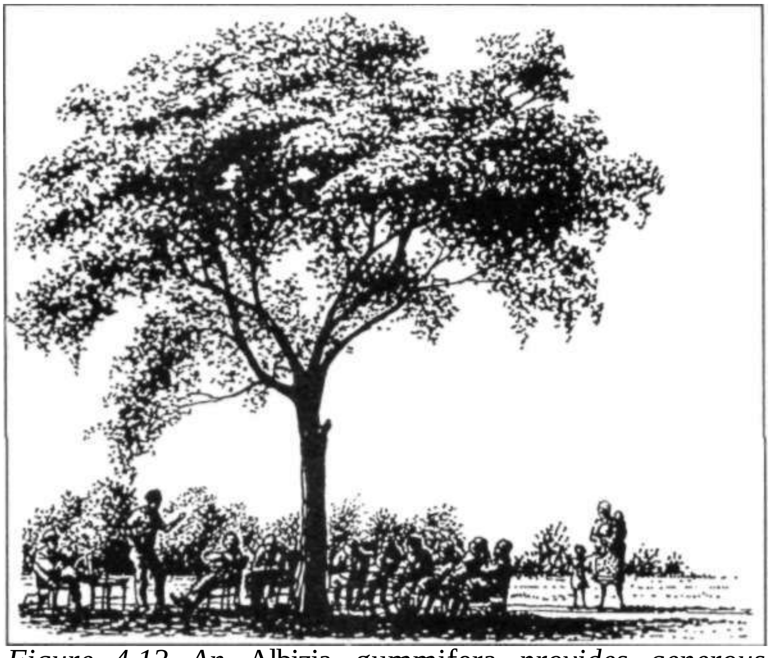


Figure 4.13 An Albizia gummifera *provides generous shade for a community meeting place*

Protection from wind

Strong winds can cause damage both to houses and crops. In a treeless landscape strong winds are often experienced, whereas an area with a lot of trees rarely has such problems. Trees around houses and schools are not only important for protection of buildings from strong winds, but they also improve the microclimate and add to the aesthetic beauty of the place.

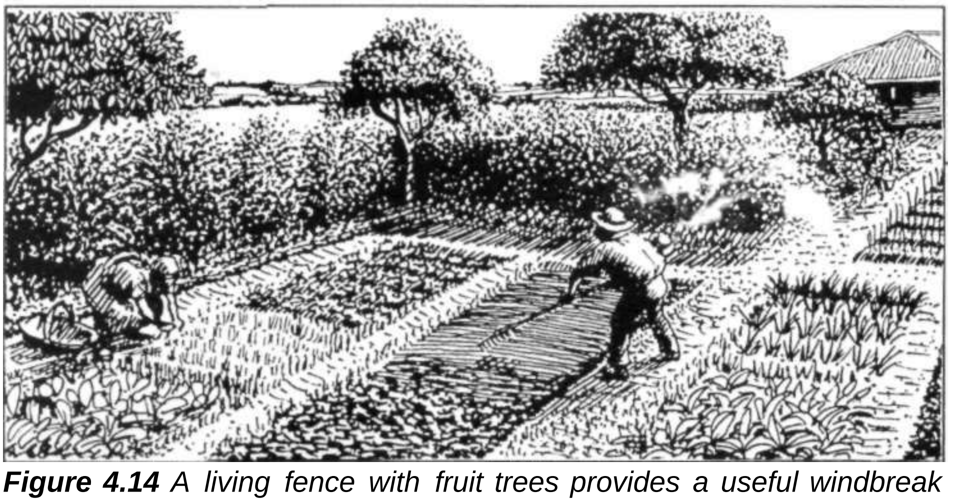


Figure 4.14 *A living fence with fruit trees provides a useful windbreak for a homegarden*

Protection from animals

Trees or shrubs planted as live fences can effectively restrict the movement of cattle and thus provide protection for homesteads and other places from which livestock need to be excluded. Such fences can also provide protection for animals, e.g. for chickens against birds of prey.

Figure 4.15 *Akamba farmers use a Commiphora hedge to provide a secure cattle enclosure*

Case Report No. 15: Hedges of *Croton* ***megalocarpus***

Croton megalocarpus is commonly used for hedges, especially in Kiambu. It is often established by direct sowing of the seeds. Some farmers pollard it to get firewood and use the leaves to ripen bananas. Others trim it to form a nice hedge. The pollarded stems sometimes also act as posts to support barbed-wire fences. Mature trees make very good charcoal and firewood that has a high calorific value.

Croton is often interplanted with other trees within a hedge. The most common ones are *Euphorbia tirucalli* and *Lantana camara.*

Mrs Mary Njoki Mwaniki is a farmer who lives a short distance from Ikinu shopping centre in Kiambu District. Mary is one of three wives of Mr Mwaniki and she has seven children.

She has recently established a hedge of Croton all around her farm as well as around the home compound. The size of the whole farm is 2.2 hectares, and Mary cultivates a portion that is almost a hectare. According to Mrs Mwaniki, a Croton hedge is easy to establish and maintain. Seeds are also easily available.

Mary says that the Croton on the road boundary, where it will not compete with crops, will grow tall so that it can be pollarded for fuel wood. Those around the home compound will be trimmed to make a beautiful 1.5 m high hedge. The trimmings can go to the goat enclosure as bedding or be used for ripening bananas. She expects the hedge to be ready for the first pruning after two seasons. Mrs Mwaniki has no problem with her neighbour since they planted the hedge together. Her neighbour cuts the hedge on his side, and she cuts it on her side. They intend to keep the hedge low to minimize shading.

Mary cites the following benefits of the Croton hedge:

- Keeps off/in livestock
- Ensures home privacy
- Provides protection from strong winds and dust.

Case **Report** No. 16: **Another farmer with hedges**

Mr Ndutire Kihuria is another farmer who lives near Mrs Mwaniki. He already has a well-established and trimmed Croton hedge which is now five years old. It is interplanted with *Lantana camara* and Grevillea. The Grevillea trees are allowed to grow tall, but the Croton and Lantana are kept 2 m high.

The hedge is trimmed once every season. When it is very dry, goats may eat the Croton leaves but otherwise the main uses of the leaves are to ripen bananas and as mulch. It takes a casual worker three days to cut the hedge which is 120 m long, and the labourer is paid Sh 40 per day. The casual labourer uses pruning secateurs, but Mrs Mwaniki uses her *panga*[1] to trim the hedge. She does all the trimming herself and has never considered any aspect of the cost of maintaining the hedge. Going by Mr Kihuria's figure, maintenance of the hedge requires one man-day per 40 m of hedge per year, or the equivalent of Sh 1 per metre per year. The trees can also provide good banana props and other staking material if allowed to grow a bit bigger.

Marking boundaries

Trees are often used for permanent boundary demarcation. Often certain species are associated with this function, e.g. *Croton megalocarpus* and *Commiphora zimmermannii* subsp. *eminii* among the Kikuyu and *Markhamia lutea* among the Luo in Siaya.

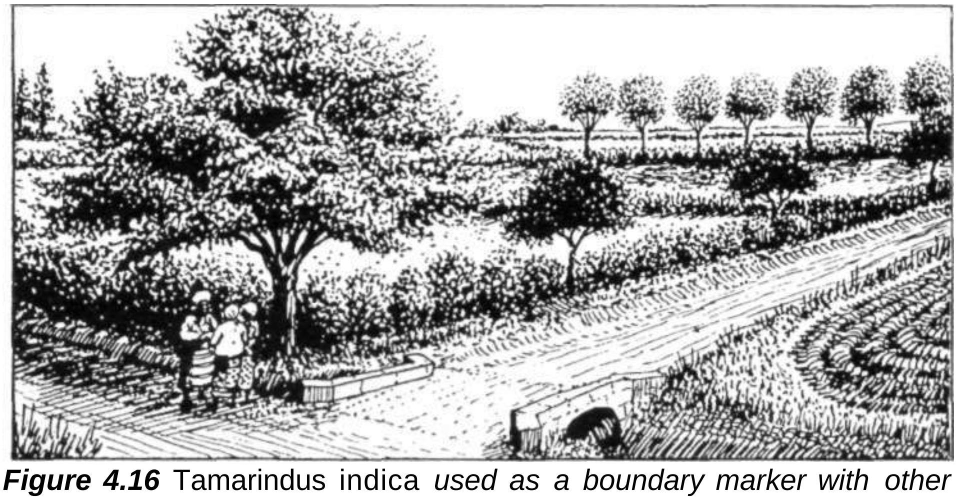


Figure 4.16 Tamarindus indica *used as a boundary marker with other fruit trees and a row of* Grevillea robusta

[1] Machette.

4.5 Trees for medicine

Figure 4.17 Traditional doctors use the bark of *Ficus sycomorus* as a remedy for stomach problems

Traditional medicine is very important for people in most rural areas. Access to a wide variety of species of trees and shrubs, as well as herbs, is, therefore, vital for the traditional healers. Usually, only a few trees of each species are required to meet these needs in a particular area, but when the desirable tree species become rare they tend to be over-used and may eventually die.

Sometimes the local people hold specific beliefs concerning the trees that they use for medicine, e.g. that planted trees do not have the same properties as trees of the same species growing naturally. Such beliefs may, of course, discourage planting of trees for medicine. Pastoralists normally have extensive knowledge of trees that can play a role in veterinary medicine. For people living in remote areas, access to other veterinary services may be limited and traditional knowledge of how to utilize the bipdiversity of the surrounding areas then becomes essential.

Case Report No. 17: Trees for medicine

Most herbalists make their traditional drugs from trees, shrubs and herbs. Lately these traditional practioners have been recognized by the Government and many now operate registered clinics.

Dr Michael A. O. Mashele is such a herbalist. He has a clinic at Shianda market centre on the Kakamega-Mumias road. He was a school teacher, but has now gone into the practice of herbal medicine full time. He says that he inherited the knowledge of herbal medicine from his mother and grandfather who were also herbalists. Later he broadened his knowledge through interaction with other herbalists.

Dr Mashele says that almost every tree has medicinal value. Many trees, shrubs and herbs that are used to make medicine are very common. He concedes, however, that many of these trees are now disappearing due to the opening up of land for agriculture. He says that any effort to re-introduce these trees or protect those that still exist would be very welcome.

Dr Mashele revealed that although almost all trees have medicinal value, some have greater strength than others. Most trees with strong healing powers are the ones that are very rare. He mentioned one species that is only obtainable from Uganda. It is known as *shikotnboti* in Luhya. He mentioned another ten species which he said are very rare. If such species were available in nurseries, herbalists could buy and grow them, according to Mr Mashele. He sometimes visits tree nurseries and has planted trees from there, e.g. a tree he calls *mutwele* in Luhya which provides a very good medicine for measles. Dr Mashele would be very willing to co-operate with foresters in providing the names of trees with medicinal value so that their propagation methods ca be studied if they are not already known.

4.6. Other products from trees

There are numerous other products of trees which are of direct use to people. Wood is used for farm implements, boats, carving, making furniture and many other things. Often specific tree species are preferred for such uses. Bark and small twigs can be used to make ropes and tooth-brushes. Certain species contain chemicals that can help purify water, e.g. *Moringa oleifera.*

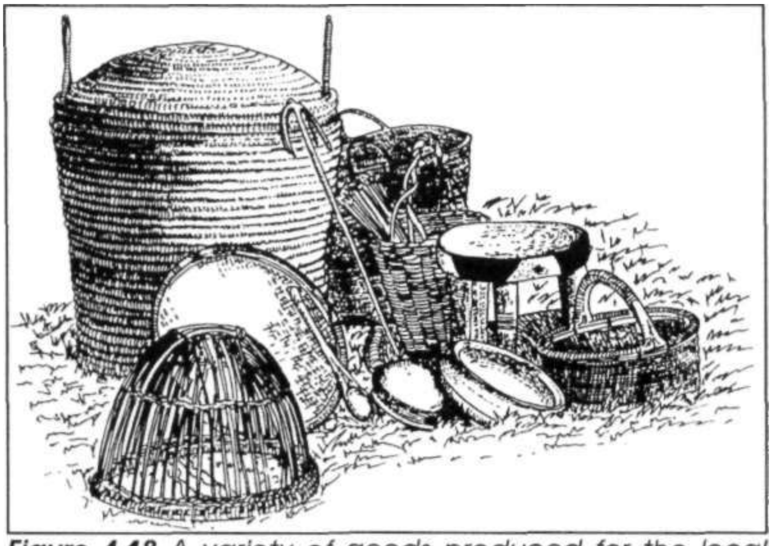


Figure 4.18 A variety of goods produced for the local market

Case Report No. 18: Trees for many uses

Mr Michael Ngare is a small-scale farmer in Gitumbuii Sub-location of Siakago Division, Embu District. He has only a 1.6-hectare farm where he grows maize and beans for subsistence and tobacco for cash. On one portion of the farm he has over 40 mature heavily pollarded trees of many different species growing dispersed in his field. In addition, he has some smaller *Catha edulis* and *Melia azedarach* trees. In spite of so many trees, the maize is doing very well as Mr Ngare has developed different management practices for the different species to avoid negative effects on the crops.

Melia volkensii is pruned and trained to grow straight for timber. *Erythrina abyssinica* is heavily pollarded, encouraging production of fuelwood and leaves for mulching. The bark of Erythrina is used as medicine. From *Ficus sycomorus* he gets fibres for making *ciondo* (African baskets) as well as firewood. Some of the species found on Mr Ngare's farm and their uses are:

- *Melia volkensii, mukau:* Timber, fuelwood, fruits as fodder for goats
- *Erythrina abyssinica, muvuti:* Fuelwood, mulch, medicine
- *Ficus sycomorus, mukuyu:* Fuelwood, fibres for *ciondo*
- *Olea europaea, muthaata:* Building poles, medicine *(mutero* soup)
- *Mururuku:* Fuelwood, beehives
- *Mwage:* Fruits, fuelwood
- *Mukuura:* Fuelwood, medicine
- *Muvuru:* Fuelwood, fruits
- *Kitharara:* Fibres for *ciondo.*

All vernacular names are Embu.

4.7 Trees for cash, savings and investment

As already noted in many Case Reports, trees play an important role in providing cash for the household. The most common products sold for cash are fruits, timber and poles. Trees may also support agricultural and livestock production, which also contributes to greater income from the farm.

A standing stock of growing trees can also be an important kind of saving and investment that can help bridge years when the harvest is poor, or help the family to manage in periods of financial crisis, e.g. when many children require funds for school fees.

Trees are not subject to inflation and may be a better kind of saving than keeping money in bank accounts.

Case Report No, 19: Mango production for market

Mr Kamau is the manager of a 60-hectare farm growing mangoes and avocadoes for sale. The farm is situated in Karurumo Sub-location in Runyenjes Division, Embu District. The area borders Siakago Division and is in the transitional zone between agroclimatic zones three and four.

Priority is given to the mangoes which fetch better prices than avocado. Several varieties of mangoes are grown: Apple, Van Dyke, Kent, Haden, Tommy Atkins and Ngowe. Avocadoes are of only two varieties: Fuerte and Hass. In order to increase the size of the mangoes, limited irrigation is carried out when the trees are in fruit but there is no other watering. An exporter comes to buy the fruit on the farm, with prices ranging from Sh 15 to 25 per kg, i.e. Sh 60-100 per 4 kg box.

The most critical time for mango cultivation is during the first two months when the fruit are being formed. During this period, spraying to control mildew has to be done every fortnight. Later in the season spraying is only required if athracnose disease appears, and if so, copper sulphate is the chemical used.

Mr Kamau runs a nursery on the farm where he raises his mango seedlings. Sometimes he sells seedlings, but the demand for them is much higher than his ability to supply. When he does sell, the price for mango seedlings is Sh 25 and for avocado Sh 15. The sale of fruit-tree seedlings can often be profitable for small-scale farmers.

According to Mr Kamau small-scale farmers often have problems with marketing and transport.

Case Report No. 20: Avocado production for market

Mr James Githinji Wainana lives in Kahuro Sub-location of Kiharu Division, Muranga District. His farm is 1.8 hectares and on it he grows coffee and avocado as perennial crops. He also has a woodlot of *Acacia mearnsii.* In other parts of the farm Mr Githinji grows his food crops, mainly maize and beans.

Mr Githinji has 48 Fuerte avocado trees which are five years old. So far he has had three harvests, the first two of which were quite poon The last one was good, and he managed to take 10 bags to Nairobi. The Nairobi market is disappointing, however, and he now prefers to take the fruit to a nearby local market. Although the prices offered there are low, at least there is no need to travel all the way to Nairobi.

Now Mr Githinji also feeds avocado to his livestock. However, he has to cut the fruit into quarters otherwise the whole seed can get stuck in an animal's gullet and cause death. The family also use avocado in place of butter or margarine. Avocado leaves rot very fast and Mr Githinji has discovered that they are useful for compost making. He now regularly puts avocado leaves on his compost pit.

Mr Githinji has faced the problem that the Fuerte variety is no longer popular. Hass is the variety in demand now, but he only has one Hass tree. He concludes that it is good to grow more than one kind of fruit to reduce the risk if demand for a certain variety falls.

Case Report No. 21: Fruit production for sale

In Case Report No. 3 we met Mr and Mrs Kabaiko, the hard-working elderly couple living in Lari Division, Kiambu District. On fruit growing for sale, Mr Kabaiko says that pears and plums have a very good market. People come to buy these fruit from his farm. Most of the fruit is then sold along the Nairobi-Nakuru road, but some ends up for sale in Kisumu or Nakuru towns. The farm-gate prices are Sh 2.50 and 5.00 per kilo for pears and plums respectively. Peaches and tree tomatoes also have a good market, and the best outlet for these fruits is with local shopkeepers. Both peaches and tree tomatoes fetch Sh 10.00 per kg on average.

Mr and Mrs Kabaiko complain of the poor market for avocado. They say that the market is very unpredictable. Sometimes exporters or local businessmen come and buy the fruit. When they come they harvest a lot but then only pick the best from what they harvested. This results in a lot of waste. Mr Kabaiko now insists that a customer should only harvest what he needs. The fruit are priced at Sh 1.50 each, but demand is very low.

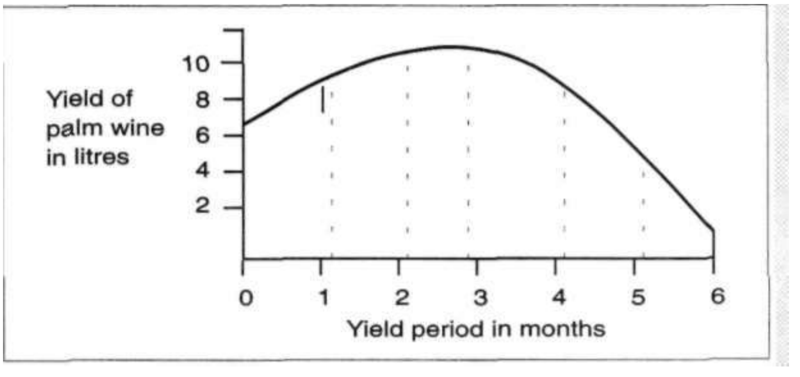
The fruit trees on Mr Kabaiko's farm do not require complicated management. During planting he advises that three wheelbarrows of *boma* manure and 20 g of di-ammonium phosphate (DAP) should be added to the soil in each planting hole. An annual input of three wheelbarrows of *boma* manure, 15 g DAP and 15 g calcium-ammonium-nitrate (CAN) is necessary to maintain high yields. Avocado only needs weeding during establishment and after that the tree will outcompete weeds. Mulching should be done under peaches, plums and pears to prevent fallen fruit from being spoilt. When the fruit trees are dormant and without leaves Mr Kabaiko plants vegetables or beans underneath.

Case Report No. 22: Coconut for cash

In Case Report No. 5 we met Mr Safari who grows coconuts on his farm at Utange, Mombasa District.

The coconut growing is not only for his subsistence but also a very important source of cash. There is a good market for four different products from the coconut: palm wine, *madaju* (the immature fruit whose juice provides a popular drink), *tnakuti* (thatching made from leaf fronds) and copra. Of these, palm wine has the highest return and is also easiest to produce, although at present it is not legalized and is discouraged by the government.

According to Ndoro Safari, Mr Safari's son, one can get 7-10 litres of palm wine per tree per day if you collect both in the morning and in the evening. One inflorescence can be tapped for six months.



The initial yield is about 7 litres per day and this increases up to about 10 litres and then declines to about 1-2 litres within 6 months. A coconut tree that is tapped for palm wine cannot produce mature nuts. The fruits are harvested while still immature 8-9 months after flowering. Nuts from a tree which is being tapped for palm wine would be of poor quality if allowed to mature.

The farm-gate price of palm wine is KSh 15 per litre. A farmer can get over KSh 2,000 per month for palm wine from one coconut tree. With one ha of coconut (recommended spacing is 9 m x 9 m, giving about 120 trees per hectare) the farmer will get up to KSh 240,000 per month from palm wine alone. Of course he can also sell *madaju* from the same trees.

The other product with a ready market is copra from the nuts. However, copra and palm wine cannot be produced from the same trees simultaneously. The nuts take 12 months to mature. The market for copra is greatly influenced by world prices. Recently the price has increased to KSh 16 per kg. Five to six nuts will give 1 kg of copra, while 2 kg of copra give 1 kg of oil.

The yield is 50-60 nuts per year. The income from one tree would then be about KSh 160 per year (10 kg of copra from the 50-60 nuts). From 1 ha the annual income would be KSh 160 x 120 trees = Sh 19,200. In addition, immature fruits can be harvested. The price is about KSh 5 per fruit, and from one tree you can harvest about 60 fruits in a year. Thus the income from immature fruit would be Sh 300 per year, and from a hectare Sh 300 x 120 = Sh 36,000.

It can be concluded that at the moment palm-wine production is by far the most profitable production from coconut. It should, however, also be noted that palm wine cannot be stored, and therefore marketing of it may pose problems.

4.8 Trees and agriculture

The supportive role trees can have in relation to agriculture is of great importance in farming areas. Trees can help in conservation of soil and water, enhance soil fertility and improve soil structure. Trees can also help retain moisture and reduce wind speeds and so contribute to higher crop yields.

On the other hand, tree species that are unsuitable in relation to the crops being grown, or that are not managed in appropriate ways, can also reduce yields significantly. Thus, successful growing of trees in farming areas depends on a good understanding of how trees and crops interact. This whole subject is so important that it will be discussed more thoroughly in Chapters 5-7.

Figure 4.19 Women tending a terraced field edged with fruit and fodder trees

4.9 Trees and livestock including beekeeping

Trees can support livestock production in many ways. The main direct benefits of trees are as a source of:

- Primary feed where grass is scarce
- Supplementary feed where grass is of poor quality or when a protein supplement is required
- Shade
- Medicinal substances
- Materials for construction, e.g. materials for fencing and *boma.*

The presence of livestock is often a complicating factor for tree growing. Livestock browse on young tree seedlings and hamper regrowth, either planted or natural. In many areas, particularly in western Kenya, post-harvest grazing of fields is a common practice. After the harvest, the fields are often opened up for grazing on a communal basis, and cattle and goats are often free to feed on whatever they find at such times. Where such practices exist it is difficult to establish new trees in cropland.

Section 4.9 is based on Nicholson, 1991; and Bradbear, 1990.

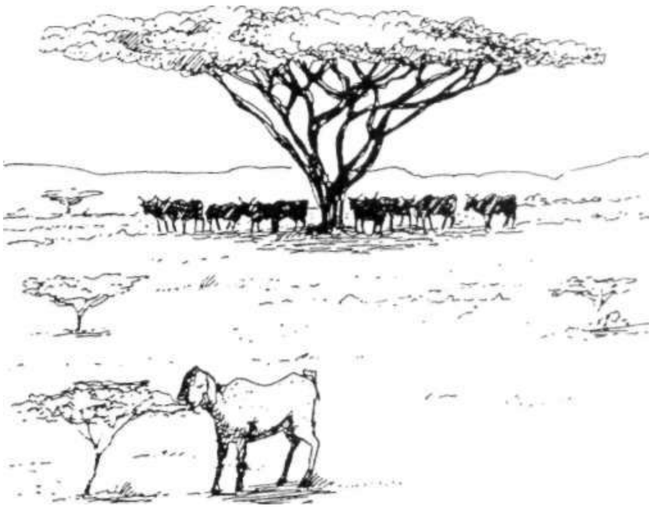


Figure 4.20 Livestock may be a complicating factor in tree growing

Primary feed source

Fodder from trees normally constitutes a primary feed source for livestock in ASAL areas during the dry season. Then browse may constitute more than half of the diet. When livestock browse on trees and shrubs it is often regarded as a sign of over-use of land. This is only partly true. In areas with long dry seasons, utilization of trees and shrubs for fodder is vital, but it is, of course, essential that the pressure on the vegetation does not exceed its long-term carrying capacity. Normally, livestock are more strongly dependent on tree fodder the drier the area concerned.

Case **Report No. 23: Tree fodder in ASAL**

In Case Reports No. 2 and 4 we met Mr Louwoto from Turkana and Mr Logeding'ole from West Pokot. They reported on the use of trees for food in their areas.

Mr Louwoto also has information on the use of indigenous trees for fodder in his area. Pollarding and lopping for fodder are common, and the most important species are Acacia. Great care is taken not to kill the tree. Examples of fodder trees used for donkeys and camels in his area are:

- *Acacia tortilis (ewoi* **in Turkana)**
- *Salvadora persica (esekon)*
- *Cordia sinensis (edome)*
- *Acacia eliator (esajet* or *esanyanait)*
- *Ziziphus mauritiana (ekalale)*
- *Acacia albida (edurukoit)*
- *Acacia nubica (epetet)*
- *Acacia Senegal (ekunoit)*
- *Hyphaene compressa (eengol).*

Sheep eat the fruit of *Cordia sinensis (edome).*

According to Mr Logeding'ole, the Pokot are heavily dependent on tree fodder during the dry seasons. Species such as *Kigelia africana (rotin* in Pokot), *Terminalia brownii (koloswa)* **and** *Balanites aegyptiaca (tuyuno)* which are not very thorny are liked by both cattle and goats, whereas thorny Acacia are mostly eaten by goats. *Acacia brevispica (ptar)* **and** *Acacia eliator (atat)* are important fodder for goats. Pods of *Acacia nilotica (kopko)* are fodder for both goats and cows, and according to Mr Logeding'ole the pods are also effective for deworming livestock.

Case Report No. 24: The importance of diversity in cattle feed

John Lokodo is a farmer in a semi-arid part of Chepareria Location in West Pokot District. He has a 20 ha farm most of which is under natural pasture. He has identified over 40 trees which can be used for fodder and has protected many of them. He classifies them into two main groups: firstly those cut whenever needed to provide fodder, and secondly there are those with a milky sap which are only cut during periods of severe drought.

The feeding regime is interesting. In the morning Mr Lokodo first cuts a tree species that livestock like to eat fresh. Some hours later he will cut another species, and later again a third species. By the end of the day he may have cut 12 different species of tree or shrub. According to Mr Lokodo, the reason is that when a cow has eaten one species it will not eat it again the same day since the palatability of many of the species is quite low. To keep the livestock eating it is necessary to vary the fodder species cut. For each species the cattle eat as much as they want. Some trees have to be wilted to improve their palatability.

According to Mr Lokodo, most trees that cattle eat are also eaten by goats, whereas sheep are more dependent on grass and low herbs. Sheep also feed on Acacia seeds and dry Acacia leaves on the ground.

In high-potential areas grass is more important than trees as a fodder source. With increasing human population densities, however, land use shifts from a more labour-extensive type towards a higher input of labour per unit area of land. In situations where people utilize the land intensively, use of tree fodder in cut-and-carry systems becomes more frequent. With a growing human population in the highlands we may therefore expect to see intensified use of tree fodder in these areas.

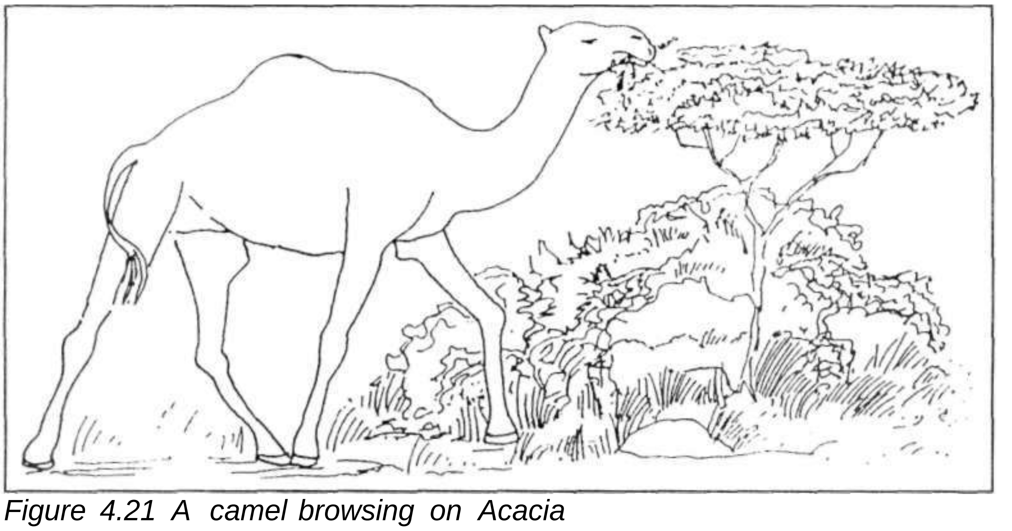


Figure 4.21 A camel browsing on Acacia

A problem associated with the use of trees for fodder in high-potential areas is that there are few suitable species already growing in those areas. Among exotics, *Leucaena leucocephala* has become widespread, but it does well only up to 1,500-1,600 m and where soils are not too acidic. *Sesbania sesban, Calliandra calothyrsus* and *Leucaena diversifolia* are other fodder species suited to high-potential areas at slightly higher altitudes. Calliandra and L. *diversifolia* are, however, not yet very widespread. Grevillea was very important in Meru during the 1984 drought: it was largely due to Grevillea leaves that the livestock in the area survived. Even during normal years Grevillea is used as fodder in some areas, but it is a poor-quality fodder. Compared to some other high-potential areas of the world use of tree fodder in these areas in Kenya is not very highly developed.

Supplementary feed source

Ruminants need a good supply of protein to be able to digest carbohydrate effectively as they depend on micro-organisms for digestion of the carbohydrate. With a low protein intake these micro-organisms cannot reproduce. This explains why ruminants can "starve on a full stomach".

Green leaves principally contain carbohydrates, proteins and minerals. When grass dries out during the dry season the protein content falls rapidly and the result is that protein will be a limiting factor in carbohydrate digestion. Because of their deep roots, trees can remain green well into the dry season, and in addition the protein content of tree leaves is normally higher than that of grass. Therefore, tree leaves have an important role to play in livestock nutrition during the dry season.

Beside tree leaves, pods from trees, mainly those of Acacia, are also very important as a protein source for livestock. Gwynne (1969) found that during the dry season in Kenya seeds and pods of *Acacia nilotica* constitute up to 60% of dry weight fodder intake in cattle.

Trees and shrubs are becoming increasingly important as cheap supplementary feed in high-potential areas. Leaves from Leucaena and other leguminous shrubs are commonly used as supplementary feed in dairy production. Leucaena can, however, cause hair loss due to its high mimosine content. There are several ways of overcoming this problem, but the simplest way is to make sure that the proportion of Leucana in the fodder is kept relatively low. Pigs are the most sensitive animals in this respect, and they will only tolerate a level of Leucaena of up to 15% of the diet. For ruminants, Leucaena should not constitute more than 30% of the diet, unless the leaves are wilted in which case the ratio can be higher.

Daily use of fodder from leguminous shrubs *(Leucaena* spp., Calliandra, *Sesbania* spp., preferably in a mixture) will increase milk yields by 10-20% compared with a diet which is deficient in protein. If tree fodder is scarce, priority should be given to cows a month before and a month after calving, and as a dry-season reserve for all stock, particularly sheep and cattle. In meat production, the weight gain will be increased by two to four times with adequate supplementary feeding.

Among indigenous trees, *Ficus sycomorus* and *Kigelia africana* have been reported as being used for supplementary feed.

Case Report No. 25: Calliandra for fodder

Mr Fredrick Kinyua Mwaniki's farm is in Kairiri Sub-location of Manyatta Division, Embu District. The farm is 1.2 ha and lies in the coffee zone on the slopes of Mt Kenya. Mr Mwaniki and his wife have three children, in Standards 3, 4 and 5 respectively. He bought the farm in 1987 and since then he has developed it so well that in 1991 he won an award as the best soil-conservation farmer in the country.

Mr Mwaniki grows many crops on the farm in rotation. He also has permanent crops and trees, and keeps livestock in a zero-grazing system. The two dairy cows are mainly fed on Napier grass grown along the terrace embankments as well as in rotation with other crops. He also harvests grass from the coffee bench risers. For protein supplementation he has *Calliandra calothyrsus* grown in hedges along the farm paths and *Desmodium notatum* grown together with the Napier grass. By using the manure from the cattle shed he is able to double production from the Napier grass from the normal 3-4 cuttings annually to 7 cuttings in the same period.

Mr Mwaniki established his Calliandra from seedlings which he raised in his own on-farm nursery. He has planted the Calliandra in staggered double rows with a spacing of 30 cm both between rows and within rows. He harvests at least four times a year, but usually more often. He allows the Calliandra to reach a height of about 1.5 m and to become much branched. Then he cuts the leafy tops for fodder, and later does the proper cutting to a height of 30 cm.

According to Mr Mwaniki, the Calliandra should be wilted and the ratio of Calliandra in the feed should not be too high if bloat is to be avoided in cattle. He claims that his milk yields have increased, but he made no exact measurements of this impact. Finally, Mr Mwaniki says that Calliandra is also beneficial in fixing nitrogen, for production of fuelwood and staking material for tomatoes, and as a beautiful hedge.

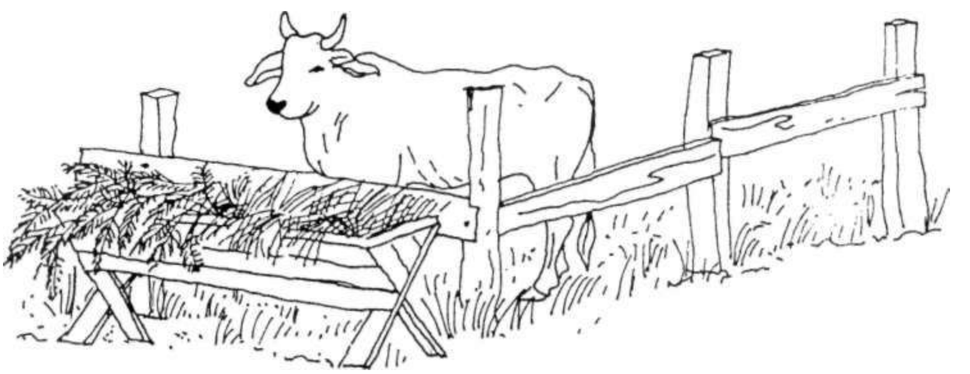


Figure 4.22 Supplementary feeding of green leaves during the dry season

Case Report No. 26: Trees for supplementary feed in ASAL

Tree leaves are richer in digestible crude protein than grasses. The palatability of tree leaves is often low due to the presence of tannins, phenols and other aromatic substances. The fruits and pods of some species may, however, be very palatable and both small ruminants and cattle like them.

Mr Lopskor, a farmer in West Pokot District, says that cattle will always sense where there is an Acacia tree in pod. The livestock go there every morning, and feeding on these pods greatly increases milk yields. He says that the pods of one mature *Acacia tortilis* or *Faidherbia (Acacia) albida* tree can keep five cattle supplemented by grass and tree leaves. In some cases people may collect and store pods for their animals, but this is not encouraged by the community. Once your cattle have eaten their fill, the pods should be left for other people's cattle. Now that land is becoming privately rather than communually owned people will start protecting their trees and pods.

Normally cattle feed on the pods that have fallen on the ground. If necessary, the trees can be shaken or the branches hit with a stick to shake off the pods. Cutting down pod-producing trees like *Acacia tortilis* is strongly discouraged.

Other harvesting methods employed are pollarding, lopping and coppicing. According to Mr Lopskor and his neighbour, Mr Lokodo, the best method of harvesting twigs for cattle is lopping some branches. This ensures a sustainable production of tree fodder. While some trees can withstand pollarding, however, others will do better when coppiced. They insist, however, that lopping is the only method approved by their society as a whole.

Shade

Trees in pastures will provide shade, and under the crown of a tree livestock can enjoy lower temperatures which will contribute to higher milk production. If there is no shade in hot lowland areas heat stress may occur. Young or newborn animals are more vulnerable since their ability to regulate their body temperature is less developed. Heat stress results in an increased loss of water through sweating and loss of appetite which, in turn, will result in lower animal productivity. Some important factors that influence temperature regimes in hot climates are wind, humidity and direct solar radiation.

Figure 4.23 Boran bull under Acacia shade at midday

Veterinary medicine

Traditional use of trees and herbs for extraction of drugs for disease control may be very important, particularly in remote areas where veterinary services are not well developed. Numerous different species are used for such purposes, and there are potential pharmacological substances yet to be identified, purified and evaluated, some of which may already have been in local use for many years.

Materials for construction

Livestock owners need wood for construction of various structures in animal husbandry. Fences are perhaps the most obvious of these. Fences often play a key role in land use. Without fencing it is difficult to control the movement of cattle and trees and shrubs play a role either as live fences or when cut to provide dead fencing material. Live fencing is important both in high potential and ASAL areas, whereas the use of dry thorny branches is more common in ASAL areas. In high-potential areas "dead" fences are more often constructed using fence posts and wire. In both cases products from trees are, of course, essential.

There are also other well-known uses for construction materials from trees in connection with livestock production.

Trees and beekeeping

The two main products from beekeeping, honey and beeswax, are valuable commodities that can contribute both to subsistence and income generation. In addition to this direct output, improved pollination by honeybees means better harvest of nearby crops. Bees feed on the pollen and nectar in flowers. This resource is not utilized by any other livestock, and thus bees do not interfere with other components in the land-use system. Beekeeping does not occupy any valuable land, and furthermore it is a flexible enterprise in terms of the labour requirement. Bees do not require daily attention and the work can be done when the beekeeper has time to spare. In other words, there are many good grounds for keeping bees.

Honey can be both a food, a medicine, or a cash crop, or it can be used for brewing. As a sweetener honey is more nutritious than sugar, and it adds diversity to the diet. The market for honey is good in most areas, and honey has a great potential as an export commodity. The three countries that export most honey in the world (Mexico, China and Argentina) are all in the developing world, and in those countries a large beekeeping industry has developed. African countries have an untapped potential in this respect considering the widespread knowledge of this age-old practice that exists on the continent.

Beeswax has many uses too. The most well-known one is for the manufacture of candles. Beeswax does not deteriorate with age and thus can be stored, and there is a good market for export.

World honey production is near one million tonnes, but still more important is the role bees play in the pollination of over 100 cultivated crops. Bees pollinate crops such as avocado, oil-seed crops, coffee, legumes, mango, pawpaw, and sunflower. It has been reported that four well-managed beehives per hectare in a field of sunflowers increase the yield Of sunflower seeds by 15-20% (Pawlick, 1989).

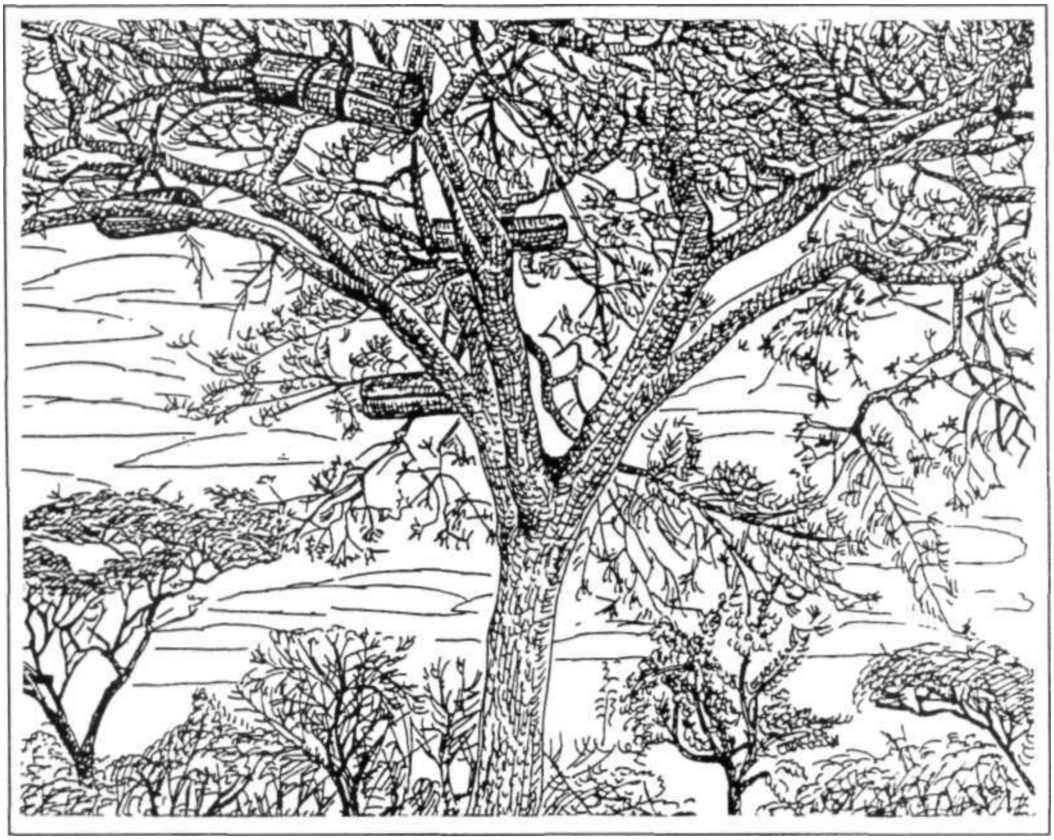


Figure 4.24 Traditional beekeeping

Kenya's production potential is estimated at 80,000-100,000 tons of honey and 8,000-10,000 tons of beeswax annually, whereas the actual production in 1987 was 34,000 tons of honey and 3,600 tons of beeswax. It is estimated that the number of traditional hives is around 2 million, and that there are some 50,000 modern top-bar hives.

Trees are important for beekeeping both as a source of nectar, to provide wood for hives and as a good habitat for bee colonies. Hence tree growing and beekeeping are strongly associated. The most important zone for further development of beekeeping in Kenya is the semi-arid zone. The high species diversity in this zone makes it the area with the highest beekeeping potential in the country. Most efforts to develop commercial beekeeping are made in that zone as other agricultural enterprises are not favoured by the climatic conditions. Honey is already a major source of income in such areas (Kagio and Muriithi, 1989).

Contact your local beekeeping officer or livestock officer for more information on improved hives, etc.

4.10 Trees and climate

The role trees play in determining climate has been extensively discussed in recent years. In spite of substantial research many important issues remain unresolved. It is necessary to distinguish the role trees can play in affecting the climate at a certain locality, i.e. the microclimate, from the role they can play in determining the climate over larger areas, the macroclimate.

Trees have a very significant impact on the climate in the locality where they grow. Trees provide shade, and hence lower temperatures. They also help in regulating wind speeds and in retention of moisture in the immediate surroundings. Thus trees can play an important role in determining the microclimate.

With regard to the climate over larger areas, the scientific proof of the role trees can play is not yet very clear. People in most areas in Africa claim that the climate has changed, and in some areas a change towards a drier climate has been verified during this century. To what extent this can be attributed to long-term trends, deforestation or other environmental changes still needs to be determined.

Figure 4.25 Trees have a substantial impact on the microclimate

5. INTERACTION BETWEEN TREES AND CROPS

5.1 Introduction

Farmers have always grown trees on their land, often noting that this has beneficial effects for the soil and crop yields. This capacity of trees and other plants to restore soil fertility was utilized in African traditional agricultural systems based on shifting cultivation. It is also a well-known fact that the topsoil in forests is usually rich in nutrients and has a good structure. Scientists have concluded that the cycles of carbon and other nutrients under natural vegetation are relatively closed, i.e. there is little leakage out of the system. In spite of intensive research, however, much still remains to be discovered and verified with regard to the effects of trees on soil properties.

Soil status is one of the important factors that determine how a crop will perform on a certain site. It is, however, not the only one. Moisture content is another important factor, and trees growing with the crops will also have an impact on the moisture content of the soil. Above ground a tree will provide shade, which will have some effect on crop performance. Additionally trees may harbour organisms that are harmful to crops, e.g. a tree may contribute to a high nematode population in the soil or attract birds to nest in its crown.

These and other factors affect the nature of the tree's interaction with the crops surrounding it. The area where this interaction takes place is sometimes called the tree/crop interface. Agroforestry is only beneficial to the farmer if the net effect of all the factors involved in this interaction is positive. Trees planted with crops certainly do not always contribute to a higher output or to more sustainable land use. The benefits will only be obtained through a combination of the right tree species with the right crops in the right spatial arrangements and with the right management practices.

In this chapter we will discuss the most important factors in tree/crop interaction. It is important to understand these factors and their effects on the trees and crops before we can discuss and plan agroforestry interventions with farmers.

5.2 How trees improve soils

The processes through which trees improve soils can be grouped into four different categories:

- Increasing inputs (organic matter, nitrogen fixation, nutrient uptake)
- Reducing losses (organic matter, nutrients) by promoting recycling and checking erosion
- Improving soil physical properties, including water-holding capacity
- Beneficial effects on soil biological processes.

The processes by which trees maintain or improve soils are listed in Table 5.1 and illustrated in Figure 5.1. Some of these processes will be discussed in more detail.

Table 5.1 Processes by which trees maintain or improve soils (not all of the listed effects are proven — see text)

Processes **which augment additions to the soil:**

* Maintenance or increase of soil organic matter through carbon fixation in photosynthesis and its transfer via litter and root decay
* Nitrogen fixation by some leguminous and a few non-leguminous trees
* Nutrient uptake: the taking up of nutrients released by rock weathering in deeper layers of the soil
* Atmospheric input: the provision by trees of favourable conditions for input of nutrients by rainfall and dust, including via throughfall and stemflow
* Exudation of growth-promoting substances by the rhizosphere.

Processes **which reduce losses from the soil**

* Protection from erosion and thereby from loss of organic matter and nutrients
* Nutrient retrieval: trapping and recycling nutrients which would otherwise be lost by leaching, including through the action of mycorrhizal systems associated with tree roots and through root exudation
* Reduction of the rate of organic matter decomposition by shading.

Processes **which affect soil physical conditions**

* Maintenance or improvement of soil physical properties (structure, porosity, moisture retention capacity and permeability) through a combination of maintenance of organic matter and effects of roots
* Breaking up of compact or indurated layers by roots
* Modification of extremes of soil temperature through a combination of shading by canopy and litter cover.

Processes **which affect soil chemical conditions**

* Reduction of acidity, through addition of bases in tree litter
* Reduction of salinity or sodicity.

Soil biological processes and effects

* Production of a range of different qualities of plant litter through supply of a mixture of woody and herbaceous material, including root residues
* Timing of nutrient release: the potential to control litter decay through selection of tree species and management of pruning and thereby to synchronize nutrient release from litter decay with requirements of plants for nutrient uptake
* Effects upon soil fauna
* Transfer of assimilate between root systems.

Source: Young, 1989.

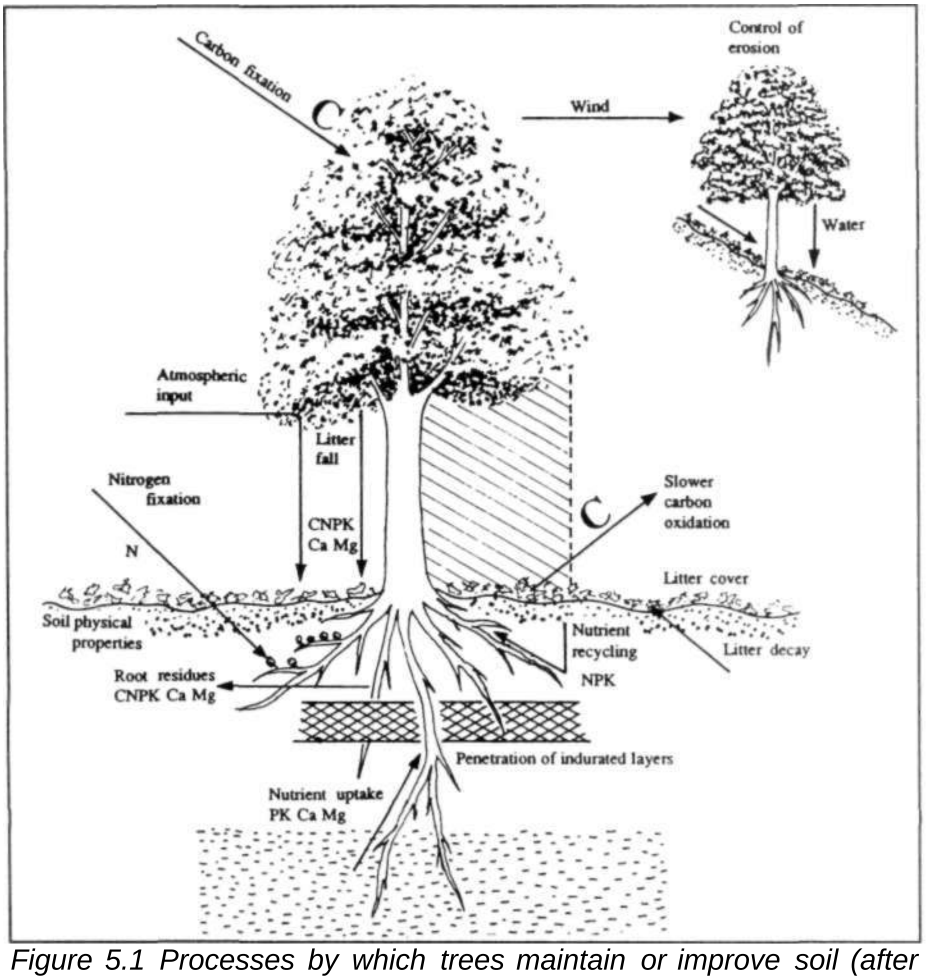


Figure 5.1 Processes by which trees maintain or improve soil (after Young, 1989)

Utter and mulch

During the lifetime of a tree, leaves, twigs and branches die and fall to the ground as litter. In agroforestry, trees are often managed and the biomass from the tree may be cut and used as mulch. The roles played by mulch and litter are similar.

In general, tree canopies only reduce the erosive effect of rainfall by about 10%, and in certain situations the canopy may make the rainfall even more erosive than if there were no tree. If the soil is covered with litter or mulch, on the other hand, erosion will often be reduced to low levels. Another characteristic of litter is its contribution to the organic-matter content of the soil after it decomposes. A soil that is rich in organic matter has a better capacity to absorb and retain water, and thus is also more resistant to erosion. A good cover of litter or mulch can also be very effective in suppressing weeds.

In general, trees do not necessarily lead to control of erosion. What matters is their spatial arrangement and the way they are managed.

Nitrogen fixation

Many leguminous trees and a few non-leguminous ones have the ability to fix atmospheric nitrogen through symbiosis with bacteria or fungi in root nodules. The fixation of nitrogen has been proven and found to be a significant factor in soil fertility. Tree species that have the ability to fix nitrogen may not always be efficient in doing so, however. One of the pre-conditions for efficient fixation of nitrogen is a minimum level of phosphorus in the soil. In exhausted soils which are low in phosphorus, therefore, nitrogen fixation may be insignificant even if nitrogen-fixing species are planted.

The roots of a plant constitute 20-30 % of its biomass. But the roots often contribute more to net primary production than the above-ground biomass. This is because the fine roots only have a short lifespan and therefore there is a rapid turnover of them. Hence, root decay is a significant process, and it is probable that cutting back the biomass above ground (coppicing, pollarding, etc.) results in a temporary increase in root die back. When the roots die, nitrogen is released and can be used by other plants, e.g. crops. So far, these processes of release of nitrogen from roots are not very well understood but they are being studied. Besides release of nitrogen, the death of the fine roots also contributes to organic-matter build-up.

A major part of the nitrogen which is fixed by the roots is used by the nitrogen-fixing plant for its own growth. The litter from nitrogen-fixing plants is often rich in nitrogen which is added to the soil when the litter or mulch decomposes.

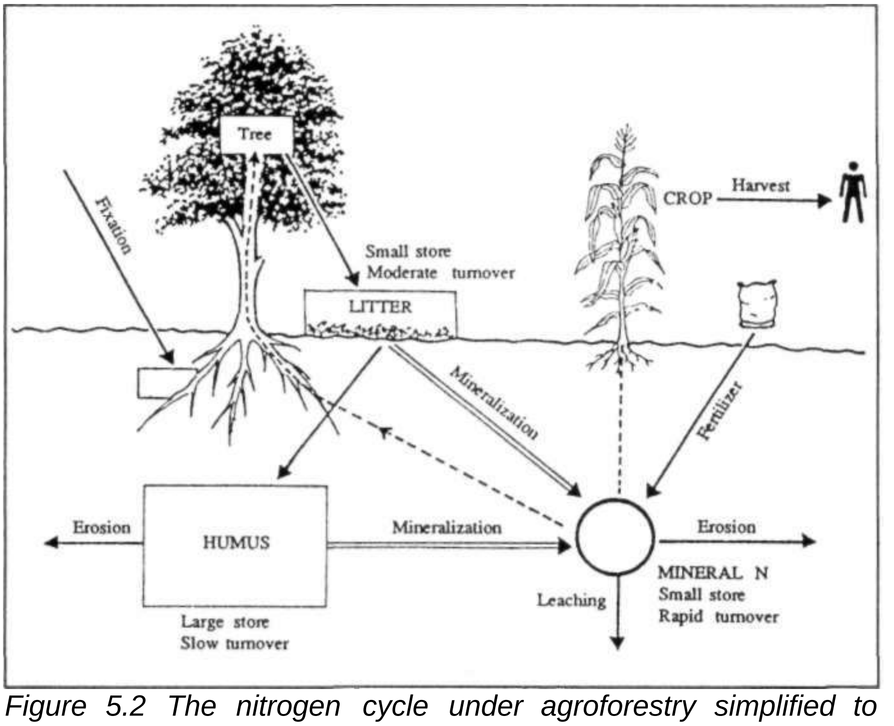


Figure 5.2 The nitrogen cycle under agroforestry simplified to show major stores and flows (after Young,1989)

Nutrient uptake

Tree roots normally penetrate deeper into the soil than the roots of crops. It has, therefore, been assumed that trees are more efficient than crops in taking up nutrients released by weathering deep in the soil. Potassium, phosphorus and micronutrients are essential for plant growth and these elements are often released through such weathering. The nutrient uptake from deep layers of the soil, sometimes called nutrient pumping, has still not been experimentally verified.

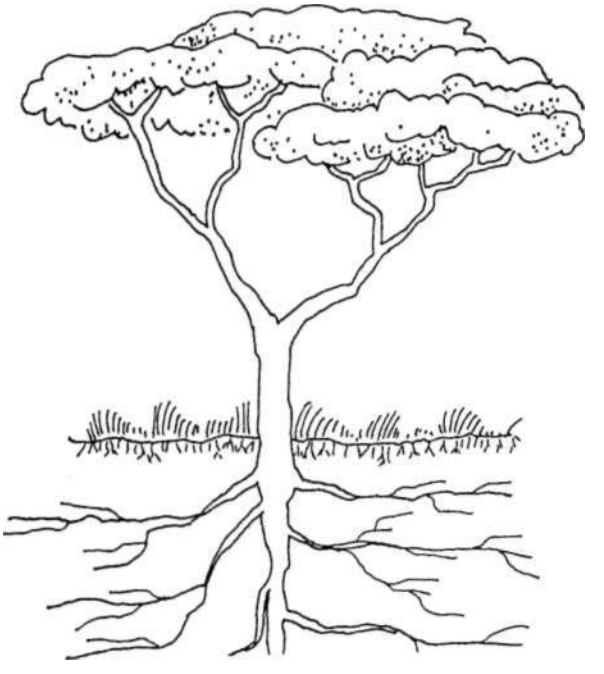


Figure 5.3 The roots of trees and crops penetrate the soil at different levels

Nutrients from the atmosphere

The presence of a tree reduces wind speed and creates good conditions for the deposition of dust. Nutrients in the atmosphere are conveyed to the soil when they are dissolved in rain or settle with dust. Rain water dripping from leaves and flowing along the branches carries the nutrients to the ground, together with those released from the tree itself and associated plants growing on it. It is known that the amounts of nutrients reaching the ground in this way are substantial.

Protection from erosion

Soil erosion can be controlled by checking the flow of water down a slope by establishing runoff barriers—the barrier approach—or through maintaining a cover of living plants and litter on the ground—the cover approach. A cover of mulch or litter on the soil reduces the impact of rain drops and provides dispersed micro-barriers to runoff (Young, 1989). Soil erosion involves loss of topsoil, including loss of both organic matter and nutrients. Trees play an important role in erosion control both through the barrier and cover effects. Formerly the barrier approach was thought to be the most important, but in recent years the cover approach has received increasing attention.

In the barrier approach, trees and shrubs play a direct role in reducing erosion if they are grown in hedgerows on contours. Another effective control method is to combine trees and grass in strips along contours. Combining trees and grass is a means of making optimal use of the strips of land which are taken out of direct crop production. If productive use is made of the strips, the soil-conservation measures are more likely to be regarded as beneficial by the farmer and therefore to be adopted on a permanent basis.

a. Barrier hedges of double rows of Leucaena with maize developing naturally into terraces, Philippines
b. Leucaena barrier hedges planted at 90-cm spacing in furrows between rows of maize developing into terracettes, Malawi
c. Trees on conservation works, Malawi: fruit trees on grass strips and Leucaena on marker ridges (ridges laid out along contours to guide cultivation ridges below)
d. Alternative arrangements for trees on conservation structures, Cameroon.
e. Alternative positions for trees on *fanya juu* structures, Kenya. *Fanya juu* structures are bunds in which the bank is above the ditch, promoting natural terrace formation.

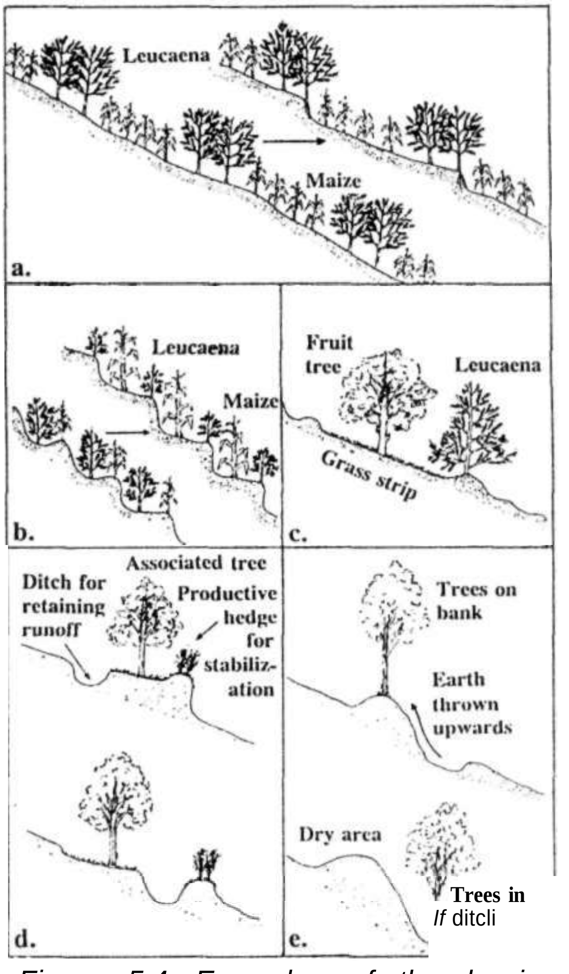


Figure 5.4 Examples of the barrier approach

If physical soil-conservation structures are constructed, trees or shrubs that are planted on or near them can help to strengthen and stabilize the structures. Another example of the use of trees in the barrier approach is the growing of trees as a windbreak.

The benefits of trees in the cover approach have been discussed earlier in connection with litter and organic-matter maintenance.

Reduction of the rate of organic matter decomposition by shading

Trees influence the microclimate (Section 4.10). The shade resulting from tree canopies and litter reduces temperatures during the heat of the day, and this cooling effect slows down the decomposition of organic matter.

Further information on how trees may improve soil can be found in Young, 1989.

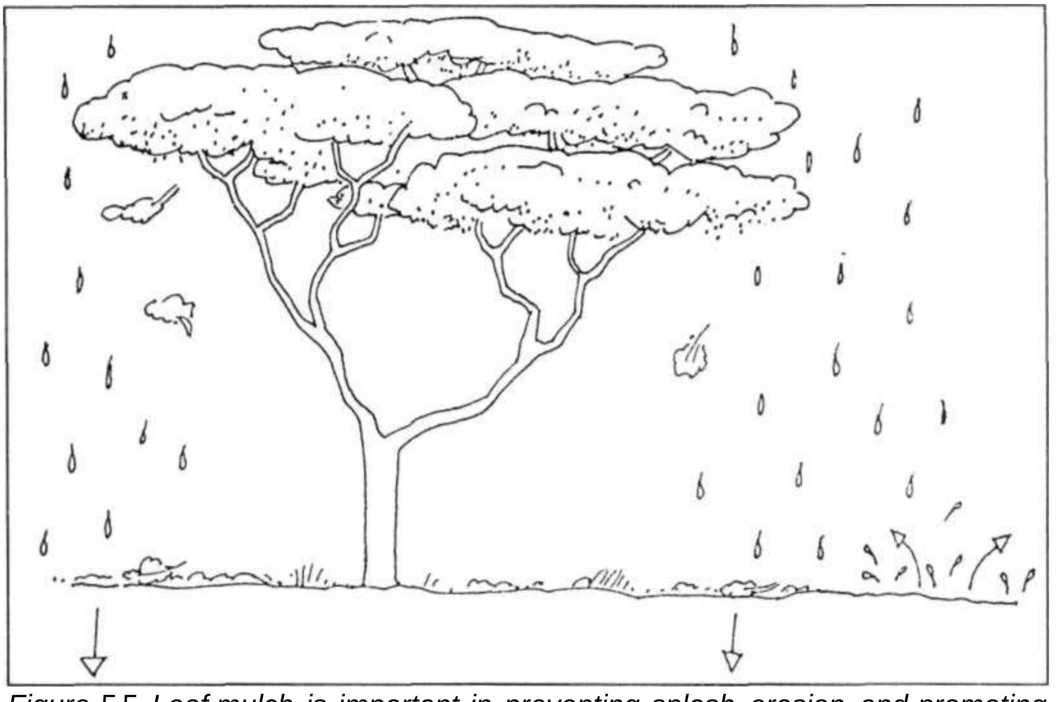


Figure 5.5 *Leaf mulch is important in preventing splash erosion and promoting infiltration*

5.3 Adverse effects of trees on soils

Trees can sometimes have a direct adverse effect on soil properties with consequences for crop performance. Such adverse effects that are relevant in the tropics are:

- Loss of organic matter and nutrients in tree harvest
- Nutrient competition between trees and crops
- Moisture competition between trees and crops
- Production of substances which inhibit germination or growth.

Loss of organic matter and nutrients in tree harvest

When trees are harvested and the biomass is removed, some loss of organic matter and nutrients occurs. However, there is a great difference between the situation where only the stem wood is removed and where the whole tree, including leaves and small twigs, is removed. In the latter case, a lot of nutrients are also removed, but use of the wood alone does not involve such a large loss of nutrients. If leaves and twigs are used for fodder and the animal manure is returned to the soil, the nutrient loss can be further significantly reduced.

Sections 5.2-5.3 are based largely on Young, 1989.

Nutrient competition between trees and crops

In general, trees are less demanding on nutrients than crops. It is generally desirable that trees growing with crops should have deep roots and few roots near the soil surface where most crop roots are found.

Moisture competition between trees and crops

Moisture competition is discussed in Section 5.4.

Production of substances which inhibit germination and growth

This phenomenon is sometimes called the allelopathic effect. Some tree species, e.g. *Eucalyptus* spp. and *Gmelina arborea,* have been reported to produce substances that may inhibit the growth of crops. In practice it is difficult to distinguish such effects from the effects of competition between trees and crops for nutrients and moisture.

5.4. Competition for moisture by the roots

Some of the positive effects attributed to trees with regard to soil improvement have a direct link to soil-moisture retention. Successful soil conservation contributes to infiltration of water into the soil and reduces water runoff. A high organic-matter content increases the water-holding capacity of the soil, and thus also contributes to reduction in runoff. Roots in the soil also increase the infiltration, as do remnants of dead roots. Litter or mulch on the ground reduces evaporation, and reduced wind speeds lessen drying of the soil.

All these positive factors have, in each situation, to be weighed against the increased competition for moisture that follows the introduction of trees or shrubs. Recent findings indicate that in alley-cropping systems the negative effects on crops of competition for moisture increase more rapidly than the benefits from having shrubs in the system the drier the area is. In other words, in dry climates (rainfall below 800 mm) the introduction of alley cropping may increase moisture stress so much that the net effect on crop yield is negative.

A tentative conclusion is that it may be extremely difficult to extend technologies that involve close interaction of fast-growing trees and shrubs with crops to dry areas (Akyeampong *et al,* 1992). It is doubtful if such technologies will be relevant in areas receiving less than 800 mm rainfall annually and in areas with acidic soils.

Fast-growing trees normally consume more water than slow-growing ones. However, some fast-growing trees are efficient water users, e.g. Eucalyptus have been reported to use less water per unit of biomass produced than many othei tree species (Davidson, 1989). So, the severe competition that can be observed near fast-growing trees should be attributed to their fast growth not to their "inefficient" use of water.

5.5. Shade

Beside competition for moisture and nutrients between trees and crops, shade is another factor of great importance. Shade has positive effects on the soil due to lower temperatures and hence a reduced rate of decomposition of organic matter resulting in improved soil structure, better water-holding capacity and less erosion.

Some trees, e.g. Grevillea, were introduced to Kenya primarily as shade trees for coffee. This use of Grevillea is an example of shade from a particular species being well tolerated which may lead to an overall increase in production as compared to coffee grown without shade.

The shade effect is, however, often negative on crops, and it becomes more significant the more light-demanding the crops are. The negative effects of shade can easily be reduced by managing the trees to reduce the degree of shade, e.g. by pruning or pollarding. Such management not only reduces shade but is also a way of harvesting useful products from the trees.

Sometimes the negative effects of shade on crop yields can be tolerated. If the value of production from the trees is high enough, it may outweigh the value of the crop loss and thus the overall benefit increases in spite of lower crop yields.

5.6. Pests and diseases

Mixtures of trees and crops make a more diverse environment than monocropping. A diverse environment enables a greater variety of species of all kinds of organisms — both desirable and less desirable — to thrive. With increased diversity, the risks of pests and diseases may also increase. On the other hand, a greater diversity of species also allows for better regulatory mechanisms which may reduce the seriousness of the pests and diseases.

Pests and diseases can be attributed to the agroforestry technology in use only if an organism has been promoted by one component in the system and is harmful to the other component or components. The most obvious situation would be if trees planted in or near a farmer's field introduced a pest that wiped out or reduced his crop yields. Birds being attracted to nest in certain trees is another such example of relevance for Kenya. The build-up of nematode populations under Sesbania trees has been mentioned as a potential threat to intercropping Sesbania in fields, but so far there is little evidence that this is a significant problem.

Beside these situations where both trees and crops are involved, there are of course numerous pests and diseases that affect only one component in the system. The occurrence of such pests has nothing to do with the agroforestry technology concerned, but since there are two important pests that have recently occurred in Kenya those two will be briefly discussed here. These are the cypress aphid and the Leucaena psyllid.

A third situation which is of interest when discussing pest and disease problems associated with agroforestry is when an agroforestry species turns into a weed itself. In the Kenyan context *Acacia mearnsii*, Leucaena, Prosopis and guava *(Psidium guajava)* have shown such potential.

Birds

Trees attract various kinds of birds as they are sources of food (fruit, nectar, insects), shade, shelter and nesting sites, and birds can be beneficial in many ways. In an agroforestry system insect-eating birds may help control insect populations and birds of prey help control rodent populations.

Some birds, however, feed on grain and have long been a problem for cultivation of certain crops. Traditionally, both children and adults would spend much time guarding crops, but nowadays such labour is unavailable. A destructive bird species in this respect is the red-billed quelea, *Quelea quelea*, which may sometimes invade cultivated areas in very large numbers. Little is known about the effects of trees on the severity of damage caused by Quelea.

Nematode build-up under Sesbania

Populations of nematodes, particularly the root-knot nematode, have been reported to infest Sesbania, reducing their growth. Nematodes cause irregular swellings called root galls that are quite distinct from the nitrogen-fixing root nodules that arise from the root surface (Evans and Macklin, 1990). Nematodes have a reputation for being harmful to certain crops, notably Irish potatoes and bananas, but so far there is little evidence that growing Sesbania would create any significant problems in this regard in Kenya.

The cypress aphid

The cypress aphid is an exotic aphid that first appeared in southern Africa around 1986. From there it has gradually spread northwards and appeared in Kenya in 1990, where it turned out to be a very serious pest on *Cupressus lusitanica*. Damage has also been reported on other conifers, e.g. *Widdringtonia nodiflora* (Mlanje cedar) in Malawi, and on *Juniperus procera* in Kenya. This pest is of significant economic importance for forestry, and since cypress has been widely used for fencing in Kenya it has also affected many small-scale farmers.

Some cypress trees appear to be more resistant than others, and if this can be confirmed it should form a basis for potential breeding from such resistant trees to obtain a cypress population which will be more resistant to the aphid. Efforts have been made to find natural enemies, so far with no practical results. The aphids are active mainly during the dry season and application of pesticides kills them. This method is not relevant for small-scale farmers, however, and may also be unacceptable from an environmental point of view.

The Leucaena psyllid

Leucaena leucocephala, which is widely grown throughout the tropics, was suddenly attacked in Hawaii in 1984 by a sap-sucking insect, *Heteropsylla cubana*. The insect, which seems to have originated from the same area as Leucaena, has spread from the Pacific to Southeast Asia, Australia and India and appeared on the Kenya coast and in Embu in 1992 (ICRAF, pers. comm., 1992). Worldwide this pest may cause losses amounting to millions of dollars.

Two different strategies are being tried to control the pest: plant resistance and biological control through the use of natural enemies. Initial results suggest that both strategies seem to be working well, although it is too early to predict what the final solution will be (Murphy, 1990).

Recent findings from the ILCA research station at Mtwapa indicate that *Leucaena diversifolia* is resistant to attack, by the psyllid. Two different accessions of *L. diversifolia* have been planted there. One is slightly attacked and the other appears not to be attacked at all.

Trees turning into weeds

There are several examples of exotic tree and shrub species in Kenya which are now spreading on their own. In this sense such species can be regarded as weeds, but on the other hand they may also be useful in some circumstances and therefore it is not always true to say that their spread is a nuisance. Uncontrolled spread of a tree or shrub species is, nevertheless, a warning sign that the species has the potential to become a nuisance. It is always difficult to predict the possible end result in the early stages of such processes.

Acacia mearnsii is known as a weed in many parts of Africa, including Kenya. Seeds of *A. mearnsii* remain viable for decades, and after fire they may germinate over large areas. This is useful if regeneration is desired, but it can also lead to an additional weeding burden. *A. mearnsii* is a useful tree, but it competes aggressively with other plants and therefore its natural spread may not always be desirable.

Leucaena definitely qualifies as a weed in certain situations. In warm areas with sufficient rainfall, Leucaena spreads very effectively if it is allowed to produce seeds, and thus it adds to the weed flora in fields. Along the Kenya coast the spread of Leucaena has been very conspicuous.

Prosopis is spreading in irrigation schemes and along rivers in dry and hot areas. So far, the positive and negative effects of this spread have not been quantified.

Guava is also spreading on its own in some areas. So far there has been no significant negative effect, however.

6. THE CROP COMPONENT

6.1 Factors of importance for interaction with trees

Some factors of importance in the relationship between crops and trees have already been touched upon in the previous chapter. Some of the more important are:

- Light demand
- Demand for moisture and nutrients (or the "aggressiveness" of the crop)
- Potential for bird damage
- The distribution of roots in the soil profile
- The potential for wind damage.

So far no systematic review of various crops has been made with regard to such factors. Most attention has been paid to the trees since they have often been regarded as the "new" component. The crop component in the system has been taken for granted and it is assumed that it is the tree component that has to be adjusted to fit into the farming system.

In order to properly understand the potential for integration of trees in a farming system, however, it is important to know the characteristics of the different kinds of crops as well as of the tree species that might be combined with them.

In the following section some important crops will be described, as far as possible with special reference to the factors mentioned above. The selection of crops to be covered posed a problem in terms of their definition as trees or shrubs. The crops covered are crops in a rather narrow sense; thus, for example, fruit trees have been excluded. Coffee, tea and cassava have been included in spite of being woody shrubs, and so have bananas in spite of being tree-like herbs.

6.2 Some important crops in relation to agroforestry

Maize (Zea mays)

Origin: Maize originated in Mexico and was introduced into East Africa as early as 1643 (Ngugi, Karau and Nguyo, 1990). The early varieties came from the Caribbean and were only suited to the coastal strip. The spread of maize into the highlands and medium-altitude areas, with a consequent decline in most places of the indigenous cereals, was largely due to the introduction by European settlers of varieties from South Africa (Acland, 1971).

Section 6.2.is based on Ngugi, Karau and Nguyo, 1990; Acland, 1971; and the author's experience.

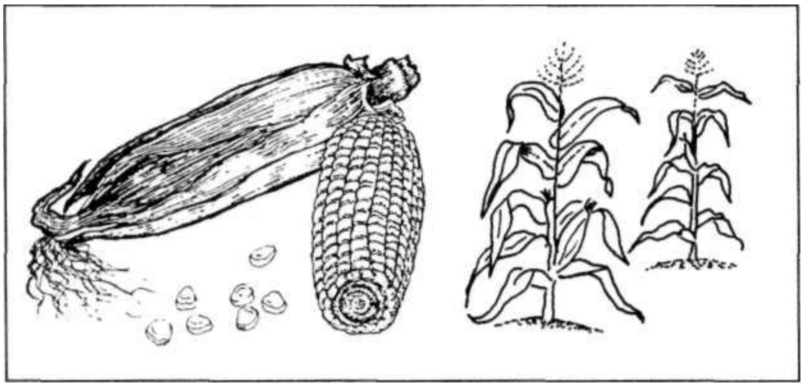


Figure 6.1 Maize

Ecology: Maize has a higher yielding potential than the indigenous cereals where water and drainage are favourable. The young maize plant is moderately drought resistant, but from five weeks onwards it is less so. Maize requires well-drained soil and a good supply of nutrients.

Features in agroforestry: Maize is light demanding, so shade may reduce crop yields. It is sensitive to competition for moisture, so intercropped trees must be of **a** non-competitive type in drier areas. For example, Leucaena in hedgerows is not recommended in areas with less than 800 mm rain. Wind damage can be **a** problem, so trees are useful as windbreaks.

Beans (Phaseolus vulgaris)

Origin: South America.

Ecology: Beans are annual legumes and have the capacity to fix atmospheric nitrogen. The degree of nodulation is very variable, however: in some areas large nodules are formed while in others none are produced. Beans are not drought resistant and ideally they need moist soil throughout the growing period. High temperatures cause a poor fruit set. Beans demand free-draining soils with a reasonably high nutrient content.

Figure 6.2 *A young bean plant*

Features in agroforestry: Beans are shade tolerant, and since they prefer lower temperatures they normally perform well under maize, bananas or other trees.

Cassava (Manihot esculenta)

Origin: Indigenous to Africa.

Ecology: Cassava is widespread in areas below 1,500 m, occasionally higher. It is very drought-resistant and is able to give good yields on poor soils. Cassava is suitable for areas with erratic rainfall where other crops may fail in bad years. Its main requirement is well-drained soil. As a result, cassava is one of the few crops that fits into a definite rotational pattern on small holdings and owing to its undemanding nature is often planted as the last crop in the arable period before the land reverts to fallow. Weeding is only required during the first year; later weeds are tolerated. Cassava has been demonstrated to be a soil improver.

Features in agroforestry: Cassava appears to be sensitive to shade but not to other forms of competition from trees.

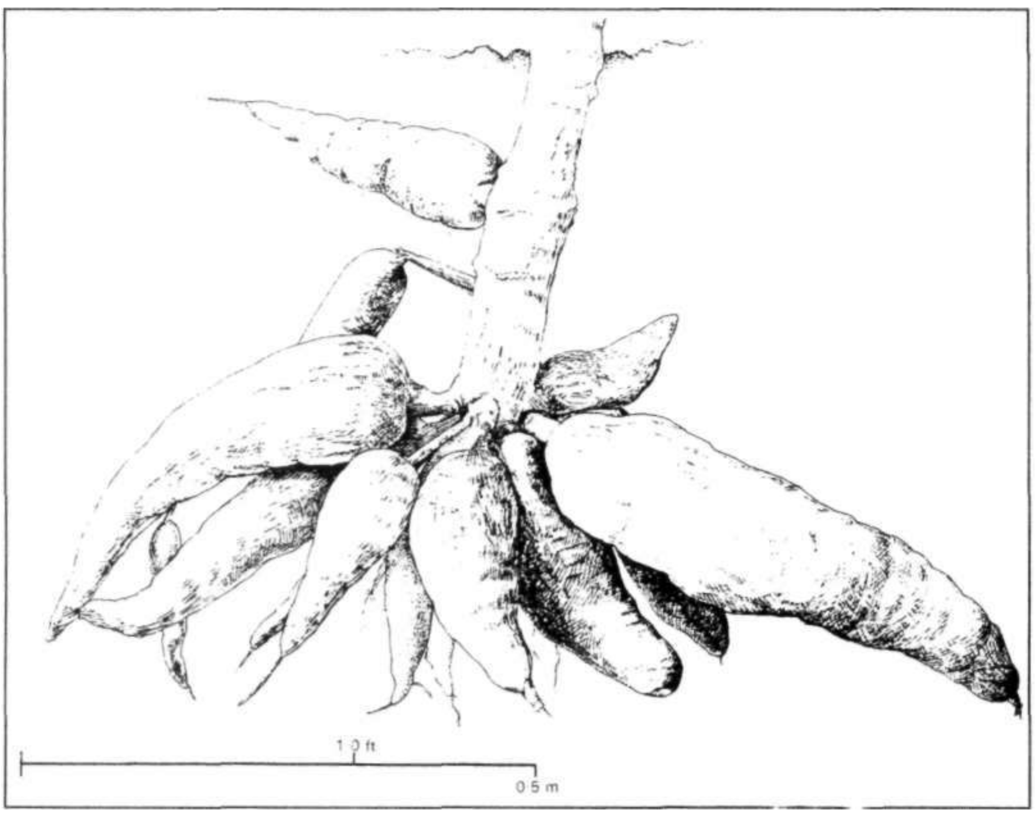


Figure 6.3 The underground structure of a cassava plant

Sorghum (Sorghum vulgare)

Origin: Indigenous to Africa. It has been cultivated for more than 4,000 years in Egypt-

Ecology: Sorghum is drought-resistant and often out-yields maize under dry conditions. It is reasonably tolerant of waterlogging and yields comparatively well on infertile soils. Sorghum has twice as many roots as maize in a given volume of soil. The roots do not die back, during drought and the leaves roll up to minimize transpiration. In this way the plant can remain dormant when other crops would be killed, and when the rains start again it recovers rapidly.

Features in agroforestry: Sorghum is sensitive to shade, as are all cereals. Birds, particularly Quelea, are one of the main causes of crop loss in sorghum: bird-susceptible varieties sometimes give no yield at all. Weavers, starlings, bishop birds and many other kinds of bird also attack sorghum but are less devastating than quelea. The exact role trees may play in attracting such birds has not been determined, and neither do we know if increasing perching sites for birds of prey, by pollarding trees for example, can reduce the damage by grain-eating birds.

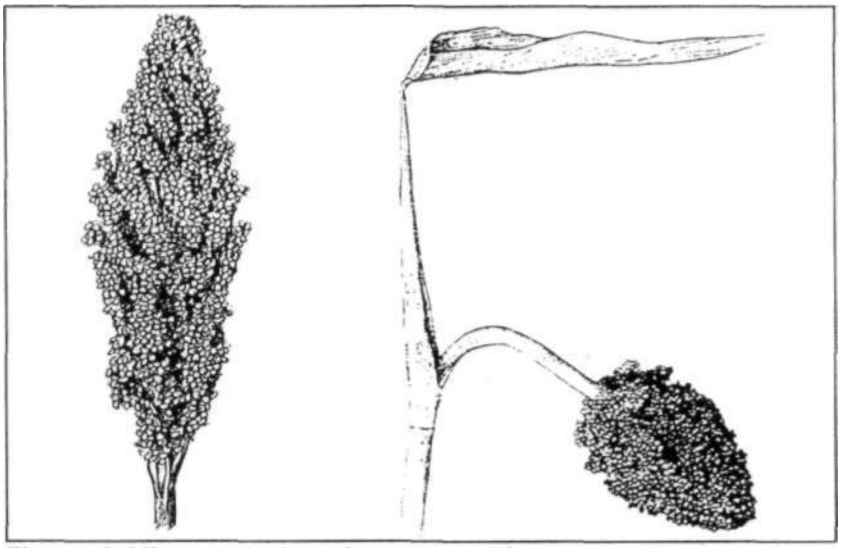


Figure 6.4 *Two varieties of sorghum: "Serena" with a compact* ponn/'c/e *and "Goose-necked" variety with red grains*

Finger millet (Eleusine coracana)

Origin: Some millets are believed to be indigenous to eastern Africa, but they are now widely grown in both Africa and Asia.

Ecology: Finger millet tolerates dry spells in the early stages of growth, but after the first month it requires a steady supply of moisture if good yields are to be obtained. It is usually grown between 900 and 2,400 m in areas with at least 900 mm rainfall. It only yields well on fertile soils with good drainage.

Features in agroforestry: Similar to sorghum with regard to shade and bird problems.

Figure 6.5 *A head of finger millet*

Rice (Oryza sativa)

Origin: Southeast Asia is regarded as the centre of origin for rice from where it has spread to many parts of the world.

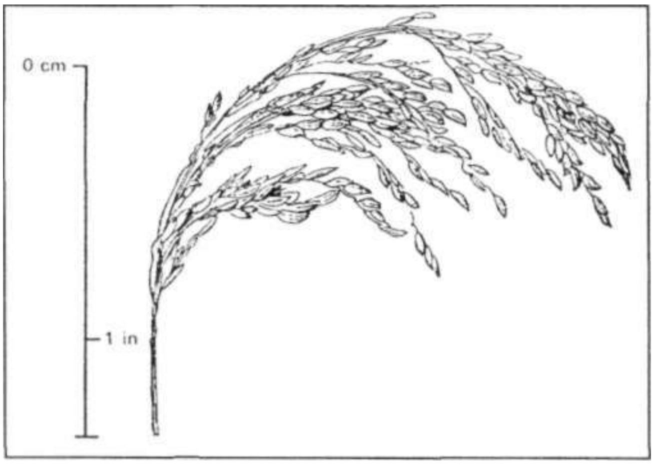


Figure 6.6 *A head of rice*

Ecology: Rice is an unusual crop in that it can grow not only under waterlogged conditions but also in standing water. It prefers high temperatures and grows best below 1,200 m. Sandy soils can support rice, but only if there is a permanent high watertable. Otherwise heavy soils are needed to retain irrigation water.

Features in agroforestry: There are practically no trees on the irrigation schemes in Kenya where rice is grown. Paddy fields are special environments and few trees can thrive there. Rice is also a shade-sensitive crop and wood supplies for irrigation schemes are best met from woodlots planted nearby.

Tea (Camellia sinensis)

Origin: From Burma tea has been taken to many other parts of the world. The first tea was planted in Kenya in 1903 near Limuru, but most tea plantations were established after 1945.

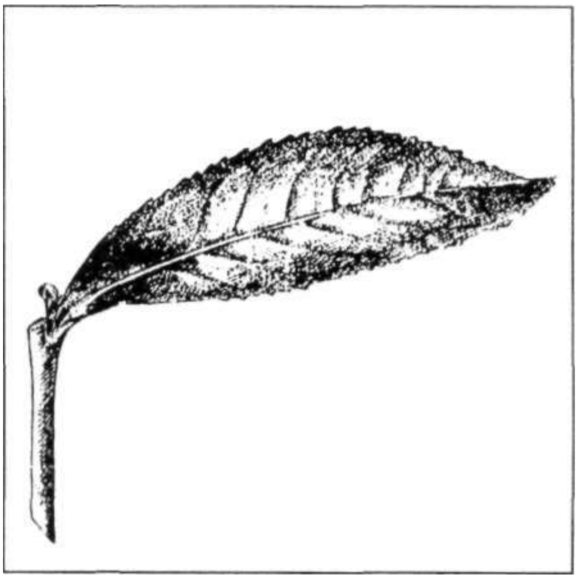


Figure 6.7 *A tea cutting ready for planting*

Ecology: Tea tolerates short dry spells but only produces well with adequate rainfall. The lowest altitude at which it will grow well, 1,200 m, is set by scarcity of rainfall, whereas the upper limit, 2,200 m, is set by the incidence of frost. For good growth, soils should be deep, well drained and slightly acidic.

Features in agroforestry: Tea growing areas frequently experience strong winds and windbreaks are recommended. A tree species particularly well suited to use in tree growing areas is *Hakea maligna.* Armillaria root rot, *Armillaria mellea,* is a serious disease of tea in east Africa. Armillaria is promoted by the presence of old stumps and roots of trees which have been infected, so such stumps should always be carefully removed before new tea is established.

In other parts of the world shade trees are interplanted with tea, but this is not normally done in Kenya. Shade trees in tea plantations are only beneficial in hot and humid areas, e.g. Assam, but due to the higher altitudes of the tea plantations in Kenya the soil temperatures are sub-optimal for the growth of tea. Shade trees serve to moderate the soil-temperature differences between day and night, but there is no need for this in the cool tea-growing areas in Kenya. The overall impact of shade trees on the micro-environment has been found to result in lower tea yields.

Drying of tea leaves requires a lot of energy. Currently the energy source for this purpose in Kenya is largely imported oil, and it has been argued that this could be substituted with fuelwood produced near the tea estates. Increased wood production for this purpose would best be achieved through establishment of more woodlots.

Arabica coffee (Coffea arabica)

Figure 6.8 An Arabica coffee tree (for clarity, the third stem was omitted)

Origin: Ethiopia. Coffee was introduced into Kenya in 1897 by missionaries. Coffee is one of the most valuable commodities in international world trade and is very important for Kenya's foreign exchange earnings.

Ecology: The best coffee areas in Kenya are between 1,400 and 1,900 m altitude, with rainfall of 1,500-2,250 mm. The best soils are well-drained volcanic soils, deep, fertile and slightly acidic.

Features in agroforestry: Coffee is shade tolerant, which enables farmers to grow trees in many spatial arrangements with the crop. Grevillea was originally introduced as a shade tree for coffee and is still the most popular tree in coffee-growing areas. Other common trees with coffee are *Cordia abyssinica* and *Albizia* spp. Armillaria root rot attacks coffee, so all old roots of trees that may harbour Armillaria should be removed when new coffee is established. In large plantations where there are no shade trees windbreaks should be considered.

Bananas (Musa *spp.)*

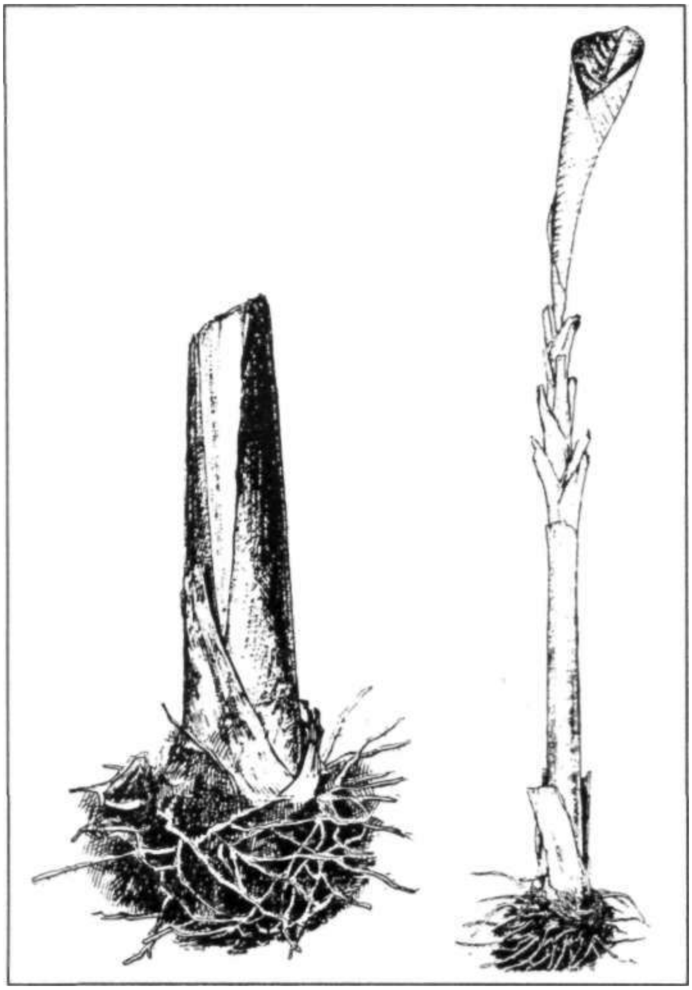


Figure 6.9 Banana planting material

Origin: Bananas originally came from Southeast Asia, but were introduced to Africa many hundreds of years ago.

Ecology: For good yields bananas require a constant supply of moisture. They are thus most important in areas with well-distributed rainfall, e.g. Kisii and Kakamega. Bananas also require a warm climate, so the crop performs best at altitudes below 1,800 m. Bananas also require rich, deep and well-drained soils.

Features in agroforestry: Bananas are often used as a middle- or upper-storey crop with other crops being grown underneath. Sometimes they are mixed with taller trees. Occasionally bananas are also grown in monoculture. Bananas are shallow rooted, most roots being found in the top 15 cm of the soil. Therefore they are sensitive to wind damage and windbreaks or support stakes to prevent the banana plants from falling over are essential. Bananas are sensitive to high nematode populations in the soil. If the nematode population is too high banana cultivation must be halted temporarily and other crops grown until the nematode population has decreased.

Wheat (Triticum *spp.)*

Origin: South-western Asia. Wheat was introduced into Kenya early this century by the white settlers.

Ecology: The best wheat-growing areas are above 1,800 m with at least 750 mm rainfall. The soils should be well drained and have a high nutrient content.

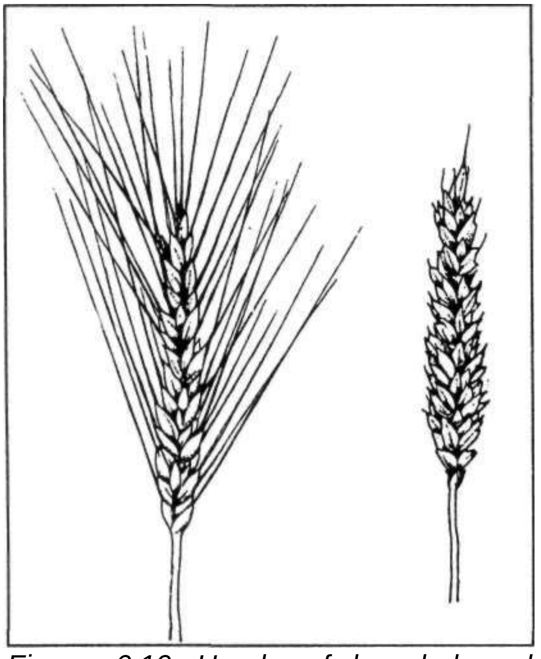


Figure 6.10 Heads of bearded and beardless wheat

Features in agroforestry: In some wheat-growing areas Acacia trees have been left in the fields, apparently with little or no reduction in yields. Strong winds may cause lodging, hence trees are useful for windbreaks. Some bird damage may occur, but it is not as serious as for sorghum and millet. Wheat is a light-demanding crop, so trees in fields must either have a natural light shade or be managed to reduce the intensity of the shade.

Sweet potato (Ipomoea batatas)

Origin: South America, but widespread in the tropics.

Ecology: Sweet potato is a crop which grows under a very wide range of ecological conditions from sea level up to 2,400 m, in a wide variety of soils, and in areas receiving more than 750 mm rainfall. Little weeding is required since the vines cover the soil very effectively and suppress most weeds.

Features in agroforestry: Sweet potatoes are not normally grown with an upper storey of trees, and in general trees do not have a big role to play in association with sweet potatoes.

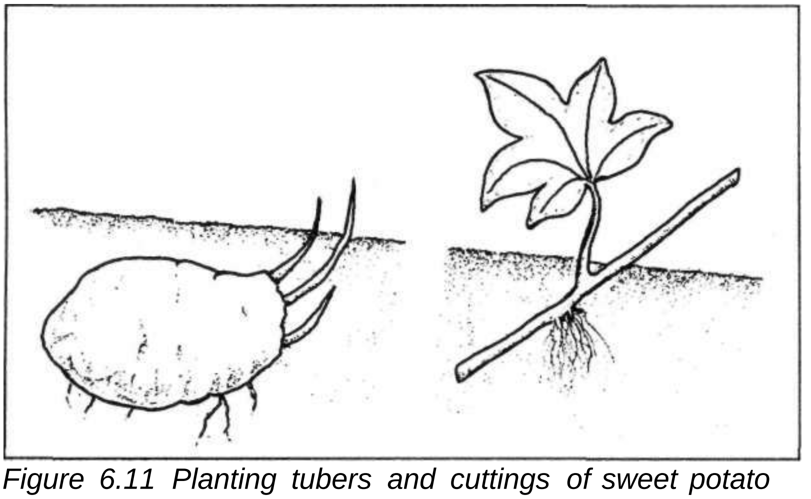


Figure 6.11 Planting tubers and cuttings of sweet potato

Irish potato (Solanum tuberosum)

Origin: South America, but now widespread in temperate regions and in the tropical and subtropical highlands.

Ecology: The Irish potato grows best in cool climates with a rainfall of 25 mm per week during the growing season and at altitudes ranging from 1,500 m to 2,900 m. The soils should be well drained and rich in nutrients. Sandy soils are better than heavy soils.

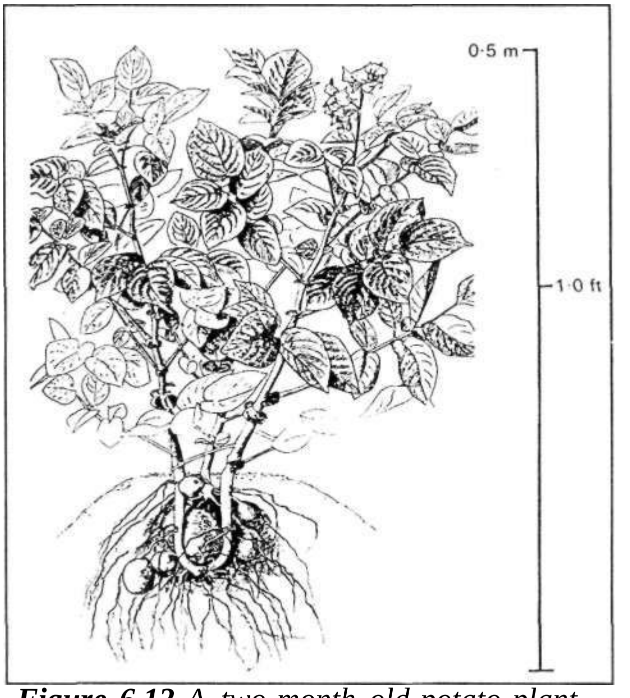


Figure 6.12 *A two-month old potato plant*

Features in agroforestry: Irish potatoes are relatively shade tolerant and can sometimes be seen growing under bananas with good results. Irish potatoes are badly damaged by high nematode populations, and if nematode infestation is severe potato cultivation may have to be discontinued.

Yams (Dioscorea *spp.)*

Origin: Different species have different origins. Now widespread all over the tropics.

Ecology: Tropical areas which have a long rainy season are best for this crop. Most types of yams require at least six months of rain, and the average annual rainfall should be at least 1,500 mm. Temperatures of 25-30°C are best for yam cultivation, and the soils should be fertile, loose and well drained. Intercropping and crop rotation are recommended since yams are sensitive to nematode build-up. In Kenya, yams are common in Central Province and in Eastern Province around Mount Kenya.

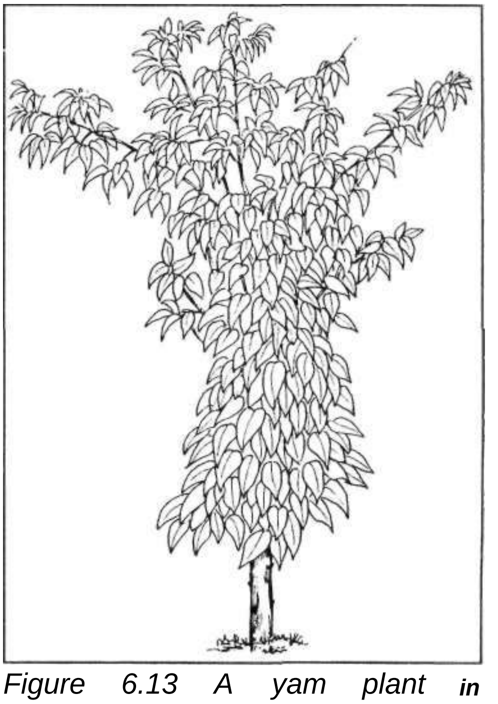


Figure 6.13 A yam plant in association with Commiphora

Features in agroforestry: In Kenya, yams are often grown in association with *Commiphora eminii,* subsp. *zimmermanni.* A cutting of Commiphora is planted as a stake for the yam, and since Commiphora cuttings take root easily eventually a Commiphora tree provides support to the yams. Both grow well together without any signs of competition and there are several other benefits from the Commiphora beside being a support to the yams, e.g. emergency fodder, timber, making of mole traps and firewood.

Tobacco (Nicotiana tabacum)

Origin: South America from where it was brought to Europe and later by the Portuguese to Africa. Tobacco growing was initiated by the British American Tobacco Company (BAT) in the late 1930s, but it was in the 1970s that the cultivation of tobacco expanded considerably.

Ecology: Tobacco requires about 750 mm of rain and the altitude range is from sea level up to 1,260 m. A high light intensity is required for good production and the relatively low light intensities in Kenya result in low yields compared to those in some other countries. Crop rotation is required to avoid build-up of nematode populations.

Figure 6.14 A young tobacco plant

Features in agroforestry: Curing tobacco requires fuelwood and BAT has long promoted tree growing among small-scale tobacco producers in Kenya. Recommended tree species are *Grevillea robusta, Cassia siamea, Markhamia lutea, Eucalyptus* spp., and to a lesser extent *Terminalia brownii, Gmelina arborea, Acacia albida, Cordia abyssinica, Sesbania sesban* and *Azadirachta indica. Eucalyptus* spp. cannot be used for fire-curing tobacco because of the odour the wood imparts to the smoke. Woodlots with a spacing of 2 x 2 m should be established, preferably on marginal land where little or no other production takes place. Planting of trees is also recommended on farm lands, e.g. on boundaries and terrace risers. In dry areas, water-harvesting methods are adopted. The light-demanding nature of tobacco limits its scope for intercropping with trees.

Sugar cane (Saccharum officinarum)

Origin: New Guinea. Sugar-cane growing expanded in Kenya during the 1920s with establishment of the first sugar factories.

Ecology: Sugar cane is a perennial grass which grows well at altitudes from sea level up to 1,600 m in areas with not less than 1,500 mm rainfall. It prefers heavy fertile soils.

Features in agroforestry: Sugar cane is strongly light demanding, so intercropping trees and sugar cane cannot be recommended when sugar cane is commercially grown. Sugar-cane growing areas are often those where severe shortages of wood are experienced, so establishment of woodlots and intensified tree growing around homesteads are recommended to meet the needs for wood. Under small-scale irrigation in the Kerio Valley sugar cane is sometimes grown with *Ficus sycomorus* and *Acacia tortilis.*

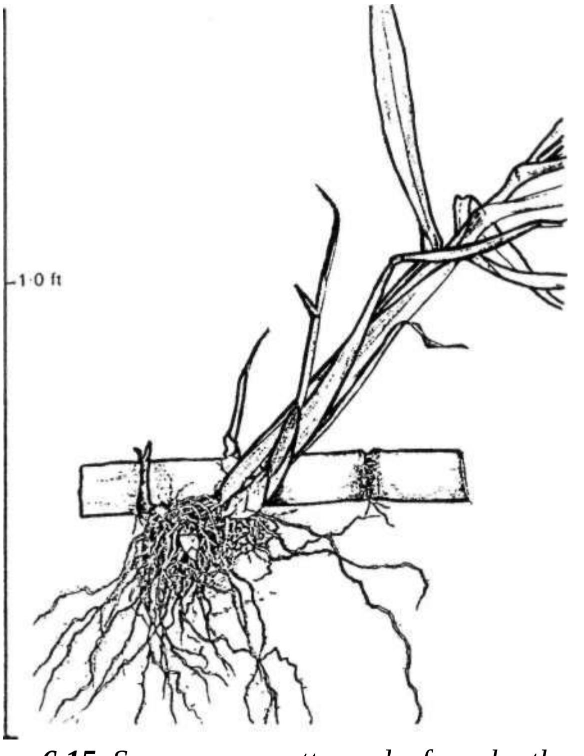


Figure 6.15 *Sugar-cane sett ready for plantlng*

7. THE TREE COMPONENT

7.1 Factors of importance

The role of trees in land-use systems has already been discussed in Chapter 4.

The most important ways in which trees can contribute to production are:

- By the direct production of tree products
- By having service functions that enhance the production of other components, e.g. crops or livestock.

There are, however, other factors to be considered:

- Ease of propagation
- Taboos and beliefs related to the tree, both positive and negative
- Ease of management
- Time from planting to harvest, i.e. growth rate.

If they are to be discussed in economic terms all these factors can be divided into two groups, the positive factors (credit, representing the gross value of the production), and the negative factors (debit, representing the cost of the production).

Positive (credit)

- Value of the direct production
- Value of the service functions
- Positive intangible value (taboos and beliefs).

Negative (debit)

- Competition with other components in the system
- Cost of establishment and management
- Risks
- Negative intangible value.

In addition, the time required between investment (planting) and harvest is of importance. A quick return is always desirable.

7.2 Criteria for a good agroforestry tree

Main criteria

The main criterion for selection of a tree species is that it be liked by the farmer. A well-known tree is better than an unknown tree, but when a new species is introduced it is, of course, necessary to work with an unknown tree. A tree that is disliked by the farmer, for whatever reason, is always a non-starter in extension.

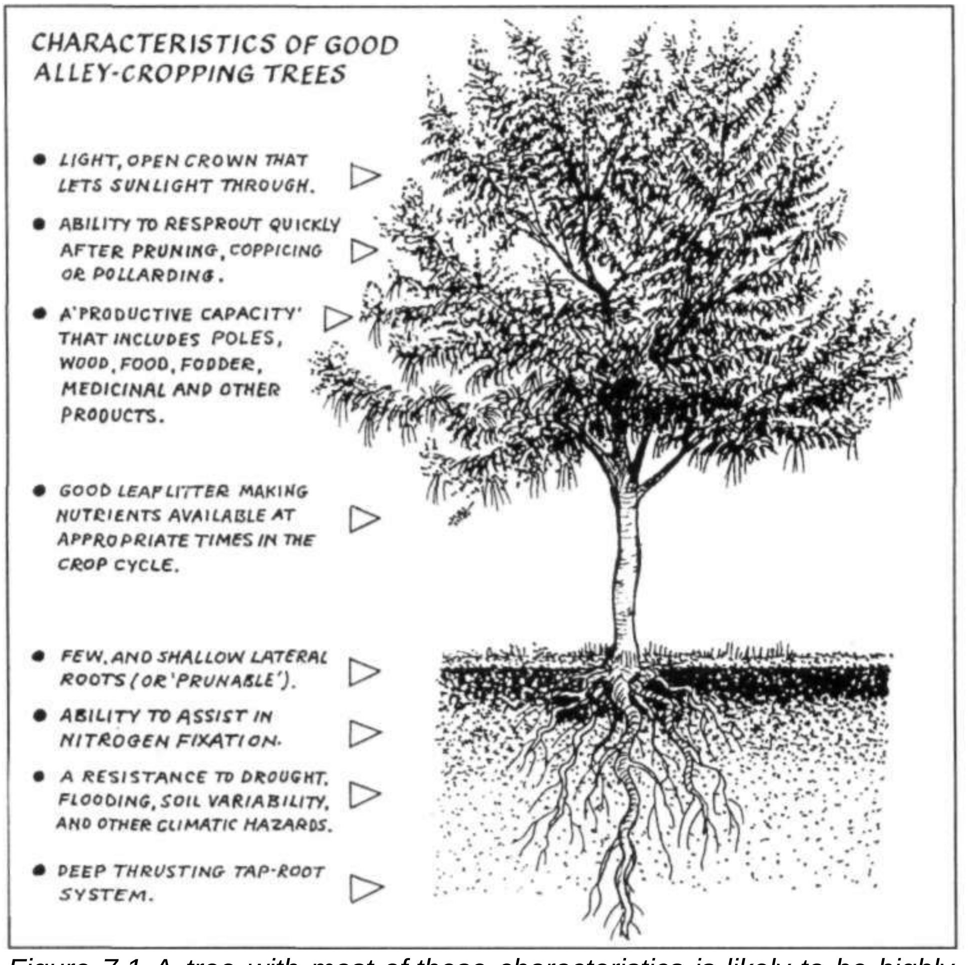


Figure 7.1 A tree with most of these characteristics is likely to be highly valued by farmers

A farmer is likely to appreciate a tree that gives a high net value, i.e. high values for the positive factors (= high "income") and low values for the negative factors (= low costs).

High "income"
The perceived value for the farmer of the direct and indirect production should be high. Which product or service is seen as being most important may vary from one area to another and from one farmer to another according to his needs. In fact the values attached to various products or services may often vary even within the family, e.g. the wife's preferences may sometimes be quite different from those of her husband. Thus it is desirable to involve both wife and husband in discussions on tree species.

Low cost
The major cost is competition with other components, which should be as little as possible. Land holdings are often small, so very competitive trees (e.g. *Eucalyptus* spp., *Acacia mearnsii)* may not be accepted by the farmers even if they are fast growing and have valuable production.

Trees with a deep root system are usually less competitive with crops than those with many shallow roots. Most indigenous trees in Kenya have deep roots, e.g. *Acacia* spp. and *Albizia* spp. Grevillea is also deep rooted. Shallow root systems may be desirable if the trees are intended to stabilize soil and the question of competition with crops is less important. Examples of trees with shallow roots are *Casuarina* spp., *Leucaena leucocephala, Cupressus lusitanica,* and *Sesbania sesban,* although the latter does not compete with crops since its overall root system is small and this species fixes its own nitrogen. Eucalyptus may represent a special category which has roots distributed both near the soil surface and deeper down in the soil profile.

Trees with dense shade compete with light-demanding crops such as cereals. Shading can be reduced through management. Other trees naturally have a light shade, e.g. *Acacia* spp., *Sesbania sesban, Casuarina* spp., *Entada abyssinica* and *Eucalyptus* spp. Such trees may either have small leaves, or vertically oriented leaves or be bare or partly bare during the crop-growing season.

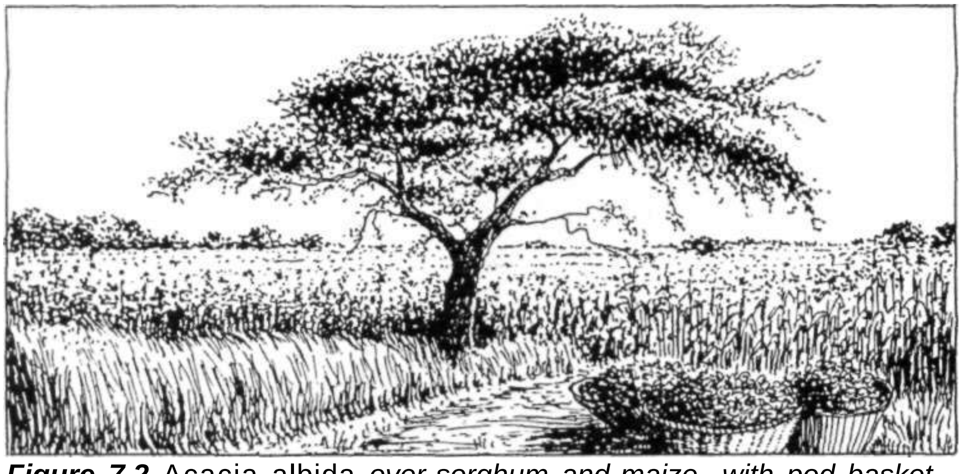


Figure 7.2 Acacia albida *over sorghum and maize, with pod basket*

Some trees which naturally have rather dense shade but that can be easily managed to reduce the shade are, for example, *Grevillea robusta, Markhamia lutea, Cordia abyssinica, Croton* spp., *Leucaena leucocephala* and *Calliandra calothyrsus.*

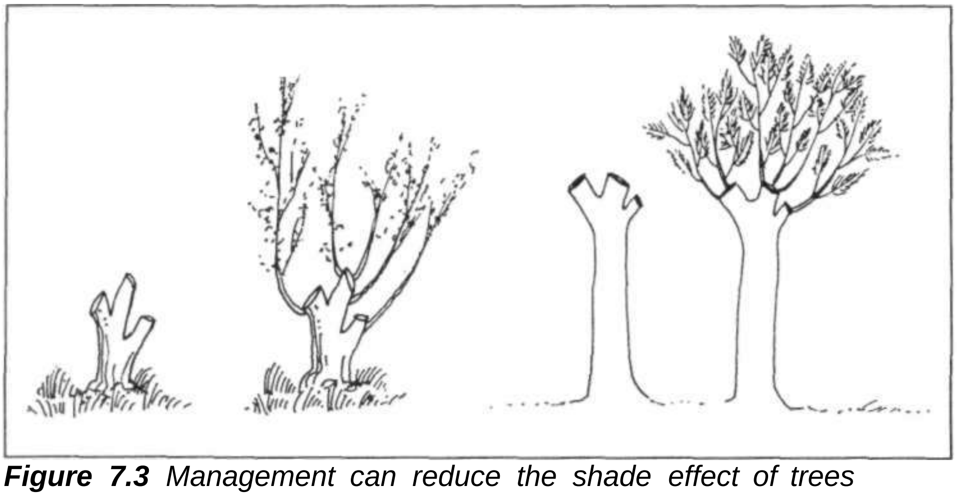


Figure 7.3 *Management can reduce the shade effect of trees*

Other factors that determine the degree of competition are ability to fix nitrogen and the chemical composition of the litter.

Easy methods of propagation also contribute to low costs. On-farm methods are usually cheaper than seedlings produced in central nurseries, and use of cuttings, wildings or direct seeding are the cheapest. A long life span reduces the relative cost of propagation. For instance, coppicing of trees once they are established makes it possible to harvest several times from just one establishment procedure.

The risks involved in agroforestry may be related either to failures of one component, e.g. the trees do not perform well, or to failures in the interaction between components, e.g. introduction of pests or diseases. Other risks may be that trees turn out to be weeds requiring more labour, or that they prove to be a nuisance in some other way, e.g. they are poisonous. The risks are usually fewer with indigenous and well-known species than with exotic or unknown species.

Finally, trees are more likely to be appreciated by farmers if there are no negative taboos or beliefs associated with the particular species.

Figure 7.4 A shady tree provides a pleasant community meeting place

How to select tree species for extension

If extension is geared towards promotion of the growing of more trees in an area, selection of species should normally be done primarily by the farmer with technical support from the extension worker. A basic requirement for the extension worker to be effective in this process is for him or her to know the common and important tree species suitable for different situations and uses, preferably including knowledge of their vernacular names in the area concerned. Refer to the ICRAF book A *Selection of Useful Trees and Shrubs for Kenya* which was developed primarily to help extension workers acquire such knowledge.

If you are looking for species in addition to those already known to and grown by farmers in the area, the following are some useful hints:

- Identification of trees in urban areas
- Identification of trees near old settlements, mission centres, institutions
- Contact central institutions where databases, e.g. the ICRAF multipurpose tree (MPT) database, are available for search of suitable species.

Exotic tree species, some of which are potentially very useful in rural areas, have often been introduced in urban areas but have not spread further. Investigation of such species may often be fruitful, and the same applies to trees at mission centres or other places where foreigners or people from other areas in Kenya have lived. The ICRAF MPT database has information on a large number of species and searches can be made based on locality, ecological and land-use conditions and desired uses. The results from such searches need to be used with caution, but they can provide useful hints on potential species. The major source of information on useful trees will always be the local people, and final decisions should also always be made by them.

7.3 Tree management

There are certain management techniques which are applied to trees and shrubs in agroforestry systems. Some of these techniques are similar to those used in the management of trees in forestry plantations, but others are different. The most important management techniques with regard to the part of the tree which is above ground are:

- Pruning
- Lopping
- Pollarding
- Coppicing
- Thinning.

In addition, root competition can be reduced by certain management techniques applied to tree roots.

Pruning

Removal of branches from the lower part of the tree crown is known as pruning or side pruning. While pruning a tree, branches are always cut near the stem.

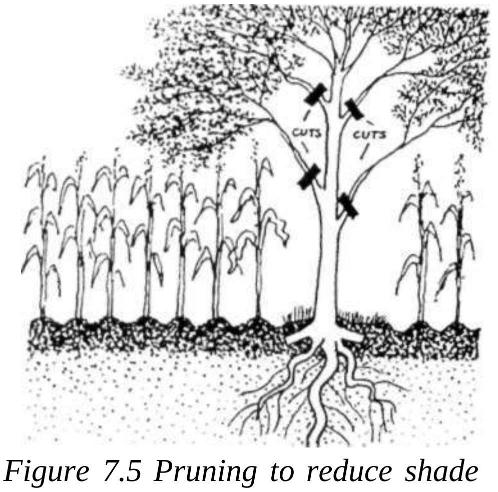


Figure 7.5 Pruning to reduce shade

The objectives of pruning in agroforestry are threefold:

- Reduction of shade for crops near the tree
- Improving the quality of the trunk, mainly for timber and poles
- Early harvest of branchwood for fuel or other use.

Too much pruning may reduce the growth of certain species. For young trees, at least four or five layers of the green branches should remain uncut, while older trees of certain species can tolerate more severe pruning (see "pollarding", below).

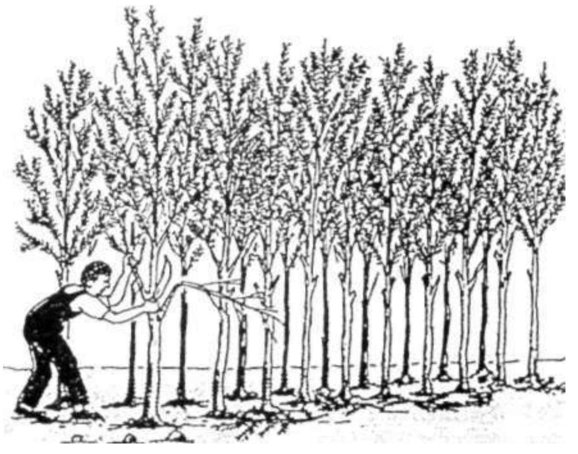


Figure 7.6 Side pruning

Pruning should be done at least up to the height the adjacent crops if trees are growing in fields. Such pruning facilitates farming operations and reduces competition. The best time for pruning is towards the end of the dry season when the work will not interfere with growing crops and when the workload in other agriculture tasks is not so heavy.

Case Report No 27: Side pruning of Grevillea

Mr Irungu Munyonge of Mirichu Sub-location, Kiharu Division of Muranga District has a 1.6 ha farm. On this farm he has three dairy cows in a zero-grazing unit, 1,000 coffee bushes, and a quarter-hectare woodlot of *Acacia mearnsii* and *Grevillea robasta.* In other parts of the farm he grows annual crops, mainly maize and beans. Other trees are scattered outside the woodlot, mainly Grevillea and fruit trees such as pawpaw, loquat and guava. Fodder is produced on terrace embankments where Napier grass is grown. Along the boundaries are many Grevillea trees spaced at intervals of 3-4 m.

Mr Munyonge side prunes his Grevillea to reduce shading of crops, to obtain firewood and to improve the quality of the timber. He emphasizes that the first pruning should be done when the tree is 4-5 years old. He then normally cuts the whole crown (pollarding) when the tree is 6-8 years old. By that time the trees have reached a height that allows him to obtain 3-4 pieces of wood each 3.0-3.6 m in length, i.e. a total trunk length of 9-15 m. The timber harvest is done when the trees are 18-20 years old, when the average diameter will be 0.6 m.

There are many reasons for frequent pruning or pollarding. According to Mr Munyonge these are:

- Demand for firewood
- Crops being affected by shade
- The need for cash.

Other uses for the products of pollarding and pruning are:

- Banana props
- F*ito* for fencing
- Dry leaves, e.g. of Grevillea, rot very quickly and make good compost when mixed with manure, while green leaves take a long time to rot.

Lopping

Lopping is distinguished from pruning in that branches are not cut from the base. Also lopping is not always done starting from the lower part of the tree but can be more haphazard. If any selection of branches is made, the main criterion is often a good green leafy biomass since the lopping is usually done to obtain branches for fodder.

Figure 7.7 Lopping

Lopping is the most common harvesting technique for tree fodder in many ASAL areas. One of the main advantages with this technique is that it allows harvest without killing the tree. All tree species can be lopped, but the growth rate of certain species can be retarded if they are heavily lopped.

Case **Report No 28: Lopping for fodder in ASAL**

Lopping is a common practice in many ASAL areas. Mr Logeding'ole of Ptokou Group Ranch reported on how the Pokot utilize trees in Case Report Nos. 4 and 23. On lopping he says that two important species that are commonly lopped are *Kigelia africana (rotin* in Pokot) and *Balanites aegyptiaca (tuyuno).* These are lopped for fodder during the dry season.

Acacia are also lopped to reduce shade on maize and their leaves used as fodder for goats. Lopping is a good harvesting method for some Acacia. If the whole tree is cut, often it will not resprout and therefore coppicing is not recommended. If Acacia are lopped, however, they readily resprout.

Mr Louwoto (Case Reports No. 2 and 23) from Turkwell, Turkana, also has more information on lopping. In his area, young Acacia are lopped or pollarded for fodder. *Acacia mellifera (ebenyo* in Turkana) and *Acacia tortilis (eoi)* are lopped in order to harvest thorny branches for fencing, and *Cordia sinensis (edome)* is lopped for branches that can be used for construction.

Pollarding

If all the branches and the top part of a tree are cut off this is known as pollarding. There can be several objectives with pollarding:

- Early harvest of wood, fodder or other biomass
- Production of wood or fodder that is out of the reach of livestock, hence there is no need for protection from browsing
- Reduction of shade for crops near by
- Regeneration of the tree crown to promote growth of the trunk for timber or poles.

The choice of pollarding height and frequency depends on the desired products. If the main aim is production of timber or poles, the top of the tree should be cut as high up as possible, and the pollarding interval should be such that the crown is kept as green and vigorous as possible for the maximum production of trunk wood. An interval of 2-5 years is appropriate in such cases.

Figure 7.8 Pollarding

On the other hand, if the main aim is production of fuelwood or fodder, it is better to pollard lower down the tree to facilitate access. Pollarding can then be done more frequently, e.g. once a year. It is advantageous to try to form a wide "stool" (the part of the tree remaining at the base when it has been cut) in order to achieve a substantial production of biomass.

Sometimes the main aim is to produce staking material, poles or *fito* for construction. In such situations a wide stool will allow many stems to grow. Initially too dense a stand may sprout after pollarding, and thinning is then recommended, leaving a suitable number of branches in relation to the size of the stems eventually desired.

Not all species can withstand pollarding. Some commonly pollarded species are:

- *Balanites* spp.
- *Bridelia micrantha*
- *Casnarina* spp.
- *Cordia abyssinica*
- *Croton* spp.

- *Erythrina abyssinica*
- *Faidherbia (Acacia) albida*
- *Ficus sycomorus*
- *Grevillea robusta*
- *Jacaranda mimosifolia*
- *Manihot glaziovii*
- *Markhamia lutea*
- *Morus alba.*

Case Report No. 29: Pollarding different species

Mr Joma Murau of Kathaari Sub-location of Kyeni North Location, Runyenjes Division, Embu District, has a 2 ha farm where he lives with his family. He has two children in Standards 5 and 6 respectively. He grows many different tree species, many of which are in the cropland and are pollarded.

Mr Murau gives five important reasons for pollarding trees:

- To get biomass for manure
- To obtain fuel wood
- To get poles for farm construction and building
- To minimize shading on crops
- For Grevillea: to enhance the growth of the bole for more timber.

Grevillea is normally pollarded high up to maintain a long stem for timber and pole production. The pollarding height is determined by the performance of the tree. If there are many branches or some type of deformity at a certain height that height may be chosen for cutting off the top. Consideration is also given to how many pieces of timber of standard lengths can be harvested later on.

For other trees, pollarding is usually much lower and more haphazard. The main aim in pollarding other species of trees is to produce more biomass, leaves or poles at a height at which crop shading is minimized and harvest is easy. The production of leaves is more important than the production of poles. Mr Murau leaves protruding stumps of branches to produce many shoots all up the tree to maximize leaf production. After pollarding, the wood is separated from the leaves. The wood is used for fuel, stakes for tomatoes, poles for fencing or house or cattle-shed construction, and the leaves are thrown into the zero-grazing unit to serve as a bed for the cattle and to obtain more compost from the manure. Leaves are also used as mulch on tomato and potato plots where they greatly reduce weed growth. Mr Murau also noted that the Grevillea leaves have to be dry before going in to the zero-grazing unit. If put there when they are still green they will not rot.

Case **Report** No. 30: **Pollarding** *Grevillea robusta*

Case Report No. 6 described the progress made by Eliphas Karuguti in becoming self-sufficient in fuelwood largely from pollarded Grevillea.

Mr Karuguti pollards his Grevillea, usually in February and March before the long rains and in September before the short rains. These are convenient times since there are no crops in the fields.

The pollarding interval depends on the product needed. For firewood and mulch, pollarding can be done once a year, but for poles it is done only every second year.

According to Mr Karuguti, Grevillea is a very good tree because it grows fast, gives good timber and can be pollarded to reduce shading on crops.

Case Report No. 31: Managing the shoots from stools

In Case Report No. 18, Mr Ngare reported on the benefits he obtained from pollarded trees. On pollarding techniques he says that *Ole europaea* and Hews *sycomorus* are usually pollarded at a height of 1.5-2.0 m. According to Mr Ngare, that height is convenient for growing poles from the stools and also gives sufficient clearance for crops to grow with minimum shading and interference. He encourages a maximum of six poles on each stool.

Coppicing

Many species of trees and shrubs have the ability to resprout after the whole tree has been cut. If this ability is utilized for regeneration of the tree the practice is known as coppicing. Coppicing can almost be regarded as a method of tree propagation since it can substitute for the task of planting a new tree after a mature one is felled.

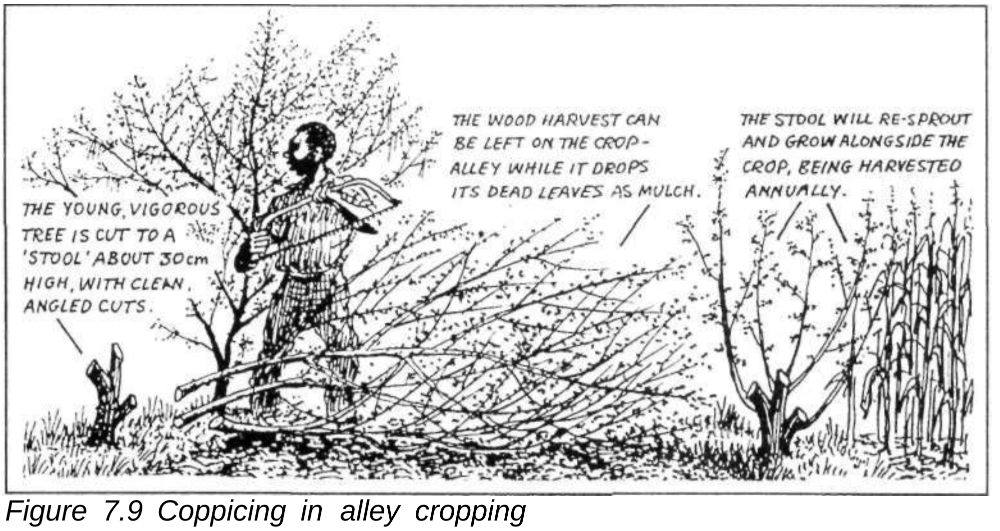


Figure 7.9 Coppicing in alley cropping

Systematic coppicing is applied as the management technique in alley cropping, and it may be an option for trees on soil-conservation structures. In such a situation coppicing may be done annually, but in other situations, e.g. regeneration of Eucalyptus for pole production, it may be much less frequent. In that case, an interval of 6-8 years may be more suitable.

Not all tree species will coppice after being cut. Some commonly coppiced species are:

- *Calliandra calothyrsus*
- *Cassia siamea*
- *Cassia spectabilis*
- *Eucalyptus* spp.
- *Leucaena leucocephala*
- *Markhamia lutea.*

Certain species coppice well when young but may not do so if cut at maturity. Examples are *Casuarina* spp., *Grevillea robusta, Sesbania sesban* and some *Albizia* spp.

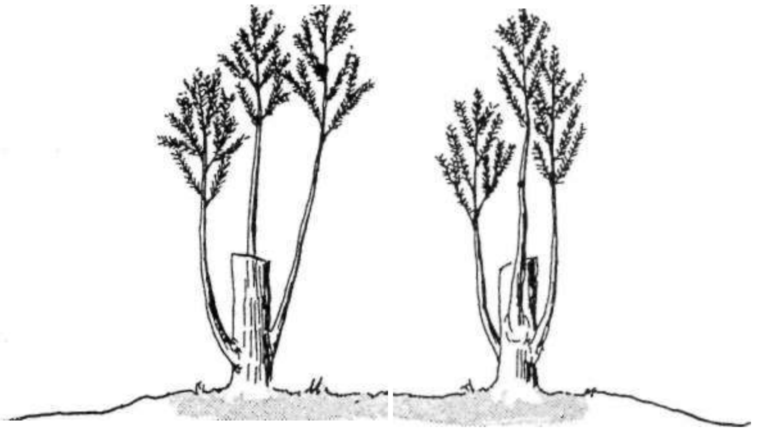


Figure 7.10 Some species only coppice well when young

Case Report No. 32: **Coppicing** *Cassia spectabilis* **and** *Markhamia lutea* **for poles and** *fito*

Mr Njeru Chomba has a 1.5-hectare farm on the slopes of Maranga Hills in Embu District. Just below the farm is a road. Most of the soil from his farm used to be carried away with run-off water coming from the hills through his farm and onto the road. Then he decided to plant a row of *Cassia spectabilis* which he is coppicing and since then the road is no longer damaged by erosion. He has also conserved the soil higher up to prevent erosion from his farm.

There are also Markhamia trees on the farm which are coppiced. Markhamia wood is mainly used for poles but also for fuelwood, whereas the wood from Cassia is best used for fuelwood and only occasionally for poles. Mr Chomba thins the coppice shoots leaving only seven per stump. This minimizes shading on his bean crop. He usually coppices just before the rains or shortly after planting when the beans are still small.

The coppicing height is about 50 cm, and the coppicing interval depends on the product required: for firewood one year (two seasons) and for poles two years. Mr Chomba cuts the coppice shoots for poles when they are 4-6 m tall and sells them at Sh 5 each. The spacing between the trees varies between 4 and 6 m. Other benefits that Mr Chomba realizes from agroforestry are mulch, cattle bedding (manure) and soil conservation.

Case Report No 33: Coppicing techniques for Markhamia

Mr Ooro reported on his use of Markhamia in Case Report No. 10. He has more information on the coppicing technique. After cutting a tree or a stand he normally heaps the leaves and twigs on the stump and burns them there. According to him the coppicing becomes more vigorous if this is done.

A young Markhamia should be coppiced for the first time when it is 7 years old, and thereafter it can be coppiced at 4-5 year intervals when the coppice shoots are 3-4 inches in diameter. Coppicing is, however, also demand driven, and if there is no demand for poles when they have grown to sufficient size, the coppicing can be postponed.

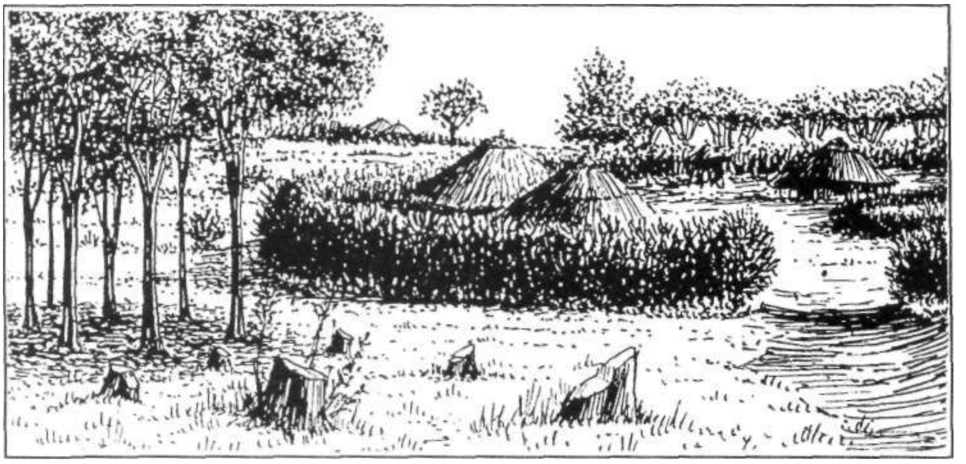


Figure 7.11 A Luo homestead with a Markhamia stand that has been coppiced

Thinning

Trees established by direct seeding or that have been planted with little space between them will soon start to compete with each other. A dense stand initially promotes straight growth and small branches, but later the trees must be thinned otherwise they will grow too slender and eventually not reach the desired size. Thinning is particularly important for trees grown in woodlots, but applies also to other situations where trees are growing close to each other. Thinning can, for example, be done by removing every second tree or two out of every three trees. Thinning is also a way of obtaining some early harvest.

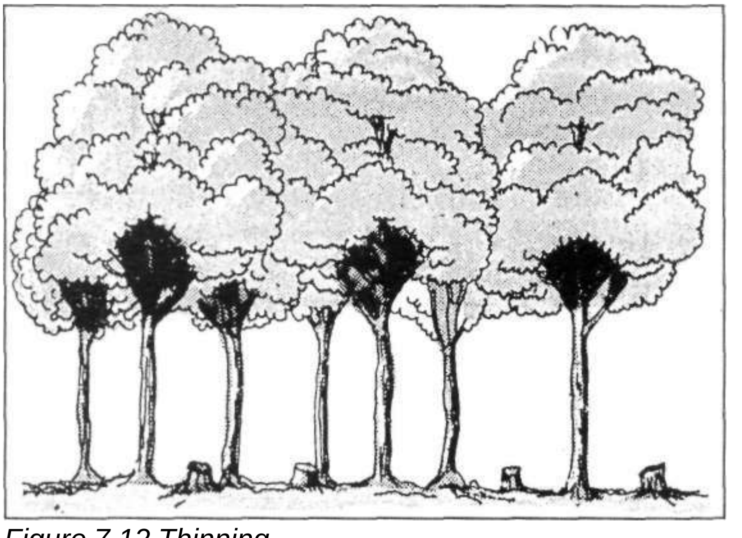


Figure 7.12 Thinning

Management of roots

Just as the tree crown can be managed to reduce competition, so can the roots be managed for the same purpose. Trees growing in cropland can have their shallow roots cut 0.3-0.6 m from the trunk when they reach a height of 2-3 m. This is applicable to species which would otherwise compete with crops.

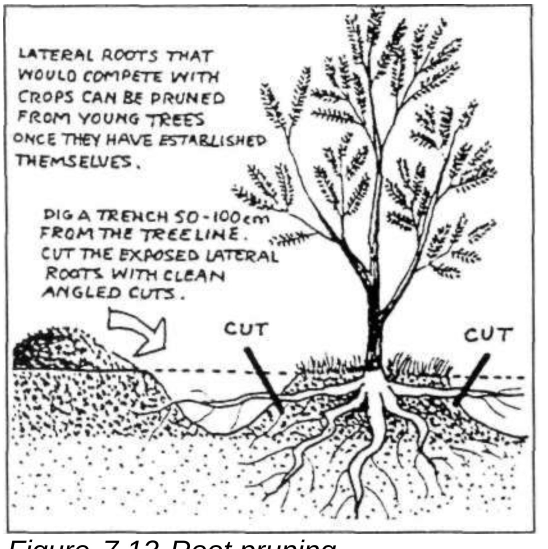


Figure 7.13 Root pruning

Another option practised by farmers in western Kenya is to dig a relatively deep trench (0.3-0.6 m) along the edges of woodlots of, e.g. of *Acacia mearnsii,* where the woodlots border cultivated land. This also serves to minimize competition.

An obvious disadvantage with all techniques for root management is that they require a lot of work-

Case Report No 34: Root pruning to minimize competition

In Laikipia Research Programme, which is a joint undertaking by the University of Nairobi and the University of Bern, Switzerland, studies were carried out on root competition between trees and crops. A reduction in maize yields was observed near live fences as well as near and quite far from single Grevillea trees. Yield reduction was, however, less significant around the Grevillea trees than near live fences. This can be explained by (1) Grevillea having mainly deep roots, and (2) the few shallow roots being extensive and competing with the crops uniformly. If the spacing is 7.5 x 5.0 m between the Grevillea trees, the maize crop is somewhat reduced all over the area, not only close to the trees.

Experiments on root pruning to reduce competition were also carried out. Trenches were dug with a *jembe*[1] about 60 cm from the trees and about 30 cm deep. The numerous small shallow roots along the live fence and a few big roots near the surface around the Grevillea trees were all cut Then the trenches were refilled with soil. The operation was repeated yearly. Mr H.P. Liniger, Ecology Co-ordinator for the project, reported that with this practice yields were as good near the fence and near the trees as anywhere else.

The type of hoe commonly used in Kenya.

Other management practices

Young trees need care and maintenance. Practices in this regard are dealt with in Chapter 9. For management of live fences reference is made to Case Report Nos. 15 and 16. Some information on management of coconut trees is provided in Case Report No. 35.

Case Report No. 35: Management of coconut trees

Mr Safari, who has already appeared in Case Report Nos. 5 and 22, has some information on how he manages his coconut trees.

According to Mr Safari, adding fertilizer or manure to large coconut trees is not a common practice among farmers at the coast. But cattle grazing under coconut will benefit the trees through their dung and urine. The cows, in turn, benefit from the shade of the trees. Sometimes weeds and crop residues are burnt under the coconut trees just before the rains. This practice helps the farmers control weeds and pests and also releases nutrients to the crops and coconut trees.

In the long run such burning is detrimental, however, since nutrients and organic matter are lost and the practice is discouraged by extension staff.

Mr Safari has another tip on the management of coconut trees. If he notes that a coconut tree is aborting most of its fruit he drives a nail or two into the trunk and abortion of young fruit is minimized.

Mr Safari says further that coconut trees of the local tall variety become productive 4-5 years after planting. They can then produce well for 5-10 years, after which production tails off. There is another shorter variety from Zanzibar which yields nuts after three years, but according to Mr Safari these nuts are not good and even the drink in the immature fruits *(madafu)* is not so flavourful.

8. SOME AGROFORESTRY PRACTICES IN KENYA

8.1 Introduction

So far this book has dealt largely with the role of trees in land use, farming systems and their agroforestry potential and the ways in which trees and crops interact. In this chapter, the way trees are arranged on the land where they grow is the main criterion for the identification of a number of different agroforestry practices. We shall discuss the following factors:

- Spatial arrangement
- Areas where each practice may be most relevant
- Establishment and spacing
- Management aspects
- Benefits and risks
- Examples of species.

It must be stressed that the recommendations made in this chapter are to be regarded as suggestions that will require further discussion with farmers during extension visits. Conditions vary from place to place and prescriptions must not be made without the full involvement and agreement of the farmers concerned. The content of this chapter should be regarded as a basis for consultations with farmers, not as providing hard and fast rules. The technical recommendations have deliberately been left imprecise; the local people must be partners in narrowing down the recommendations so that they become precise enough for application to a particular farm or area.

Another general recommendation is that farmers who want to plant more trees should be encouraged to do so gradually. Continuous planting of a few new trees every year for 5-10 years is a better option than planting a large number all at once. If many trees are planted at once, most of them will become mature at the same time and the management of the trees will require a lot of work in certain years and almost no work in others. A more even labour demand is achieved if trees are planted gradually.

8.2 Trees dispersed in cropland

Spatial arrangement

In most farming areas there are scattered trees growing in the fields. Often such trees were left when the land was cleared for agriculture, or naturally dispersed seeds may have germinated and the seedlings been deliberately protected during farming operations. In such cases, the spatial arrangement is a random one. In other situations, trees may have been planted or sown, and then they are often in lines. In areas where farming is mechanized, a system with trees in lines rather than at random will facilitate operations.

Figure 8.1 Trees dispersed in cropland

Areas where the practice is relevant

In most situations, it is feasible to have trees in cropland but it is particularly relevant in areas with shade-tolerant crops like coffee or beans. There are limited possibilities in irrigation schemes. The benefits to be obtained from the trees, in terms of soil fertility and soil structure, are normally more clearly seen in areas where little or no inorganic fertilizer is used.

Establishment and spacing

Many methods of tree propagation are possible. Which one is chosen will depend largely on which species are desired. Protection of wildings is a good option which should always be considered before recommending nursery production of seedlings. Direct sowing may be feasible if trees are to be grown in lines, otherwise it is difficult to know where the seeds will germinate.

A population of up to 100 trees per hectare, corresponding to a spacing of 10 m x 10 m, is appropriate in high-potential areas if the crop is light demanding, e.g. maize. If trees are to be planted, a better option than square spacing may be to plant trees in lines with close spacing in the rows and a wider between-row space resulting in a similar overall density. A spacing of 5 m within rows and 20 m between rows can be suggested. The tree and crop species and management methods chosen are factors that will influence decisions on spacing. With shade-tolerant crops a greater density of trees can be tolerated, as can a certain loss in yield if the tree products are in high demand. If the trees are of a species which has very light shade, e.g. some Acacia, more trees can be grown per hectare, and the same applies if the trees will be intensively pollarded. Root pruning can also be done to minimize competition.

In ASAL areas, lower tree populations are recommended, e.g. 40-70 trees per hectare, corresponding to a square spacing of 12-15 m. If trees in cropland are to be established from seedlings, a greater number than that ultimately required need to be planted since there will always be some mortality.

Management aspects

Tree-management practices will depend on the tree and crop species concerned and the need for tree products. With a light-demanding crop, pollarding or pruning is essential, but this does not apply to shade-tolerant crops or to trees that naturally only have light shade. Species that need and tolerate pollarding are *Albizia* spp., *Balanites aegyptiaca, Bauhinia* spp., *Bridelia micrantha, Cassia siamea, Commiphora eminii* subsp. *zimmermanni, Cordia abyssinica, Croton macrostachyus, Ficus sycomorus, Grevillea robusta, Markhamia lutea, Morus* spp., *Piliostigma thonningii, Spathodea nilotica, Syzygium* spp. and *Terminalia* spp.. Timber production and light reduction both call for pollarding high up, at 12-15 m, but shade tolerance and pole or *fito* production call for lower and less frequent pollarding. It is important to consider the land-use pattern throughout the year before recommending tree planting in cropland. Post-harvest grazing and burning of crop residues are other factors that need to be taken into account.

Benefits and risks

Establishment of trees is easy since the tree seedlings will benefit from weeding and protection of the crop. A variety of products can be harvested from the trees, and among service functions soil improvement, wind-speed reduction and improved microclimate are important. Too many trees can cause reduced yields due to shade, and trees may attract birds which may be a threat to crops. Competitive trees with shallow roots, such as Eucalypts, pines and *Acacia mearnsii* should be avoided. Trees that cannot be pollarded and which grow to a considerable size producing dense shade should also be avoided, e.g. *Acrocarpus fraxinifolius.* Other trees to avoid are *Croton megalocarpus, Cupressus lusitanica* and *Ficus benjamina.* Nematode build-up has been reported under *Sesbania sesban.*

Examples of species

Albizia spp., *Cassia siamea, Commiphora eminii* subsp. *zimmermanni, Grevillea robusta, Sesbania sesban, Ficus sycomorus, Bridelia micrantha, Croton macrostachyus, Cordia abyssinica, Jacaranda mimosifolia* (only in high-rainfall areas), *Spathodea campanulata, Markhamia lutea, Acacia* spp., *Combretum* spp., *Terminalia* spp., *Piliostigma thonningii, Erythrina abyssinica, Entada abyssinica, Balanites aegyptiaca, Morus* spp., *Faurea saligna, Ficus natalensis, Grewia* spp., *Melia volkensii, Moringa oleifera, Psidium guajava, Calliandra calothyrsus, Flemingia macrophylla, Gliricidia sepium.*

8.3 Trees on boundaries

Spatial arrangement

Tree growing on farm boundaries is a very common practice, but it requires agreement between the neighbours involved to avoid conflicts. There are different ways of sharing trees planted on a boundary. Sometimes two rows of trees are planted, one on each side of the boundary, and then each farmer grows and manages his own trees. A disadvantage with this system is that it occupies more land than a single row. If trees are grown in a single row, the neighbours can agree on ownership of every second tree, for example. In such cases it is recommended that trees of the same species are grown, although it may be difficult to keep track of which tree belongs to which farmer. If different species are chosen, one species may outcompete the other and one of the two farmers be disadvantaged. Another option is for the neighbours to agree to own trees in different sections of the boundary. This may be easier than owning every second tree, and it is then possible to choose different species for different sections according to the farmers' preferences.

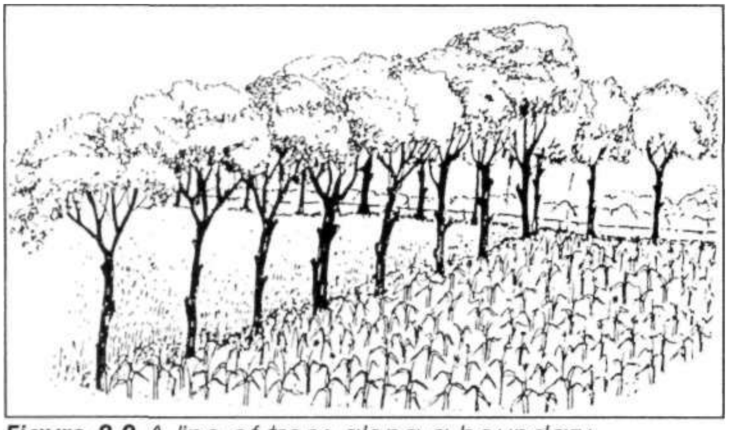


Figure 8.2 *A line of trees along a boundary*

Areas *where the practice is relevant*

This technology is relevant for all farming areas except irrigation schemes.

Establishment and spacing

Initially trees can be established at a close spacing (0.75-1.00 m) and then later thinned for poles, *fito* or firewood to a final spacing of 1.5-3.0 m. With double rows the spacing between the rows should not be less than 2 m. The tree propagation method will depend on the species, but use of seedlings or transplantation of wildings are common.

Management aspects

Management is similar to that for trees in fields.

Benefits

In small-scale farming areas boundary planting is usually enough to reduce wind speed, and there is no need to establish windbreaks. Trees on boundaries which are regularly pollarded can meet most of a family's need for firewood. In addition, other products and services are obtained and the boundary is effectively demarcated.

If the trees are not well managed there may be negative effects on crops, and if competitive species are planted root competition may be a problem. Conflicts with neighbours may arise if the sharing arrangements are not well handled.

Examples of species

Certain species, e.g. *Cordia abyssinica* and *Croton megalocarpus,* have traditionally been used as boundary markers. Grevillea is a very popular tree too. Trees with a short lifespan, e.g. *Sesbania* spp. and *Acrocarpus fraxinifolius,* are less suitable unless they are combined with more permanent trees. Competitive trees such as eucalypts, pines and *Acacia mearnsii* should be avoided. Many other non-competitive trees are suitable (see the list under "Trees in fields"). Non-commercial fruit trees, e.g. *Syzygium cuminii, Vitex* spp. and *Annona* spp., can also be suggested.

8.4 Live fences and hedges

Spatial arrangement

Live fences may be established all around the farm, but it is most common to establish such a fence around the homestead.

Figure 8.3 Markhamia lutea *used as boundary markers in a living fence*

Areas where the practice is relevant

This practice is relevant for most farming systems except on irrigation schemes and in the most arid areas. Fences are more important where livestock graze and hedges elsewhere.

Establishment and spacing

Very many individual shrubs are required to make a fence or a hedge. Thus the propagation method must be simple and cheap. Direct seed sowing or use of cuttings (depending on species) is primarily recommended, but for *Dovyalis caffra* and cypress it may be better to raise seedlings in an on-farm nursery since they have small seeds and are relatively slow starters.

It is best to plant seeds, seedlings or cuttings in two staggered rows so that an impenetrable fence or hedge is formed. The distance between the rows can be 15-30 cm with the same space within the rows. Directly sown fences must be well looked after and protected initially.

Management aspects

Fences and hedges need regular trimming so as not to overgrow (see Case Reports No. 15 and 16 for details). Some species which are very thorny, e.g. *Caesalpinia decapetala,* are sometimes regarded as too difficult to manage and should be avoided if the thorniness is not really needed as a deterrent to cattle. Live fences are often combined with trees for the production of wood. Either some stems of the fence species can be allowed to grow large, e.g. cypress, or trees of another species can be planted in the fence and allowed to grow well protected by the fence.

If live fences are to be introduced it is essential to consider the land-use pattern throughout the year. Fires are a hazard for many species, and livestock may be a threat in the initial stages.

Benefits

Fences and hedges are often multipurpose. Some of their uses are to:

- Provide shade and a windbreak for the compound
- Control movement of cattle
- Be ornamental
- Provide protection for chickens against birds of prey
- Provide privacy
- Production of mulch, fruit, bee forage or wood
- Help in soil conservation.

There are few risks. Live fences require labour for maintenance, and if they are not maintained they lose their intended function and begin to compete with crops. *Caesalpinia decapetala* may be too thorny to have near houses as children may suffer. The latex of *Euphorbia tirucalli* is very poisonous and dangerous for the eyes. Fences and hedges may harbour snakes, and some shrub species may turn into weeds, e.g. *Lantana camara. Thevetia peruviana* is also very poisonous.

Examples of species

Acacia brevispica, Acacia nilotica, Acacia tortilis, Agave sisalana, Albizia amara, Balanites spp., *Caesalpinia decapetala, Calliandra calothyrsus, Carissa edulis, Croton dichogamus, Croton megalocarpus, Cupressus lusitanica, Casuarina* spp., *Dovyalis cajfra, Euphorbia* *tirucalli, Gliricidia sepium, Morus alba, Lantana camara, Parkinsonia aculeata, Pithecellobium dulce, Prosopis* spp., *Psidium guajava, Thevetia peruviana, Ziziphus* spp.

Figure 8.4 A cattle-proof sisal hedge also provides material for basket making

8.5 Trees on soil-conservation structures

Spatial arrangement

Trees can be planted as biological soil-conservation measures (tree strips), either in combination with grasses or alone. Trees alone are effective enough only on gentle slopes (less than 8%). On steeper slopes combinations with grasses are desirable.

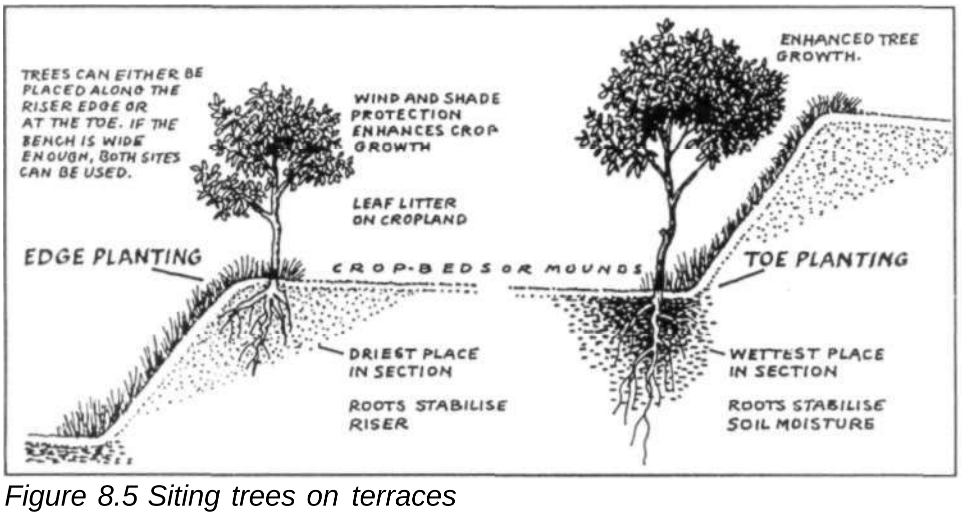


Figure 8.5 Siting trees on terraces

Trees can also be planted on terrace edges in order to stabilize the structure and make maximum use of the land. Trees planted on the edge of a terrace will not have ideal moisture conditions but are effective for stabilizing the soil. Fruit trees, which need the best moisture conditions, can be planted just below the edge of the terrace where they can benefit from run-off and more moisture generally.

Trees can be planted on many other types of soil-conservation structures to stabilize the soil and to make optimal use of the land.

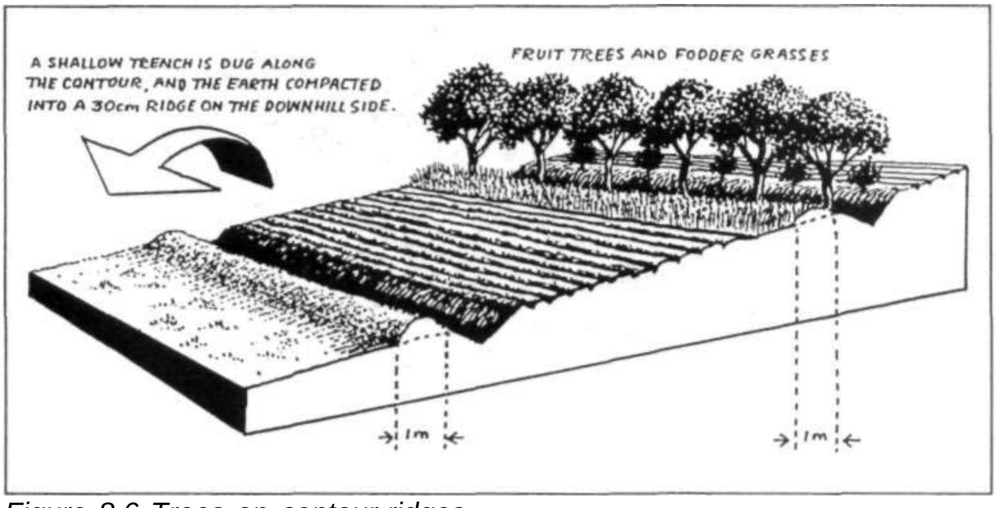


Figure 8.6 Trees on contour ridges

Areas where the practice is relevant

These technologies are relevant in all areas where cultivation takes place on sloping land.

Establishment and spacing

To be effective as tree strips, trees should be planted in lines along the contours. The spacing between the contour "tree strips" is determined in the same way as for other soil-conservation structures. Within rows spacing can be 0.1-0.2 m for shrubs and 0.5-1.0 m for trees. If the trees are combined with grasses or shrubs the spacing can be wider, and the spacing should also be wider in dry areas because of moisture competition between the trees.

The spacing for trees and shrubs intended to stabilize terraces can be 1.5-3.0 m for trees (including banana, pawpaw and guava), and 0.3-0.5 m or wider for shrubs if the farmer so wishes. Initial establishment can always be more dense and thinning can be carried out later to obtain the final spacing. On steeper slopes an option is to grow trees on every second terrace to avoid having too great a density of trees.

Management aspects

The trees are managed in the same way as trees in fields. Shrubs must be trimmed almost as though they were in a live fence in order not to occupy too much land.

Benefits

Which of the many possible products and services can be obtained from the trees will depend on the choice of species. The role of stabilizing structures is important. If perennials are grown on bunds, for example, the structures will become more permanent and will be respected by tractor drivers when they are ploughing.

Examples of species

Basically the same as for trees in fields, but more fruit trees can be added, e.g. bananas, *Citrus* spp., *Psidium guajava, Cyphomandra betacea,* and *Carica papaya.* On steeper slopes, preference should be given to trees which either will not grow very big or to trees that can be pollarded since it is desirable to have a high density of trees. The steeper the slope, the shorter the horizontal interval between the soil-conservation structures, so if trees are grown on all the structures more trees are required per hectare to stabilize them.

8.6 Improved fallows

Spatial arrangement

When land is fallowed due to the need to restore soil fertility after a period of cultivation, shrubs can be sown to speed up the process. These shrubs can fix nitrogen and add organic matter to the soil.

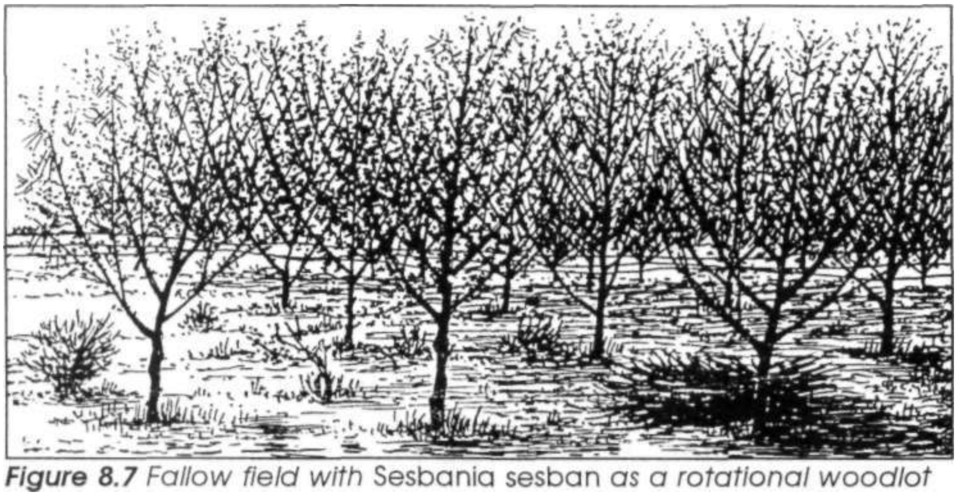


Figure 8.7 *Fallow field with* Sesbania sesban *as a rotational woodlot*

Areas where the practice is relevant

This practice is relevant in areas where land is regularly fallowed. However, fallowing is not common in Kenya now due to population pressure, although it does occur in western Kenya (mainly in the Lake Victoria basin) and in semi-arid areas. Improving fallows is relevant where farms are relatively large, and where labour is more of a constraint than size of farm holding. Improving fallows by establishment of shrubs is not a very common practice in Kenya.

Establishment and spacing

Since very many individual shrubs are required, all with a relatively short life span, a simple and cheap propagation method is necessary. Direct sowing is the best option. The denser the spacing the more effectively will weeds be suppressed.

Management aspects

The shrubs require little management once they are well established. But protection from livestock, is an absolute necessity. If the shrubs are very densely spaced some thinning can be done for harvesting of staking material, *fito* or firewood. When land is to be brought back under cultivation, some shrubs can be left to supply propagation material for the next fallow period.

Benefits

The main benefits are quick restoration of soil fertility and wood production. The risks or potential problems are damage by livestock and increased labour demand for establishment and up-rooting of shrubs.

Examples of species

Nitrogen-fixing shrubs which are easy to propagate and which have a short lifespan and relatively small root system are desirable. *Sesbania* spp. and *Gliricidia sepium* are promising.

8.7 Trees along roads and paths

Spatial arrangement

Trees are commonly planted along small rural roads and paths. This practice is similar to boundary planting, but the competition aspect is less important since the land is not cultivated, at least on one side. Quite often land between the homestead and a road or path can be set aside for trees, and then there is little or no competition with crops since the cultivated land is not adjacent to the area with trees.

Trees can be planted in one or several rows, on one or both sides of the road or path.

Figure 8.8 Tree-shaded footpath and road in a rural area

Tree growing along bigger roads is more complex. Road safety requires that trees not be grown too close to the road. Ownership issues may also arise, and the road authorities must be involved in planning and decision-making.

Areas where the practice is relevant

This practice is relevant in all areas with permanent settlements.

Establishment and spacing

Any propagation method can be used, the choice depending mainly on species. Initially, spacing can be as dense as 0.5 m, but later the trees should be thinned to allow them to grow to the desired size.

Management aspects

Management is the same as for trees in fields, but trees along roads may not always be pruned or pollarded.

Benefits

The benefits are the same as those from trees in fields, and in addition the trees will reduce dust from roads.

Examples of species

Almost any desired species can do provided that it is well suited to the ecological conditions of the area. Competitive species can be used in situations where there are no nearby crops.

8.8 Alley cropping

Spatial arrangement

Alley cropping is an agroforestry practice where crops are grown between lines of trees and/or shrubs that are managed and spaced at regular intervals in cropland. This practice has received much research attention and is regarded as having promise for solving problems of declining soil fertility in situations where farmers cannot afford to use inorganic fertilizers at the recommended rates.

Areas where the practice is relevant

The practice of alley cropping is not yet widespread among farmers in Kenya. Research findings indicate that alley cropping is not feasible where average rainfall is less than 800 mm annually. The practice has its major potential in humid lowlands, e.g. in the coastal strip. Since the technology is labour demanding, it is relevant mainly in areas with small farms and a high population density or, in other words, where labour is not a limiting factor.

Figure 8.9 One form of alley cropping

Establishment and spacing

The establishment of hedgerows requires many trees or shrubs and therefore a cheap propagation method is called for. Direct seeding or use of cuttings would be ideal, but so far seedlings have been used in most research experiments. If seedlings are to be raised, on-farm nurseries are recommended since growing the relevant species does not require much skill. Calliandra may be an exception due to the scarcity of seed supplies in Kenya, and expensive seeds are often imported.

The spacing used in field trials has ranged from 4 to 8 m between rows and from 0.25 to 2.00 m within rows. In humid areas, close spacing can be tolerated, but in drier conditions a wider spacing is required if competition for moisture is not to be too severe.

On flat land, hedgerows should be oriented in an east-west direction to reduce shading. On sloping land, hedgerows must be oriented along the contours.

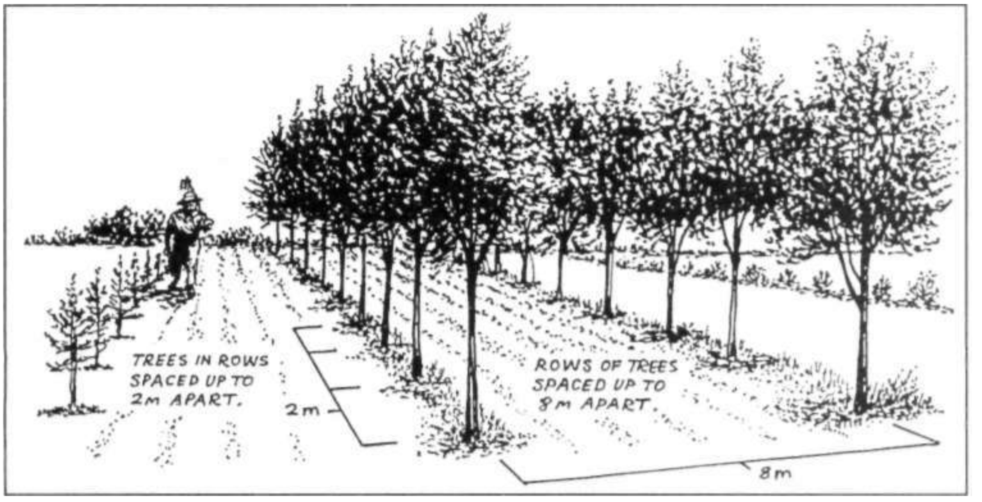


Figure 8.10 Tree spacing in alley cropping

Management aspects

Intensive management is required. The first coppicing is done 6-18 months after establishment, depending mainly on growth rate. The frequency of cutting depends on what type of wood is preferred, and on whether or not some reduction in crop yield due to shade can be tolerated. If the leaves are to be used for green manuring or fodder, frequent (up to monthly) prunings are required, but if firewood or staking material is the desired output, cutting should perhaps be only yearly. With yearly cuttings one would, however, expect some loss in crop yield due to shade unless the shrubs are regularly pruned.

Benefits

The focal point in research has been the potential for sustaining or improving soil fertility. Other important benefits can be fodder, small-size wood and improved microclimate. Labour has sometimes been regarded as a constraint since the management of hedgerows requires a lot of work. Competition for moisture has been recognized as an obstacle for this technology, becoming increasingly severe the drier the conditions. The technology is not recommended at all where the annual average rainfall is less than 600 mm. Leucaena often turns into a weed in warm and moist areas, and lately the Leucaena psyllid (see Section 5.6) has appeared as a threat to Leucaena in Kenya.

Examples of species

Leucaena leucocephala, Calliandra calothyrsiis, Gliricidia sepium and *Cassia siamea* have been tried with relative success in Kenya. *Sesbania* spp. have also been tried but are short lived and normally have a high mortality rate after cutting.

8.9 Trees as windbreaks

Spatial arrangement

Windbreaks are lines of trees or shrubs whose main aim is the reduction of wind speed. Well-designed windbreaks, i.e. ones that are not too dense, not only reduce wind speed but may also increase humidity and reduce water loss from the soil. The positive effect of a windbreak is said to be felt up to a distance 20 times the height of the trees in the windbreak.

Areas where the practice is relevant

Large windbreaks are most relevant in large-scale farming areas since otherwise they would extend over many small farms thus causing complicated planning and requiring good co-operation between the farmers. Boundary planting of trees and live fences is usually sufficient as windbreaks in small-scale farming areas. Larger windbreaks are mostly seen in the former White Highlands, e.g. Trans Nzoia, Nakuru, and Uasin Gishu.

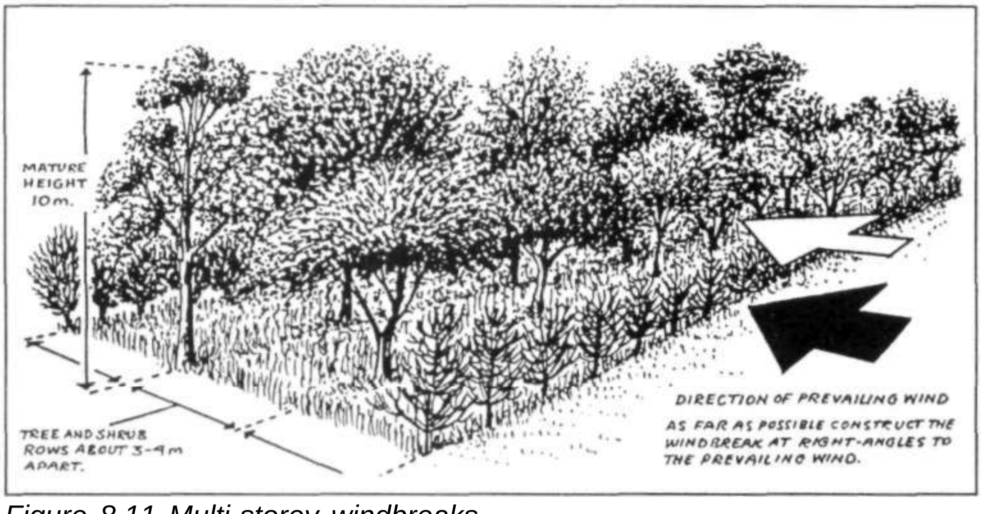


Figure 8.11 Multi-storey windbreaks

Establishment and spacing

Any propagation method is suitable, and for large-scale farms planting of seedlings raised in nurseries may be the most common. A windbreak, should be planted at right angles to the prevailing wind. It can either consist of a single line of trees with a spacing of 1.5-2.0 m, or two lines with a spacing of 4-5 m within the line and 2-4 m between the lines. In addition to one or two lines of trees, a line of shrubs spaced at approximately 1 m can be planted on the side facing the prevailing wind.

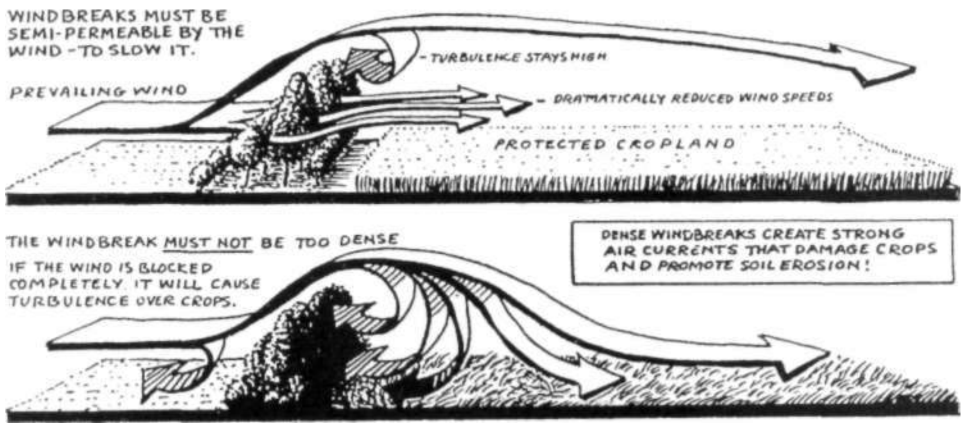


Figure 8.12 Windbreak design

Management aspects

As with any other newly planted trees, initially a windbreak needs to be protected against livestock and fire. Careful weeding and replacement of dead seedlings also need to be carried out. Later the trees in the windbreak may need pruning or pollarding to maintain a suitable density and to minimize the shading effects on crops. Dead trees or trees that have been blown over must be replaced.

Benefits

The environmental benefits, reduced wind and increased retention of moisture, are the most important ones. On the negative side, some land is lost for crop production, but the reduction of wind may well compensate for the loss of land. In addition the windbreak will produce wood.

Examples of species

Acacia albida, Albizia spp., *Anacardium occidentale, Annona senegalensis, Azadirachta indica, Balanites aegyptiaca, Calliandra calothyrsus, Calodendrum capense, Cassia siamea, Casuarina* spp., *Cupressus lusitanica, Ekebergia capensis, Eriobotrya japonica, Eucalyptus* spp., *Gliricidia sepium, Gmelina arborea, Grevillea robusta, Hakea saligna, Juniperus procera, Macadamia tetraphylla, Mangifera indica, Markhamia lutea, Morus alba, Olea europaea, Prosopis* spp., *Prunus africanus, Psidium guajava, Spathodea campanulata, Syzygium cuminii, Trichilia emetica, Vitex* spp., *Ziziphus* spp.

8.10 Trees in homesteads and around schools

Spatial arrangement

Tree growing in homesteads is a very common practice in most parts of Kenya. Spatial arrangements vary, but mostly the trees are scattered and of many different species. Trees are often intercropped with vegetables, and much effort is made to maintain soil fertility. Waste water and chicken manure are available and these factors make homesteads ideal places for trees.

Homesteads have other specific advantages for tree growing. They are near where people live and thus can easily be looked after. The harvest of products is accessible to all family members, e.g. fruits can be picked even by small children who otherwise do not go very far away from their houses. Proximity is also an advantage from the point of view of labour since even short periods between other work can be used to work in the homestead. The homestead is well suited for production of fruits and nuts, for example, and such valuable production should be given priority in the homestead. Shade and ornamental trees are also important. Trees which supply products of concern to women need to be easily accessible to them.

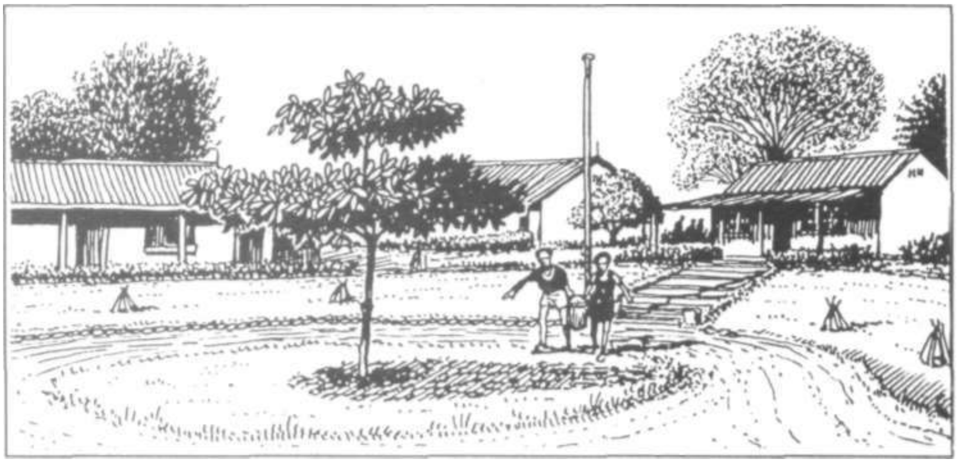


Figure 8.13 With care and protection a Terminalia catappa *tree becomes a striking feature in a school compound*

School compounds have a great potential for being improved as training grounds for the pupils. Trees of a wide variety of species can be planted so that pupils have a chance to learn about them. Propagation and management techniques can be demonstrated and practised, and the school and pupils can benefit from the tree products and services. Fruit trees can provide snack food for the children, and if several species are planted a more or less continuous supply of fruit can be obtained. The role of trees in improving the aesthetic quality and the microclimate of the school compound is also important.

Areas where the practice is relevant

All areas where settlements are reasonably permanent.

Establishment and spacing

Any tree-propagation method is possible; spacing and spatial arrangement will depend on species and intended uses. Citrus can be spaced at 6 m x 6 m in pure stands in lower zones, and large fruit trees like avocado and mango at 15 m x 15m. The recommended spacing for grafted mango in pure stands is 9 m x 9 m.

Figure 8.14 A homestead with a variety of trees in the garden

Trees of different heights can be grown together in multi-storey systems to make maximum use of the little space available. Trees with brittle branches or big root systems should not be planted too near houses. Schools with a continuous water supply can run school nurseries.

Management aspects

Management will also depend on the species chosen and their intended uses. Normally seedlings are well protected in the homestead, but chickens can cause a lot of damage if seedlings are not protected.

Benefits

All the products and services can be useful. Priority should be given to valuable production, which requires management, and where access is important. The risks include brittle branches or heavy fruits falling or trees blowing over and damaging houses or injuring people. Roots penetrating under a house may damage the foundations. Some species produce a lot of litter which may add to the work of keeping the homestead tidy. Bamboo and mango trees, for example, may attract snakes.

Examples of species

A complete list of suitable species would be too long to include here. Very tall species, e.g. eucalypts or *Acrocarpus fraxinifolius,* are not ideal, and neither are trees with brittle branches or aggressive roots, e.g. *Ficus benjaminii* and *Jacaranda mimosifolia* which have a reputation for damaging foundations and water and sewage systems.

8.11 Woodlots

Spatial arrangement

If an area is set aside more or less entirely for trees, such an arrangement is known as a woodlot. Vegetables or crops are often intercropped in the woodlot in the early stages of establishment, but with time wood production is the most important use.

In small-scale farming areas woodlots are often very small, 0.1 hectare or less. Large-scale farms may have woodlots of many hectares.

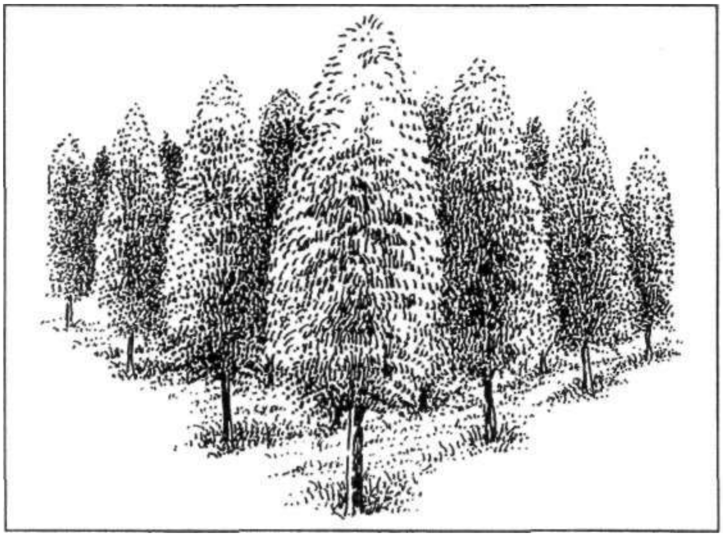


Figure 8.15 A good Eucalyptus woodlot

Areas where the practice is relevant

Woodlots are particularly relevant in areas where light-demanding crops are grown, e.g. in areas where maize or sugarcane are dominant crops. Woodlots are also relevant for meeting wood requirements near irrigation schemes. In coffee-growing areas they are only relevant on waste land that is not fit for other use. Otherwise it is better to intercrop trees and coffee, or use boundaries, etc., since the coffee will tolerate a certain amount of shade. Tea performs best in Kenya without too many intercropped trees, so woodlots are also relevant for those areas. The British American Tobacco Company has also promoted woodlot establishment in tobacco-growing areas in Kenya.

Poor land that cannot be used for anything but trees is primarily recommended for woodlots. In some areas, however, tree production may be as profitable as crop production, so it would be justifiable to plant a woodlot on good land where the trees will grow fast. In certain areas, e.g. Vihiga near Kisumu, some farmers have opted for tree growing as the major use of their small farms since the market for poles and other tree products is good. Such arrangements may be profitable, but of course they also make the family vulnerable as they will be economically dependent on market forces and middlemen.

When discussing the location of a woodlot, transport requirements must be borne in mind. The site for wood production for domestic use should preferably be near the house to reduce the burden of carrying firewood, for example. Such considerations may also lead to a decision to use better land for a woodlot rather than the poorest land which may be further away.

Establishment and spacing

Establishment can be from seedlings or by direct sowing of seed, depending on species. *Acacia mearnsii* can be directly sown, and so can eucalypts, but the latter are difficult as the seeds are very small. Raising seedlings may be a better option.

The initial spacing can be very dense: 0.5 by 0.5 m, or even less if there is a demand for thin poles, *fito* or firewood. Gradual thinning will then enable the trees to grow to the desired size, while at the same time small-dimension wood can be harvested.

Management aspects

Protection from livestock and fire is always important for young trees. Initial intercropping with crops or vegetables helps protection and weed control. Pruning and thinning must be continuous to produce good-quality poles and timber. If the trees compete with adjacent crops, deep ploughing or digging a trench 50-80 cm deep will reduce the penetration of tree roots into the rooting zone of the crop.

Species with good coppicing ability are preferable to eliminate the cost of repeated establishment. Short rotations (6-8 years on good sites) are recommended.

A natural woodlot requires maintenance through selective bush clearing and protection in the early stages.

Benefits

In woodlots the most fast-growing trees, e.g. Eucalyptus, can be used since the land is used entirely for trees and there is little need to worry about competition with crops. A high level of wood production for domestic or cash-income purposes can be achieved. Trees in woodlots can also be a good way of making some savings. The negative aspect is that land, which is normally scarce, is taken out of agricultural production.

Examples of species

Fast-growing and coppicing species are best, e.g. *Eucalyptus* spp., *Acacia mearnsii*, *Markhamia lutea* and *Cassia siamea.* Pinus patula can also be used although it hardly coppices. *Cupressus lusitanica* has been used, but due to problems with the cypress aphid it should not be encouraged at present. *Casuarina* spp. may be alternatives. *Grevillea robusta* can be used, but sometimes only the trees at the edge of the woodlot perform well, while trees in the interior are stunted due to competition and possibly allelopathic effects between the trees.

8.12 Fodderlots

Spatial arrangement

Areas where trees or shrubs are grown in a stand to produce fodder are known as fodderlots. Trees and shrubs may be intercropped with fodder grasses to maximize fodder production but sometimes the grasses compete so much with the shrubs that the production of protein-rich leaf fodder is severely reduced.

/Areas *where the practice is relevant*

The practice is relevant in all areas where zero-grazing is practised. In semi-arid areas trees can also be grown primarily for production of protein-rich pods or for browsing, and in that case livestock may be let into the fodderlot.

Establishment and spacing

Fodderlots can be established in rows using seeds, seedlings or cuttings. The spacing can vary from 0.2 m within the row and 0.5 m between the rows for shrubs, to 0.5 m within the row and 1-2 m between the rows for trees. Fodderlots for browsing or for pod production should be established at a wider spacing. In ASAL, natural regeneration of indigenous trees can be utilized for fodderlots. Selective clearing will then be needed to promote the growth of the best species. If establishment is poor, the plants may need inoculation with nitrogen-fixing bacteria.

If fodder shrubs are grown together with Napier grass in high-potential areas, the fodder shrubs should be planted first and the grasses a season later. If they are planted simultaneously, the grasses will compete too much with the shrubs.

Management aspects

Cutting for fodder should be done frequently since young leaves are most nutritious. A fodderlot may need to be fertilized, especially with phosphates, in order to sustain its productivity. With intensive cutting or browsing, the shrubs may sometimes need to be given time to regrow. Leucaena, for example, should not be cut or browsed for more than 6 months in a year.

Benefits

The main benefit is improved supply of fodder. Fodderlots may also conserve soil on slopes, and if planted in strips along the contour they may serve as biological soil conservation measures. On the negative side is loss of land from crop production.

Examples of species

Species producing pods with a good fodder value are *Leucaena leucocephala*, *Prosopis* spp., *Acacia tortilis* and *Tamarindus indica.*

8.13 Trees in rangeland

Spatial arrangement

Scattered trees in rangeland are beneficial in many ways, e.g. providing shade for livestock and herdsmen, and fodder and wood. Normally such trees are scattered at random and there is no need to be particular regarding any regular spatial arrangement.

Areas where the practice is relevant

This practice is relevant for all rangelands.

Establishment and spacing

Any propagation method may be applicable, but use of seedlings can be recommended since it is essential to minimize the period during which protection is needed. Natural regeneration should be considered before tree planting is recommended, but both methods can be used at the same time.

If trees are to be planted, they should not be too dense since this may interfere with grass production. A spacing of 10 m x 10 m has been recommended for small trees and 15 m x 15 m for large trees (Mbote and Fahlstrom, 1992).

Trees can be planted either scattered in the rangeland or in other arrangements, e.g. in lines.

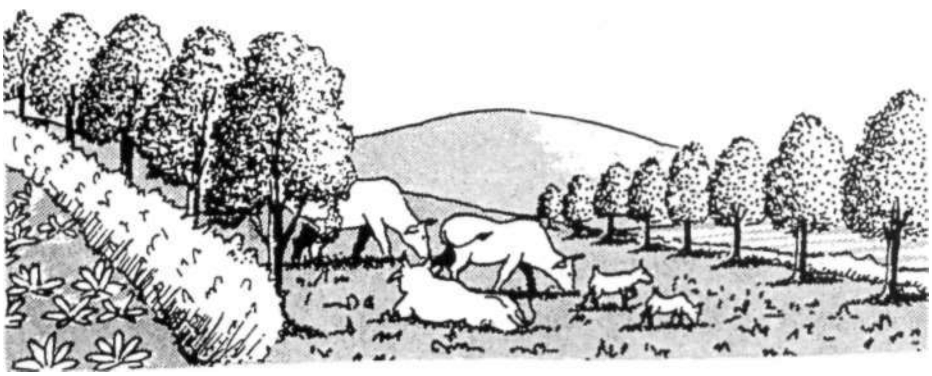


Figure 8.16 Trees in rangeland

If there are too few trees on sloping land they may contribute to land degradation through intensive trampling by cattle seeking shade. If there are signs of this, it is a clear indication that more trees need to be established.

Management aspects

Protection of the seedlings is required in the initial stages. In communal grazing areas this will require the full support of all people using the area.

Benefits

Improved supply of fodder and environmental benefits, e.g. shade. Certain species may suppress the growth of grass and such species should, of course, be avoided. Another risk is that drought or overgrazing may kill off most of the trees that the people have spent a lot of time and money planting and then they will lose interest in trying to establish trees again.

Examples of species

Acacia brevispica, Acacia elatior, Acacia gerrardii, Acacia mellifera, Acacia nilotica, Acacia polyacantha, Acacia Senegal, Acacia seyal, Acacia tortilis, Annona senegalensis, Balanites spp., *Bauhinia* spp., *Berchemia discolor, Boscia coriacea, Cadaba farinosa, Calliandra calothyrsus, Combretum molle, Cordia* spp., *Dicrostachys cinerea, Diospyros scabra, Dobera glabra, Gliricidia sepium, Grewia* spp., *Lannea schweinfurthii, Maerua subcordata, Piliostigma thonningii, Salvadora persica, Terminalia brownii, Ziziphus* spp.

8.14 Trees along streams and rivers

Spatial arrangement

River banks are prone to erosion if they are not well covered with vegetation. Furthermore many important indigenous trees are riverine, i.e. they occur naturally only or mainly along water courses. Thus vegetation along rivers is important both from an environmental point of view and for the production of special commodities, e.g. medicine or fruits. No particular spatial arrangement is called for.

Areas where the practice is relevant

Along all water bodies.

Establishment and spacing

Protection of the existing vegetation is the first priority. If there are already too few trees, protection of natural regeneration should be the second option to consider. If trees need to be actively planted or sown, priority should be given to indigenous trees since they are generally better conservers of water than exotics. (This is, however, counter to the desire to produce wood with fast-growing exotics.) Spacing will depend on species and purpose, but usually no large pieces of land should be put under trees. Hence, normally a few trees will be planted at selected places and a fixed spatial arrangement will not be relevant.

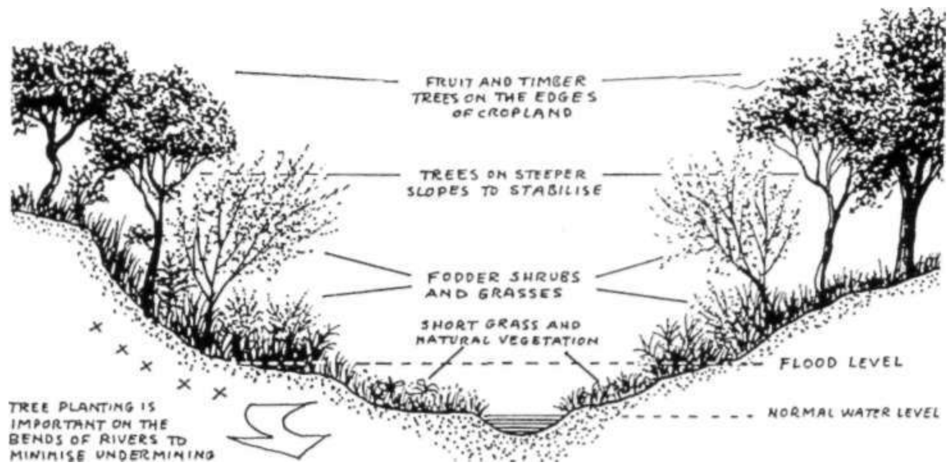


Figure 8.17 Stream-bank protection

Management aspects

As always, protection during regeneration is important with young trees. Other management steps will depend on the species and the purpose for which the trees are intended. Sites along rivers are often fertile and therefore are often used for growing vegetables. Pollarding and pruning can then be considered for minimizing shade.

Benefits

Protection of the water bodies and protection of the stream banks from erosion also reduce problems with siltation downstream. Products can be harvested from the vegetation along the streams and rare tree species can be preserved—a "gene bank".

Examples of species

Very many indigenous species can be considered. Examples of more-or-less riverine species in Kenya are *Acacia albida, Acacia elatior, Acacia gerrardii, Acacia polyacantha, Acacia xanthophloea, Ficus sycomorus, Populus illicifolia, Garcinia livingstonei, Vitex doniana, Syzygium guinensee, Terminalia brownii, Phoenix reclinata, Phoenix dactylifera, Conocarpus lancifolius, Hyphaene coriaceae, Tamarindus indica* and *Trichilia emetica.*

8.15 Trees in gullies

Spatial arrangement

Trees or bananas can be used together with other vegetation to reduce erosion in gullies. By planting trees in gullies, land can be brought back into productive use.

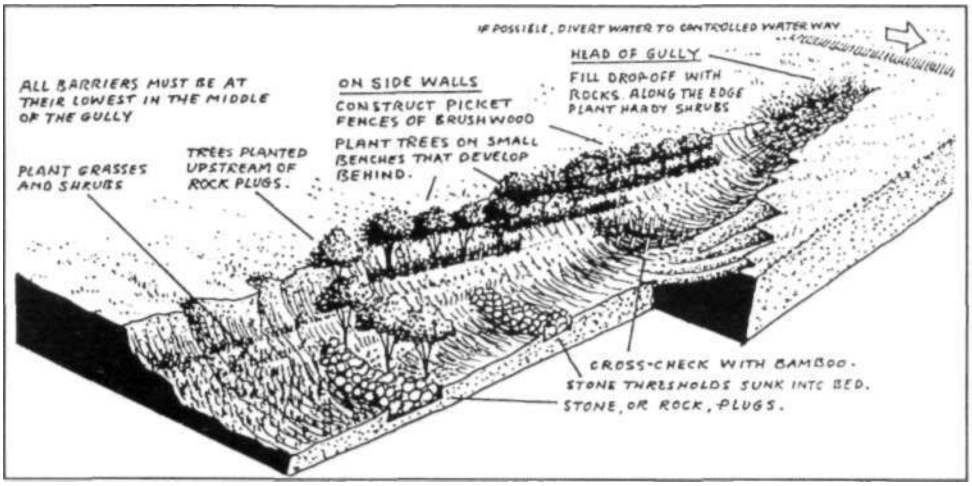


Figure 8.18 Gully control

Areas where the practice is relevant

Generally in most gullies where efforts are made to stop the gully formation.

Establishment and spacing

Trees or bananas should not be planted on the floor of narrow gullies since the stems will decrease the cross-section of the gully thus increasing the velocity of any water flowing down its sides. The stems can also divert the stream to the sides of the gully, causing undermining erosion of the gully sides.

When the sides of a gully are not steeper than 1:1, or if there are steps on the sides, trees can be planted to stabilize the gully walls.

Management aspects

Management will depend on the species and purpose.

Benefits

Reclamation of land, tree production and reduced siltation downstream.

Examples of species

The best choices are easily propagated species with quick initial growth. Use of cuttings is recommended. Bananas and *Morus alba* are recommended. *Euphorbia tirucalli, E. candelabrum, Croton* spp., and *Commiphora* spp. are also very useful in gully reclamation.

9. TREE PROPAGATION METHODS

9.1 Existing methods

Trees can be propagated in many different ways, as illustrated in Figure 9.1.

Some methods require a significant amount of work and expenditure, whereas other methods are simple and involve no cost. Simple and cheap methods are always preferable, but for certain species such methods may not work well and then the more complicated methods are called for.

Examples of simple and cheap methods are:

- Use of wildings
- Use of cuttings planted directly at the desired site
- Direct seed sowing at the desired site.

Labour-intensive and more costly methods are:

- Use of seedlings raised from seeds or cuttings in central nurseries.

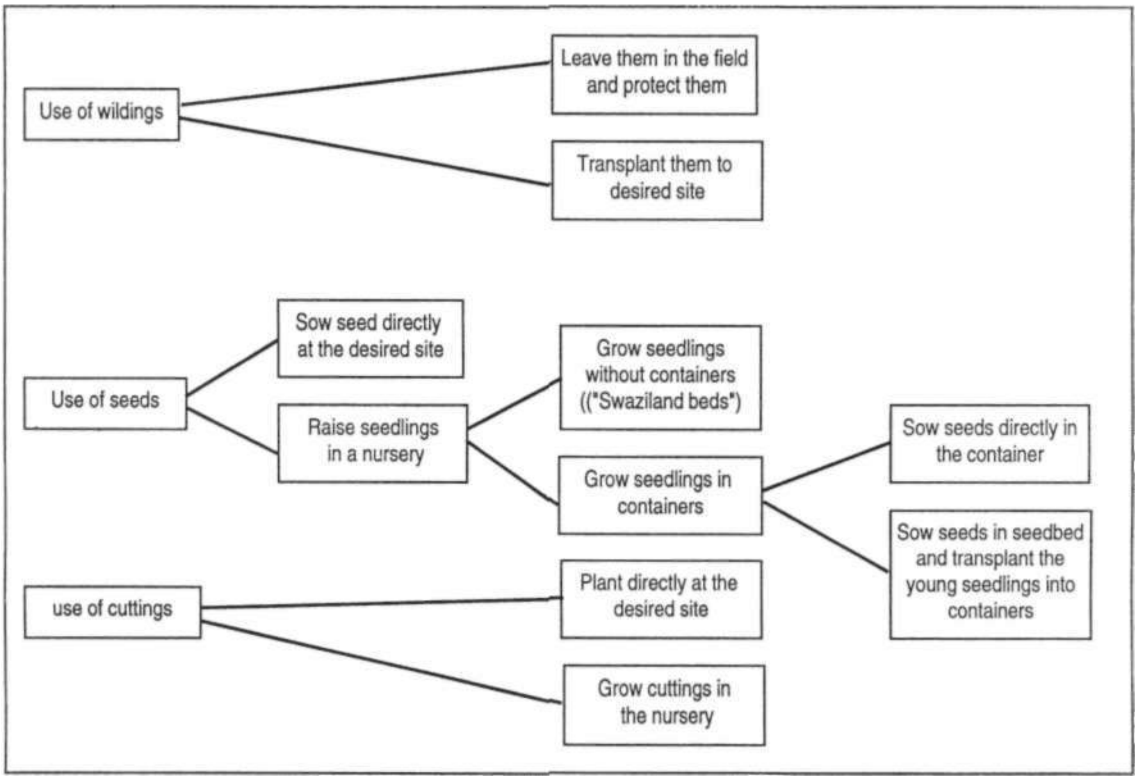


Figure 9.1 *Methods of propagation*

Methods which enable farmers to have full control over the production are also preferable to those where government agencies or other authorities are responsible, e.g. for raising seedlings. Such "farmer managed" and normally "on-farm" methods are use of wildings, direct planting of cuttings, direct seed sowing and raising seedlings in on-farm nurseries. When the farm family controls all the steps in the process of tree propagation, all decisions are made by the family and so the choice of species, planting time, etc., is likely to be made according to the family's wishes.

Although simple farmer-managed methods are preferred for the propagation of many species, there is still a need for central nurseries. In central nurseries which are managed by trained and specialized staff experiments can be carried out on propagation techniques for a greater variety of tree species, and such nurseries can also serve as testing grounds for species that are new to a particular area. Propagation of some tree species requires certain skills, e.g. budding and grafting of fruit trees and special seed treatment for some indigenous species. Such trees may be best propagated in central nurseries from where seedlings are sold.

In the following sections some important methods of tree propagation will be discussed.

9.2 Use of wildings

Wildings are seedlings that have grown naturally from dispersed seeds. Such seedlings are often found under mature trees, but may also be found far from the mother tree if the seeds were dispersed by birds or wind, for example.

A very simple way of promoting the growth of more trees is simply to protect young seedlings that come up naturally. This method is important both in ASAL areas and in high-potential areas.

In ASAL there is normally a good natural regeneration of trees as soon as an area is protected from grazing. This regeneration is not only from seedlings germinating from seeds, but often even more from root suckers or coppice shoots. Before any efforts are made to plant trees in ASAL areas, this potential for natural regeneration should always be considered, and normally only trees that for some reason cannot regenerate naturally should be planted. This may apply to introduced species, for example, or to indigenous species which have become rare due to over-exploitation.

9.3 Direct seed sowing at the desired site

Another simple way of getting more trees on a farm is to sow the seed directly at the desired site. This is an important method for species and technologies which require very many trees or shrubs, e.g. live fences or dense woodlots.

A good seed supply is a must for this method since normally a certain amount of seed will be wasted. Normally, directly sown seedlings cannot be as well cared for as seedlings in a nursery, and one must also expect accidents, e.g. seeds being washed away by rain, being eaten by birds, or young seedlings being mistaken for weeds and removed. Occasionally there may be a dry spell soon after germination and if watering cannot be easily arranged such a dry spell may result in almost total failure. It is then necessary to have access to plenty of seed so that the sowing can be repeated.

Case Report No 36: Natural regeneration of trees in West Pokot

Mr Logeding'ole of Ptokou Ranch in West Pokot District, whom we have already met in earlier Case Reports, has observed how the vegetation regenerates when the rain starts. After the grass, *Acacia tortilis (ses)* and another local tree called *kabarsamu* are the first to germinate. Wildings of both species emerge at places where goats have left their manure, and Mr Logeding'ole concluded that goats eating pods of these and other species play a role in the propagation of the trees. Passing seeds through the goats' intestinal tract is a natural pre-sowing treatment. Plenty of wildings of *Balanites aegyptiaca* and *Acacia tortilis* germinate in the goat *boma* during the rains and can be transplanted from there to desired sites.

If wildings are available in the surroundings but not growing exactly where they are wanted, they can be uprooted and transplanted to the desired site. If wildings of a certain species are wanted, the area under a seeding tree can be cleared of weeds and the soil loosened to help the seeds to germinate. When the rains start, the seeds will germinate and the wildings can be collected soon thereafter. Wildings can be collected when they are very small, e.g. with only two to four leaves. However, such a small wilding requires good care, including weeding, after transplanting, and therefore it is more common to transplant bigger wildings of up to 25 cm.

If bigger wildings are transplanted, they must be carefully uprooted, leaving soil around the roots, and planted on the farm in the same way as seedlings from a nursery.

Farmers already use wildings of very many species, both exotic and indigenous. *Grevillea robusta* and *Cordia abyssinica* are examples of species commonly propagated in this way.

Case Report No 37: Use of wildings in Embu

In earlier Case Reports we met Mr Ngare of Siakago Division, Embu District. Mr Ngare uses wildings of several species.

He says that most of his trees are a result of protection of natural regeneration. An example is *Melia volkensii.* When the fruit of *Melia volkensii* fall on the ground, Mr Ngare buries them in the soil. Most of the buried fruit germinate after two rainy seasons. If he wants to transfer a seedling to another place, he transplants it when three leaves have formed. His propagation of *Grevillea robusta* is similar to that of *Melia volkensii.*

Mr Ngare has taken this keen interest in natural regeneration because, according to him, it is both cheap and effective. However, he concedes that one has to keep watching to ensure that the wildings are spotted and transplanted before they grow too big. He has assisted the Gitumburi Catchment Nursery, of which he is a member, with his experience so that the nursery members have been able to raise all their Grevillea seedlings and one *Melia volkensii* through transfer of wildings under mother trees into polythene pots. Through natural regeneration of trees, Mr Ngare has made himself self-sufficient in fuel both for his household and for curing tobacco without any expenditure on seedlings. In addition to fuel, he gets timber from *Melia volkensii* and many essential commodities from other trees.

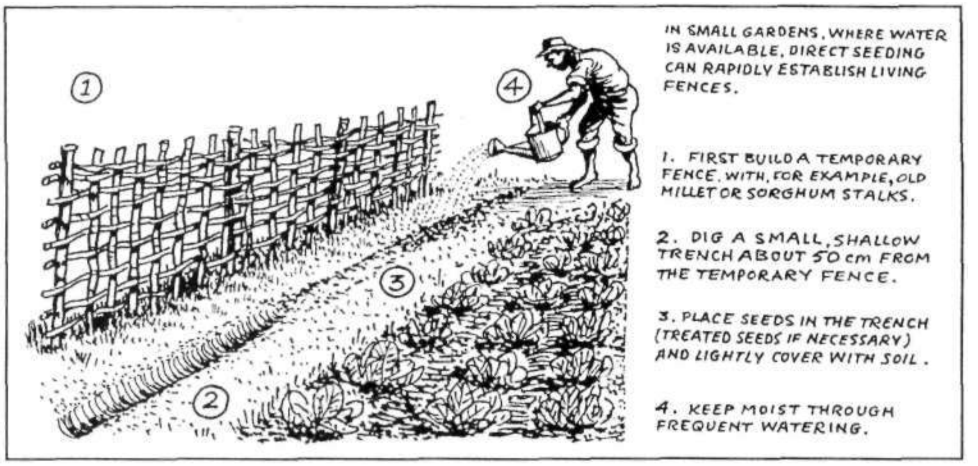


Figure 9.2 Direct seeding fences

Direct-seed sowing is a method that can be used both in high-potential areas and in ASAL areas. The risk of failure is, however, higher in dry areas where rainfall is erratic, but often it is still worth trying. In dry areas, it may be necessary to repeat the sowing several times, but it is still justified since the cost involved is small. Use of seedlings may be a safer method in ASAL areas, but if many seedlings are required the problems of raising and transporting them and still having to expect a relatively high mortality makes it uneconomical to use seedlings on a large scale.

Criteria for species and technologies where direct-seed sowing is recommended are:

- Many seedlings are required, hence transport of seedlings is difficult
- A good seed supply, allowing for waste of some seed
- Fast initial growth of seedlings
- Large seeds are better than small seeds since they are not so easily washed away by rain.

Some species and technologies that meet most of the criteria are:

- *Croton megalocarpus* for fencing
- *Acacia mearnsii* for woodlots
- *Balanites aegyptiaca* generally
- *Caesalpinia decapetala* for fencing
- *Sesbania* spp. and *Leucaena* spp. generally
- *Thevetia peruviana* for fencing
- *Eriobotrya japonica* generally
- *Cajanus cajan* generally.

It is rarely justifiable to raise any of these species in nurseries.

Apart from climatic factors, sowing depth is a factor which frequently causes problems when directly sowing trees or shrubs. If seeds are sown too deep, the seedlings may not reach the soil surface after germination, and if they are sown too shallow the risk of the seeds being washed away by rain increases as well as the risk of drying out during germination. As a general rule, a sowing depth about twice the seed diameter can be recommended.

It is also important that sowing be done as soon as the rains are well established to give the seedlings time to grow as big as possible before the dry season. If there is a dry spell, a little supplementary watering may make a big difference to survival. Weeding is even more essential after direct seed sowing than with any other tree-planting method since the seedlings are very small initially.

Case Report No. 38: Direct sowing of an *Acacia mearnsii* woodlot

Earlier we met Mr Maina who lives in Moiben Division, Uasin Gishu District. He has established his *Acacia mearnsii* woodlot through direct-seed sowing. He bought seeds from Eldoret town at Sh 10 per 0.5-litre tin. He scattered the seed on the site before harrowing, and then he harrowed and planted wheat. The wattle seeds germinated in the wheat but were still small when the wheat was harvested and thus were not cut by the combine harvester. According to Mr Maina, it is advisable to remove the wheat stubble which would otherwise cause too much shading on the small seedlings.

Mr Maina's children tried transplanting wildings of *A. mearnsii* and found this also to be a successful method.

Case **Report No 39: Direct** sowing of a *Ctvton tnegalocarpus* hedge

In Case Report No. 15, Mrs Mary Njoki informed us about her Croton hedge. On the subject of propagation she reports that it is easy to establish such a hedge. Seeds are easily collected from mature trees. Then Mary makes a 8-cm-deep furrow and drops the ripe Croton fruit 15-20 cm apart along the furrow. Alternatively, she sows the fruit as she would maize, with a panga. Each fruit will produce 2-4 seedlings, depending on the number of viable seeds in it. When she wants a thick, trained and straight hedge, she supports the two-season-old seedlings with *fito* or wires on both sides of the hedgerow. Some seedlings can be uprooted where too many have germinated, and they can be used for filling in the gaps where germination has been poor. In less than six months a Croton hedge will reach a height of 75 cm.

9.4 Cuttings

Another simple and cheap method of propagating trees that can easily be managed by the farmer and his family is propagation by use of cuttings. A cutting is a section of stem which will strike roots when it is placed in the soil, and only certain species have the ability to reproduce in this way. This method can be recommended both for high-potential areas and ASAL areas, but only for a limited number of tree species.

Case Report No. 40: Propagation of coconut

In earlier Case Reports we met Mr Safari who lives in Utange in Mombasa District

Mr Safari has information on how to establish new coconut trees. He says that first he selects a tree that produces large good-quality nuts with a nice-flavoured juice in the *madafu* (immature fruits). He allows a mature nut to fall on the ground and then puts it on wet ground. When the nut germinates he transfers it to the planting site. At the planting site, Mr Safari digs a hole 60 cm in diameter and 60 cm deep. He puts a layer of dry grass at the bottom of the hole followed by a layer of dry cattle or goat manure, and fertile topsoil is placed on top of the manure. Black cotton soil is preferred for coconut growing.

The germinated fruit is then dug into these layers and placed in such a way that the shoot is above ground and the primary root and fruit are buried in the soil. The soil level should be just at the root collar, which means that the nut will have a smalt section left uncovered by the soil.

The "seedling" is then watered for a week or until the rains come. Normally the planting is done just before the onset of the long rains. To reduce water loss, grass and weeds are put around the stem, but this practice is discouraged by extension staff because mulch serves as a good breeding ground for the rhinoceros beetle which is a serious pest of coconut.

Young coconut seedlings can be weeded, or alternatively the weeds near the seedling can simply be slashed. Since no special planting pattern is required, Mr Safari plants coconut on any open ground within the farm. Sometimes a good coconut may fall on the ground and germinate in a place which is suitable for a new tree; then he simply protects the seedling from livestock.

Cows can destroy young coconut trees, thus livestock must not be allowed near the trees until their leaves are beyond reach. Mr Safari estimates the time required for this to be between five and eight years.

Some important species from which cuttings can be taken are:

- *Euphorbia tirucalli*
- *Morus* spp.
- *Erythrina* spp.
- *Gliricidia sepium*
- *Manihot glaziovii*
- *Commiphora* spp.
- *Ficus* spp.
- *Moringa oleifera*
- *Pithecellobium dulce.*

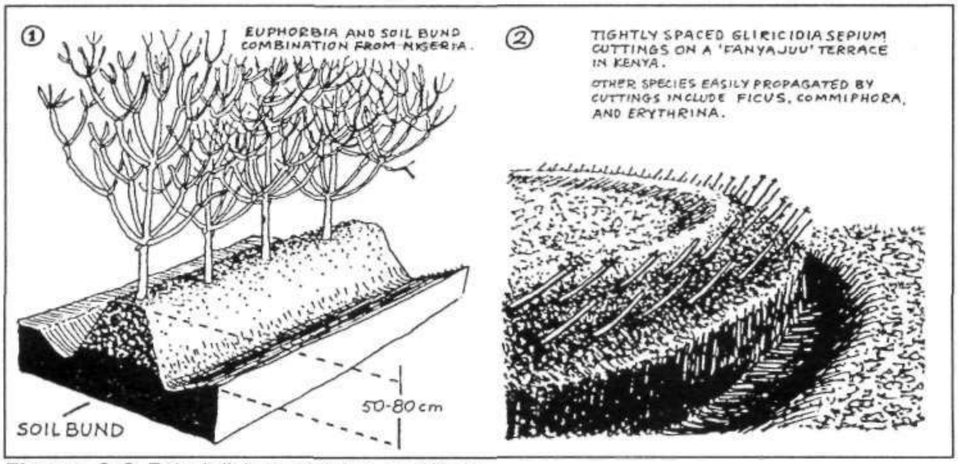


Figure 9.3 *Establishment by cuttings*

Apart from being a cheap and simple method, use of cuttings has other advantages. A tree that has grown from a cutting, or any other form of vegetative propagation, will be genetically identical to the "parent" tree. This is important since it allows a simple form of selection and propagation of trees with desired characteristics.

Cuttings can be both stem cuttings and root cuttings. Many species, and a majority in ASAL areas, e.g. *Balanites aegyptiaca,* have the ability to produce shoots from roots that are exposed. Such shoots can be separated from the mother plant and planted elsewhere. Another option is to take care of coppice shoots and root suckers which many species produce vigorously after a tree has been cut or damaged.

The size of stem cuttings can vary. Some species, e.g. *Commiphora* spp., grow well from cuttings of 1 m or more. Such large cuttings are, of course, quite resistant to damage by livestock. Most species, however, grow best from woody cuttings that are 30-50 cm long and 1-2 cm in diameter. Best results are achieved if approximately two-thirds of the length of the cutting are in the ground and it has at least two buds under the soil surface. Planting should be done at a slanting angle to speed up growth, and the buds must be facing upwards. Cuttings planted upside down will not grow. The planting site must be well prepared, weeded and protected from livestock to get good results.

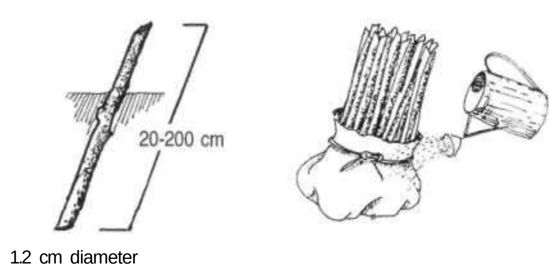


Figure 9.4 *Stem cuttings*

If possible, cuttings should be planted immediately after being cut from the parent tree. If this is not possible, due to distance for example, the cuttings must be protected from drying out by wrapping them in a wet sack and keeping them in a cool place.

All these methods are simple and highly recommended since farmers can grow more trees without having to establish nurseries or buy seedlings. If a new species is to be introduced to an area it may be a good idea initially to grow cuttings in pots. These cuttings grown in nurseries are better able to withstand transportation and delays in planting than fresh cuttings. For species that can be propagated both from seeds and from cuttings, cuttings normally grow faster.

9.5 On-farm nurseries

Suitable species

Some popular tree species are best propagated in on-farm nurseries. Species with small seeds, e.g. Eucalyptus, Grevillea and Cypress, are difficult to sow directly with good results and thus are best raised in small on-farm nurseries. The seeds of other species may be scarce and therefore optimum use must be made of the little seed that is available. This also calls for raising seedlings in nurseries.

Timing and availability of water

Seeds should be sown in time to obtain seedlings of a suitable size for planting out at the beginning of the rains. Fast-growing species need less than three months from sowing to attaining a suitable size for planting, whereas more slow-growing ones will require 4-6 months. Thus the nursery will need to be in operation during the dry season, and all nurseries of any size should therefore be located near a good water source.

Figure 9.5 Watering a home tree nursery

If there is no water source on farm, then it is advisable to have only a very small nursery with 30-40 seedlings which can be watered using household waste water. Carrying water long distances for tree nurseries should always be avoided; it is easier to carry seedlings once to the desired planting site than to transport water for the seedlings throughout the dry season.

Section 9.5 is partly based on Fahlstrom, K. 1991. *Home Nurseries.* Extension Leaflet. Nairobi: Ministry of Agriculture, SWCB.

Establishment

Small nurseries can easily be established and managed by the farmer with the help of his family. The number of seedlings raised can vary from very few to as many as may be needed on the farm or can be sold in the area. Ordinary farm tools are normally sufficient for managing such a nursery, e.g. a *jembe,* a *panga* and a tin with punched holes for watering.

Seedlings can either be raised in containers or without containers. Those grown in containers normally have a better chance of becoming quickly established and surviving than seedlings raised without containers. If polythene tubes are not available, old tins, milk packets or containers made from banana fibre can do as well. If a farmer prefers to raise seedlings without containers, a small nursery bed, approximately 60 x 100 cm and 20-30 cm deep can be made in a well-protected area of the farm. Banana stems, poles, boards or bricks can be used for a frame for the bed, which can be secured by pegs, stones or soil.

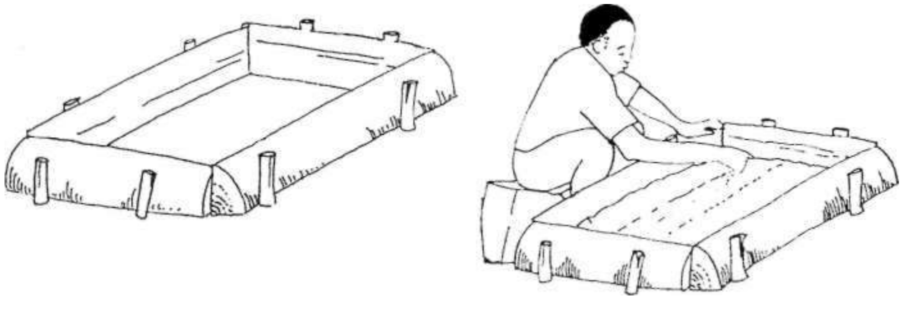


Figure 9.6 A farmer sowing seed

Fill the frame with good fertile topsoil, not too clayey nor too sandy. Firm the soil lightly. Sow seeds in furrows which are 10 cm apart and at a depth corresponding to twice the seed diameter. Cover seed with soil and firm lightly after sowing. Cover the seedbed with leaves or grass to conserve moisture, and water carefully. Remove the cover when the seedling shoots appear.

Management

The seedlings need watering, weeding, root pruning and protection against sun and animals. Construct a light shelter with sticks, about 75 cm high, and a roof of grass, straw or leaves to shade the seedlings. Reinforce the sides with a rough fence of thorny branches or sticks to protect the nursery from browsing and trampling. The seedlings should be watered twice a day, morning and evening, when the sun is not too hot. A tin with punched holes can be used for sprinkling the water. Weed regularly and thin the seedlings to an in-row spacing of 5 cm.

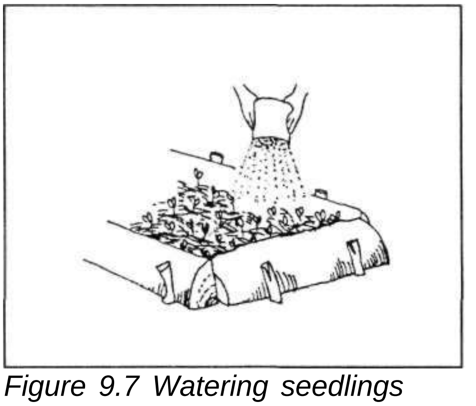


Figure 9.7 Watering seedlings

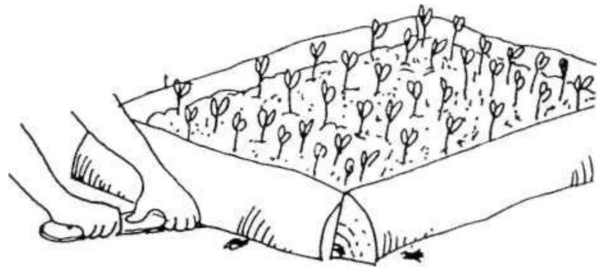


Figure 9.8 *Root pruning*

Root pruning helps the seedlings grow stronger and to build up a balanced root system. The first pruning is done when the seedlings are 5 cm high. Root pruning should be done in the early morning or in the evening. Remove pegs or stones from around the frame and water the nursery bed thoroughly. Use a sharp *panga* and run it underneath the nursery bed to prune the taproots. Then prune the side roots by running the *panga* carefully between the rows of seedlings. Put back the supports around the frame after pruning.

Newly pruned seedlings are sensitive for the first few days and need careful watering and shade. Root pruning should be done at least once a month, and more often for fast-growing species. Before outplanting, the seedlings should be hardened off during the last month. This involves gradually removing shade until the seedlings are exposed to full sunlight, reducing the watering to once a day and gradually increasing root pruning to once a week.

Planting

Water the nursery bed and remove the frame. Use a sharp *panga* to cut up the nursery bed into one soil block for each seedling. Carry the seedlings carefully to the planting site where holes have been prepared in advance. Place the soil block in the hole and firm soil around it. Water the seedling immediately after planting if it is not raining. Weed and protect the seedling just like any other planted tree.

Where are on-farm nurseries feasible?

Very small on-farm nurseries using household waste water can be established and managed both in high-potential areas and in ASAL areas. Larger on-farm nurseries which depend on a permanent water source cannot so easily be run in ASAL areas due to the scarcity of water sources there.

Figure 9.9 Young seedlings need shading

9.6 Group, school and central nurseries

So far we have discussed farmer-managed tree propagation techniques. Propagation of certain species does, however, require skills that not all farmers will have, and such seedlings are best raised by specialists for sale to other farmers. These specialists can be entrepreneurs running commercial nurseries, groups running commercial nurseries or government authorities or NGOs running nurseries.

Government-run nurseries should not primarily aim at mass production of seedlings. Farmer-managed methods are more suitable for this. Government nurseries and other central nurseries should, however, serve as experimental stations and extension centres where new or less well-known species are tried out and tree propagation techniques can be demonstrated to farmers. The production should primarily be geared towards a wide variety of species, with priority on those species that people cannot easily raise themselves. Fruit trees that require budding and grafting, and species where aspects of seedling health and good propagation material are important can be raised in central nurseries.

Species for which simple propagation techniques are applicable and known to farmers should be raised for demonstration only, i.e. in small numbers. Schools may also run tree nurseries with a dual purpose: both to act as training grounds for pupils and for production of seedlings for the school.

A good and permanent water source nearby is a must for all nurseries of any size. Management of larger nurseries requires good organization to cater for continuous attention and care. A short period of negligence, e.g. due to one member of a group failing to meet his or her obligations, or a school failing to organize people to water the nursery when the pupils are on holiday, may ruin months of work.

Since information on nursery techniques is available from many other sources no further elaboration is made here.

Figure 9.10 *Members of a community group tend tree seedlings in a horticultural nursery*

9.7 Tree-planting techniques

Time of planting

Tree seedlings are best planted out at the onset of the long rains, i.e. by the beginning of April in most parts of Kenya. In some areas, e.g. in Meru and in north-eastern Kenya, the short rains are preferred, and in those areas the best planting season is November or December. The rains should be well established, and it is recommended that the soil be moist to a depth of at least 20 cm at the time of planting. If after one or two showers only a few centimetres near the surface are wet, the seedlings may easily dry out if those showers are followed by a dry spell. In some areas where the infiltration capacity of the soil is poor it may take a very long time before the upper 20 cm of soil are wet. In such areas it is necessary to loosen the soil by digging and to refill the holes prior to the rain.

Tree planting is best done on a cloudy day. Since this tree planting will coincide with a peak period for other farm work, as much preparation as possible should be made in advance.

Figure 9.11 *Planting tree seedlings along a grass strip*

Site preparation

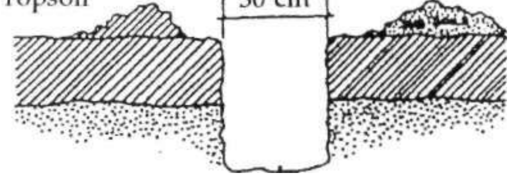


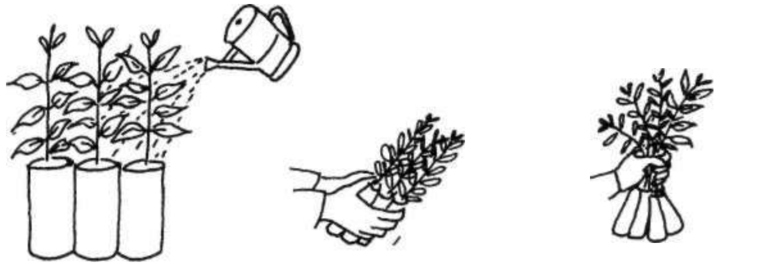
Figure 9.12 A hole and soil prepared for planting

A hole 30-40 cm deep and equally wide should be dug for each seedling. In this way, the soil is loosened and the roots can establish easily. The topsoil should be separated from the subsoil, and when the hole is filled up again the topsoil should be put back first since it is usually more fertile and should be near the tree roots. The holes can either be dug at the time of planting or in advance. Digging holes in advance has the advantage that it saves labour during the tree-planting period and if the soil is loosened early it may trap and retain more moisture.

If the soil at the planting site is poor it can be improved with manure, compost or other organic matter.

Care of seedlings

Ideally, seedlings should be about 30 cm high when they are planted out. Smaller seedlings may compete less successfully with weeds, and since their stems are not yet very woody they are easily damaged during transport. An exception to this is the case of wildings which are sometimes planted when they are much smaller. Overgrown seedlings are also easily damaged during handling and may have lost vigour due to many root-pruning operations and a too-small root compared to the shoot. In order to avoid damaging them, seedlings grown in pots should not be carried by the shoot but rather by holding the pot.



The night before planting out, water the seedlings thoroughly

not the seedling

Never pull by the shoots

Figure 9.13 Core of seedlings

If seedlings are raised without containers, care should be taken to retain soil around the roots when the seedlings are planted out. Occasionally this may fail, however, and in such cases it is very important to avoid the roots drying out or being exposed to sunlight.

How to plant

While planting the following points are important:

- After planting, the soil surface should be level with the overall ground level in the nursery, neither deeper, nor higher up.
- If the seedling was grown in a pot, the pot should always be removed. Otherwise the pot may restrict the growth of the roots eventually strangulating the seedling and severely reducing its growth.
- After refilling the hole, pack the soil firmly around the seedling's root mass and make sure that there are no pockets of air in the soil. Water if there is no rain.
- Mulch near the seedling to reduce evaporation of moisture and to suppress weeds.

Figure 9.14 Remove the container before planting the seedling

Application of a small amount of fertilizer or manure will help fruit tree seedlings to get a good start (see Case Report No. 21).

Care after planting

Regularly spot weed around the seedling for at least a year after planting. Weeding reduces competition for nutrients and moisture and dramatically enhances growth.

Protection against livestock trampling and browsing is, of course, important, as is protection against fire during the dry season.

Mulching helps to retain moisture and suppress weeds, but may also attract termites. If termites attack young trees, an application of ash can help. Leaves of neem, *Azadirachta indica,* also act as termite repellants. If a few valuable seedlings are attacked by scales or aphids, wash them with a strong solution of detergent (e.g. Omo) and water the tree if the soil is dry.

Some species tend to bend or produce many branches in the early stages, e.g. *Cordia abyssinica* and *Acacia* spp. Such seedlings may perform better if they are trained up a stake and side pruned.

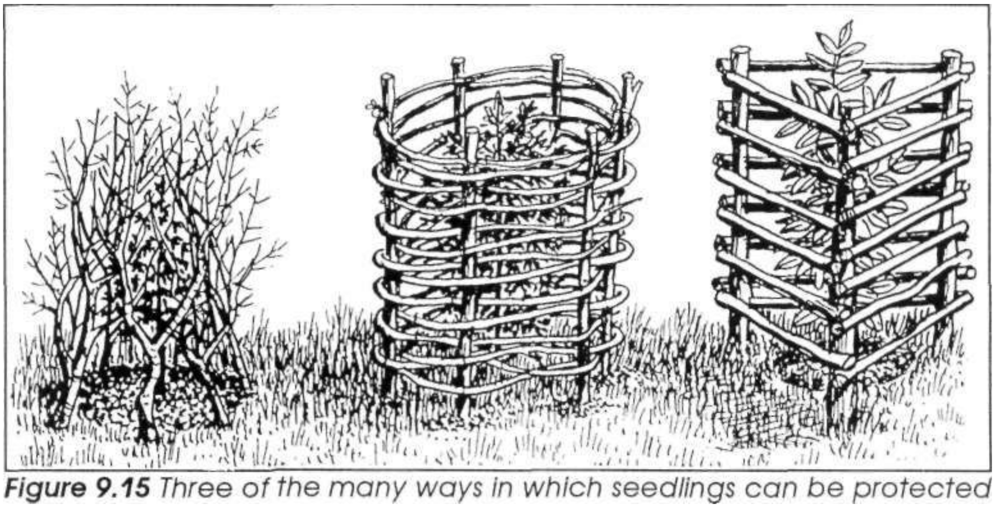


Figure 9.15 *Three of the many ways in which seedlings can be protected*

9.8 Tree planting in ASAL areas

As noted earlier, tree planting in ASAL areas should be avoided as much as possible due to the high investment required for raising and transporting seedlings, the huge areas that may be involved and the high risk of failure due to erratic rainfall. Always consider whether natural regeneration or direct seeding of trees and shrubs is possible before starting major tree-planting activities.

It is, however, sometimes necessary to plant trees in ASAL areas, e.g. fruit trees near houses or along streams or shade trees around homesteads or at meeting places. Water-harvesting techniques, if effectively and correctly applied, can significantly reduce the risk and improve seedling performance in these areas. Refer to *Soil and Water Conservation in ASAL, Field Manual Volume 3: Agroforestry.*

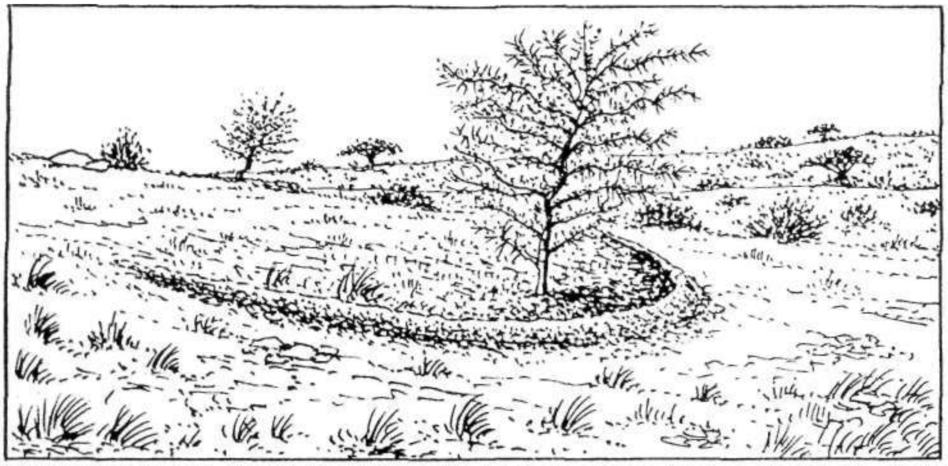


Figure 9.16 Semi-circular micro-catchments allow Acacia tortilis to grow and mature more quickly in dry areas

9.9 Tree planting in waterlogged areas

In waterlogged areas, such as marshy low-lying areas of a farm, only those trees that are known to tolerate such conditions should be planted. Among such species are *Sesbania sesban, Syzygium guineense*, and *Eucalyptus camaldulensis, E. globulus* and E. *microtheca.* Natural vegetation growth in wet areas is likely to be lush, so the tree grower must be prepared to cut back competing vegetation periodically.

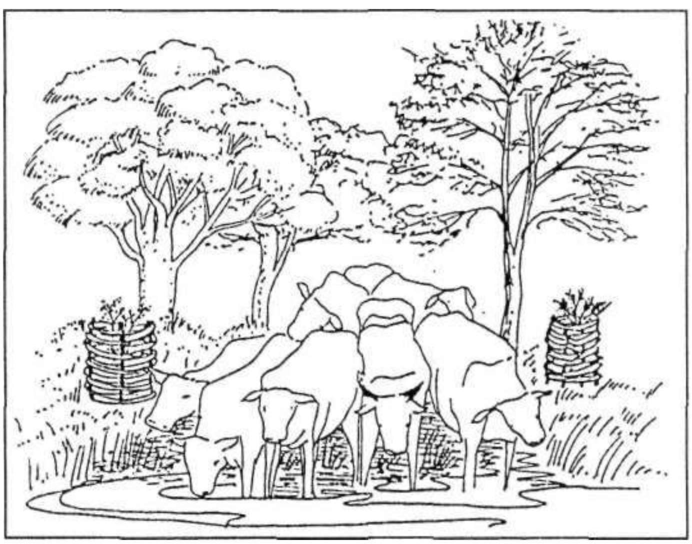


Figure 9.17 Trees in a waterlogged area

10. SEED

10.1 Obtaining tree seed

If seedlings are to be raised, or if trees are to be directly sown, seeds are essential. Access to seed and information about different kinds of seed is often a limiting factor in the growing of certain species.

There are two major ways of obtaining seed:

- Local collection
- Organized distribution from central institutions or projects.

Both methods have their advantages and disadvantages.

10.2 Seed provenances

Indigenous trees growing in a particular area have become adapted to the conditions in that area over a very long period of time. Trees of the same species growing in different areas may be slightly different from each other from the genetic point of view. These genetic differences are, of course, reflected in the seed. Foresters call these different types of the same species "provenances".

The choice of seed from good provenances may be as important as the choice of good species. But for most agroforestry tree species there is no information about which are the good provenances, so it is best to use seed from the area where the seedlings are to be planted or the seeds sown. This recommendation is mainly valid for indigenous trees.

Exotic trees have been introduced very recently in genetic terms, so significant local adaptation to site conditions in Kenya has not yet taken place. Commercial species, mainly the ones used in forestry plantations, have, however, been subject to research for a long period and central institutions such as the Kenya Forestry Research Institute (KEFRI) can supply seeds of particularly good provenances of a few of those species.

10.3 Selection of mother trees

Genetic factors combined with environmental factors determine the characteristics of the young tree as it grows. Seeds from straight and vigorous trees will most likely produce straight and vigorous trees, while twisted or stunted trees may produce the same deformities. Thus the selection of good mother trees is important.

Selection of mother trees should be related to the intended use of the trees to be grown. Shrubs or trees that produce particularly dense or thorny branches are best for fencing, whereas fast-growing and straight trees are best for poles and timber. Trees that produce palatable, dense foliage and/or pods are best for fodder.

If seeds are collected on a large scale, it is important to collect them from several trees in order to provide genetic variation in the new generation of trees. For small-scale collection for local use this is less important, however.

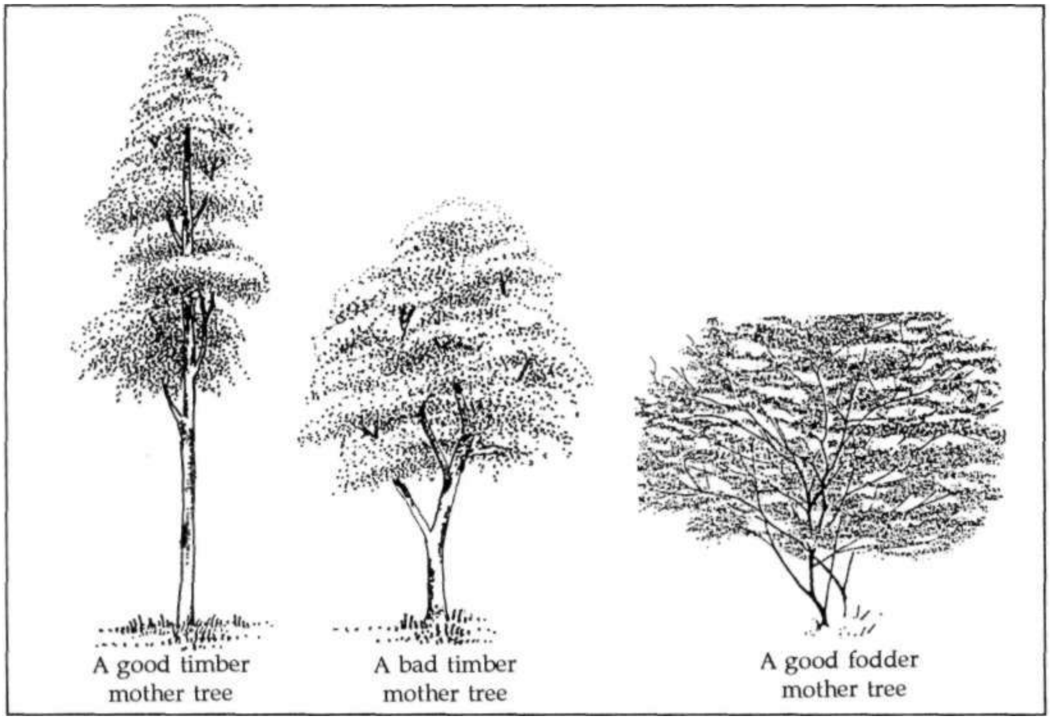


Figure 10.1 *Various types of mother tree*

10.4 Time for seed collection

Different tree species produce seeds at different times, and one species may even produce seeds at different times in different areas. Seed collection is, therefore, an activity that can and should be considered throughout the year.

Seeds should be collected when they are mature and ripe, but not damaged by insects or fungi. This calls for close monitoring of seeding trees of the desired species during the seeding period. It is necessary to check the seed quality with regard to insect damage even if the seeds are collected directly from the tree, and even more so if the seeds are collected from the ground. Seeds of *Croton macrostachyus* and *Albizia* spp. are examples of seeds which are often damaged while still on the tree.

10.5 Local seed collection

Advantages

Local collection of seeds has the following advantages:

- There is no provenance problem with indigenous trees since seeds are collected locally

- Seeds of the desired species are available at the right time; no dependency on other people
- The method is cheap both for the government and for farmers; little expense for transport of seeds
- This is the only possible way for seeds that cannot be stored even for a short period, e.g. *Bridelia micrantha* and *Syzygium* spp.

It is not difficult to collect seed locally. It is simply necessary to observe the flowering and fruiting of the desired species so that you can get to know when mature seed are available. It is good to take notes on this and to keep the notes for use in future years.

Timing

When seeds appear to mature it is good to check the inside of the seed (the seed aril). Using common sense is often enough to determine if the seed is mature or not. For most species the seed aril should be hard and white. If the aril is still soft and wet it is better to wait and check again a few days later.

Seeds of certain species, e.g. *Combretum* and *Terminalia* spp., appear to be ripe long before they are ready for collection since they turn brown very early. Another way of telling whether the seed is mature or not is to test the dryness of the seed cover. Immature seed, e.g. of *Combretum,* are moist and soft as compared to mature seed which are hard and dry. Species with edible fruit can be tasted. If the fruit is ripe the seed is also ready for collection. In certain *Acacia* spp., e.g. *Acacia Senegal,* seed are best collected before they have fully matured and dried. The best time is when the seed coat is still pale in colour and relatively soft and the swollen pods are just beginning to turn brown. In this way insect damage is minimized and germination is good even without pre-sowing treatment.

A brown, black or dust-like aril is normally a sign that the seed is damaged. Insect holes can also be spotted on the seed surface, occasionally large and easily seen as on *Acacia* and *Albizia* spp., but sometimes very small and difficult to see as on *Terminalia* spp. Insect damage can be very local. If damaged seeds are found on one tree, it may be worth trying other trees some distance away since they may have escaped damage. This applies to *Croton macrostachyus, Terminalia* and *Albizia* spp., for example.

An effective way of gaining experience in this regard is to run small local trials to determine the best times and methods for seed collection. If there is doubt about seed maturity or damage, for example, it is recommended to try a small amount of seed first and to monitor the outcome even if this means a year's delay in giving clear advice to farmers.

Practical hints

The best way of collecting most seeds is to harvest the pods or fruits when they are ripe but before they open and the seeds disperse. Some large and hard-coated seeds and fruits can, however, be collected after they have fallen to the ground. Seeds and fruits should then be collected immediately they have fallen to reduce insect or other damage.

When seeds are collected before they have fallen to the ground, which is recommended as the best practice for most species, several methods can be employed. A simple way is to shake the tree, or branches of the tree, so that the seeds fall down. The same effect can be achieved by beating the tree with a long slender pole, by throwing sticks at the branches, or by climbing the tree.

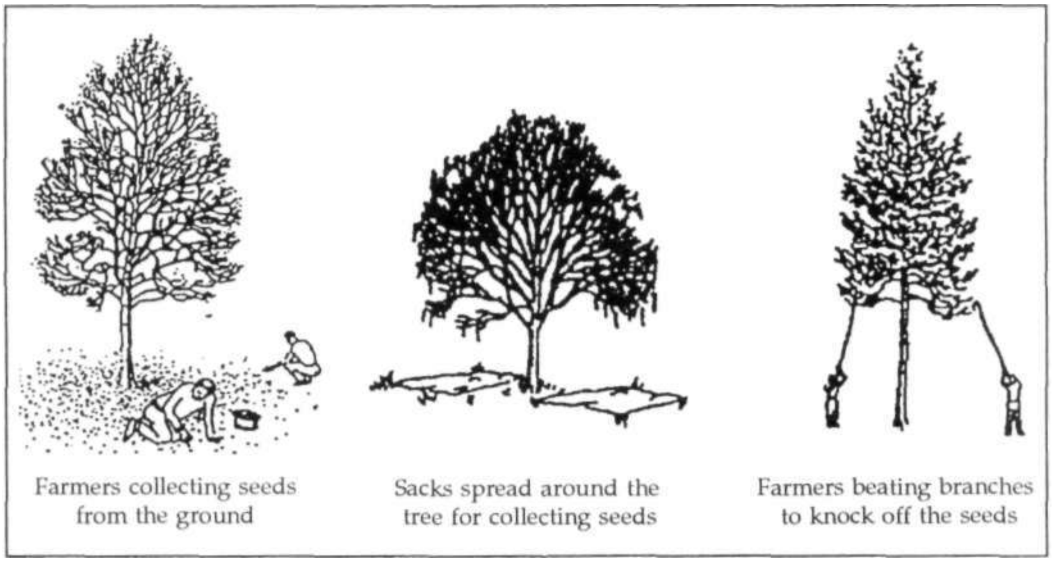


Figure 10.2 Methods of seed collection

It is helpful to clear the ground below the seed tree of bushes and weeds. Newspapers, polythene sheets or sacks can be placed under the tree so that the seeds fall on them and can be collected easily. If there are branches within reach of the roof rack of a vehicle, for example, seeds can be picked directly from the tree. Climbing the tree or use of a ladder may also be possible. A rope with a weighted end can be thrown over small branches which are then broken off by pulling the two ends of the rope. Branches up to 12 m from the ground can be reached using this method. Of course large branches can be cut using a *panga*, or the whole tree can be felled in order to get access to seeds, but these are destructive methods and hence not to be recommended if there are other alternatives.

If seed collection is carried out on private land, permission must always be sought from the land owner before any collection starts.

Local seed collection is normally best carried out by the farmers themselves with advice from extension workers. It is recommended that extensionists take on the role of facilitators, helping with exchange of seeds, information on where and how good seeds can be collected, etc.

10.6 Seed from central institutions

A number of projects operating in different areas of Kenya can be approached for seeds, but the most prominent central institution for tree seed is the Kenya Tree Seed Centre at the KEFRI headquarters at Muguga near Nairobi. This institution has advanced facilities for testing and storing seeds, and has organized collection through its field stations. Tree seeds for Forest Department plantations are often procured from KEFRI, and seeds of many species are available for purchase by projects and even for export. The Tree Seed Centre can also advise on seed pre-treatment, storage, etc., and may buy seeds from collectors if prior arrangements are made.

Reliance on centralized seed supplies should, however, be avoided. Local collection is a more effective way of ensuring a timely supply to the user of the seed of the right species and provenance. An advantage of central seed handling, however, is that it can provide seeds of the best genetic quality. So far this is valid mainly for commercial timber species, but with increased efforts to breed good varieties of agroforestry trees, centralized seed supplies may become increasingly important in the future.

10.7 Seed extraction

After collection, seeds should be extracted. The methods for this vary according to the seed type.

Pods, cones and certain other types of fruits, e.g. of *Croton* spp., can be dried in the sun until they split open. When they begin to open, the fruits can be shaken or beaten to remove the seed. This can be done by placing the drying pods or capsules in a sack and beating the sack with a stick (threshing). There are some pods for which this method is not appropriate, e.g. *Prosopis* spp. and *Piliostigma thonningii* do not easily split open when they are dried. Such pods either have to be mechanically opened, which is cumbersome, or alternatively the whole pod can be sown.

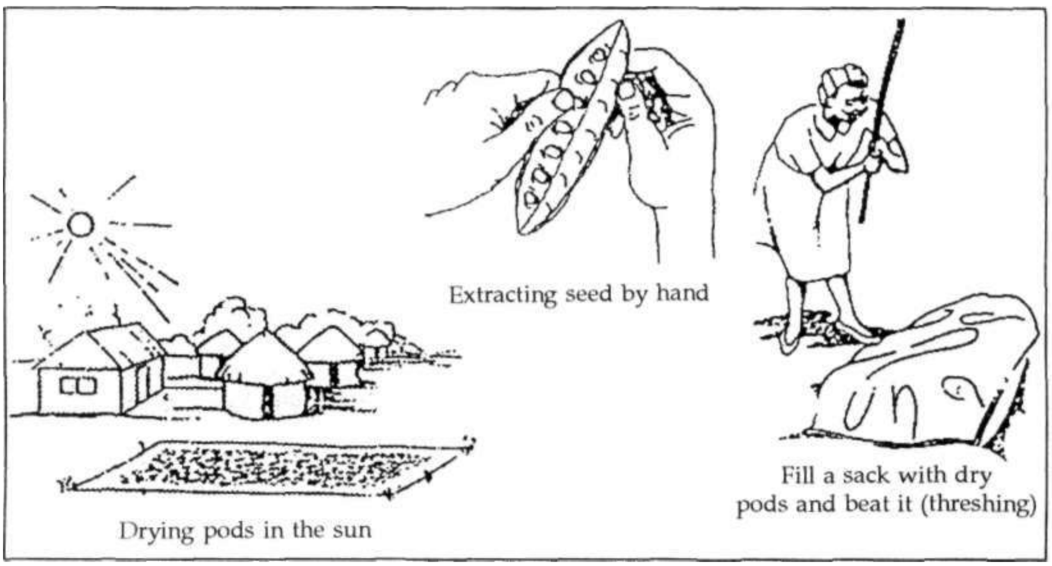


Figure 10.3 Methods of seed extraction

Seeds which are in fleshy fruits should also preferably be extracted before sowing. This is best done by soaking in water for a day or two until the fruits start to ferment or decompose. It is generally recommended to extract the seeds from fleshy, pulpy fruits rather than to dry the fruit since dried fruit pulp normally inhibits germination to some extent.

After seed extraction, the seed should be separated from the husk, fruit pulp, etc. The method for doing this may vary according to the nature of the seed. Sometimes wind can be used, or the seed can be sieved out, or simple mechanical separation may do.

10.8 Seed storage

Certain species produce seed more or less all the year round, e.g. *Leucaena* spp., *Sesbania sesban,* and *Markhamia lutea,* and for such species it is better simply to collect the seeds when they are needed. For other species the desired seed-sowing time may not correspond to the seeding time and then it is necessary to store seeds. Storage of seeds should be avoided as much as possible. Some species cannot be stored at all - they have to be sown immediately - whereas others store for shorter or longer periods without too much loss of viability.

Seeds are best stored in dry and cool, or even very cold, conditions out of reach of insects, rodents and birds. Before storage the seeds must be properly dried otherwise they will become mouldy. Airtight containers, e.g. tins or bottles, are good for storage of most seeds, and are essential for storage of seeds that are easily attacked by insects, e.g. *Acacia* and *Albizia* spp.

Figure 10.4 *Containers for storing seed*

10.9 Pre-sowing treatment

Seeds of many species do not germinate well unless they are exposed to certain conditions. This state of not germinating unless the required conditions are met is called dormancy. In the natural environment the conditions may be exposure to fire or being eaten by animals. When seeds are eaten they are exposed to the hydrochloric acid in the stomach of the animal, and this breaks the dormancy without damaging the seed.

Similar methods are used by man to treat seeds and break the dormancy of seeds he wishes to germinate. There are several methods of pre-treating tree seeds, but knowledge of a few simple techniques is sufficient to get reasonable germination of almost all species.

For pre-treatment purposes, seeds can be divided into five groups.

Group 1: *Seeds requiring hot water treatment*

This group includes most leguminous trees with pods and more-or-less flat seeds with a hard seed coat. Normally, such seeds germinate faster and better if treated with hot water. The procedure is as follows. Heat some water to near boiling point and then take it off the fire. Pour the hot water over the seed in another pot and leave the seed to soak for about 24 hours. (Do not boil the seed.) The seed will absorb water, swell and sink to the bottom of the pot. All swollen seeds should be removed and sown immediately, whilst those which are not swollen should be left in the pot for a further 24 hours. After they have swelled up, they should be sown too.

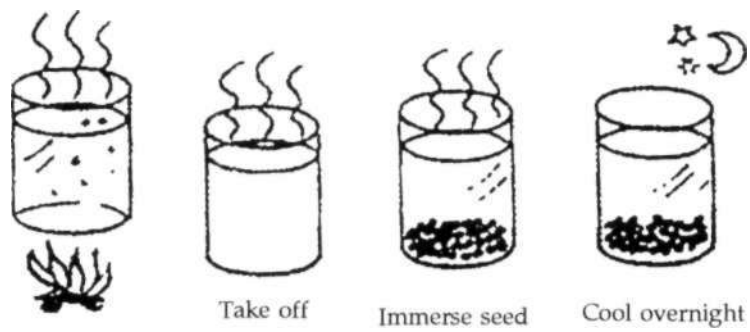


Figure 10.5 Hot-water treatment of seeds

Another efficient but time-consuming technique of pre-treatment for hard-coated seed is to nick the seed coat with a knife or fingernail clipper. Only a small nick is required. Due to the amount of labour required, nicking can only be recommended for small quantities of seed. Examples of species in this group are *Acacia* spp., *Calliandra calothyrsus, Cassia* spp., *Leucaena leucocephala, Cassia spectabilis,* and *Parkinsonia aculeata.*

Seeds in this group can usually be stored for some time, and hot-water treatment is normally more important if the seed has been stored than if it is fresh.

Group 2: *Small light seeds with no need for pre-treatment*

Many important species have small, dry seed, some of which can be stored for at least a few months without losing viability. Examples are *Eucalyptus* spp., *Casuarina* spp., *Cupressiis lusitanica, Jacaranda mimosifolia, Juniperus procera, Pinus* spp., and *Psidium guajava.*

Other species also have small, dry seeds which do not require treatment but they cannot be stored for long. For these species the best germination is obtained from fresh seed. Examples are *Grevillea robusta* and *Markhamia lutea.*

Group 3: *Large seeds with wings which should be removed before sowing*

Species with large winged seeds normally do not require treatment, but removal of the wings makes the seed easier to handle and speeds up the penetration of water after sowing. Combretum fruit should be opened and the fleshy seed sown immediately. Seeds of many Terminalia species and of *Tipuana tipu* can be stored for some time, but Combretum seeds should be sown fresh. Examples of species are: *Combretum* spp., *Tipuana tipu, Terminalia* spp.

Group 4: *Medium-sized or large seeds with no need for pre-treatment*

This group includes many seeds with a high oil content, e.g. *Croton* spp. and *Vitex* spp. Some of these seeds are surrounded by fruit pulp, which should preferably be washed away before drying or sowing the seed. Seeds of *Azadirachta indica, Bauhinia* spp., *Bridelia micrantha, Croton* spp., *Dovyalis caffra, Eriobotrya japonica, Erythrina abyssinica, Prunus africanus, Syzygium* spp., and *Vitex* spp., for example, should be sown as fresh as possible for best results, whereas seeds of *Afzelia quanzensis, Cordia* spp., *Melia azedarach, Schinus molle* **and** *Sesbania* spp. can be stored for some time. Albizia seeds can also be stored for some time, but only if they can be kept free of insects. Seeds of *Calodendrum capense* should be floated in water before sowing to separate the floating non-viable seed from the sinking good seeds. Examples of species are *Afzelia quanzensis, Albizia* spp., *Azadirachta indica, Bauhinia purpurea, Calodendrum capense, Cordia* spp., *Croton* spp., *Dovyalis caffra, Eriobotrya japonica, Melia azedarach, Prunus africanus, Schinus molle, Sesbania* spp., *Syzygium* spp., and *Vitex* spp.

Group 5: *Large seeds with hard seed coats which require cracking*

Some seeds which have a very hard seed coat could be treated mechanically to break the seed coat and allow water to penetrate inside the seed. Cracking the seed coat must, however, be done with great care in order not to damage the seed. This type of seed can normally be stored. Examples of species are *Adansonia digitata, Podocarpus* spp. and *Ziziphus* spp.

What to do if the recommended seed treatment Is not known?

If the recommended method for a desired species is not known you need to try various options and monitor the result. One option is to sow the seed without any treatment. Comparison of the seed's appearance and structure with the groups described above is recommended as similarities with other better-known seed may give hints as to what might be suitable treatment.

Further reading

The information provided here is a rough guideline. More detailed information can be found in other publications. *A Selection of Useful Trees and Shrubs for Kenya* **and** *Multipurpose Tree and Shrub Seed Directory,* both published by ICRAF, are particularly recommended.

11. SOCIO-ECONOMIC ISSUES IN AGROFORESTRY

11.1 Introduction

Rural Kenya varies a great deal from one area to another. Such variation is due to biophysical factors such as soils and climate, as well as to the different land-use practices and other activities of the people living in the areas concerned. In the ASAL areas, pastoral and semi-pastoral land-use systems dominate, and the people largely depend on cattle or camels for their food production and as a saving and investment for future needs. High-potential areas are dominated by intensive agriculture. Infrastructural development has progressed further in the central highlands and access to markets has improved over the years. Hence, people are more involved in the monetary economy.

Traditions and values, organization of communities and level of development vary between different ethnic groups, and even within ethnic groups. Effective extension work in agroforestry or in any other field must take such factors into account. Factors which relate more to conditions in the communities and less to the biophysical environment can be called socio-economic factors. Examples of such factors that are of particular importance for agroforestry extension are land and tree tenure, gender issues, traditions and beliefs, policy issues and legislation, and the economics of agroforestry. These factors will be briefly discussed in the following sections.

11.2 Tenure

Land tenure issues in agroforestry

Land tenure refers to the possession or holding of the many rights associated with each parcel of land. Ownership or user rights are not static. Such rights can be subdivided or transferred by the holder. Also the different kinds of right to a certain piece of land may not be held by the same person. An example of such a situation is farm land which is cultivated and "owned" by an individual family but communally grazed after the harvest. In such cases, communal grazing may be regarded as a right that the neighbours have to the land in spite of formal individual ownership.

Insecurity of tenure or unclear rights to land are strong disincentives to all forms of long-term investment, e.g. tree growing. Where tenure is based on communal rights, any initiative such as tree planting requires a communal decision, which may not always be easy to obtain. On the other hand, communal tenure also often involves restrictions on land use, e.g. cutting of trees, which are recognized and observed by all members of the community. Communal tenure is common in the pastoral areas of Kenya.

In many communities, tree planting is looked upon as a move to demarcate and indicate that a certain piece of land belongs to the person planting the trees. This tradition further reinforces the unwillingness to plant trees in areas where sub-division of large farms is being carried out. It is not only that it is unattractive to invest in tree planting if you are not sure of getting the benefits of the investment, but it may also be unacceptable to plant trees on land which has not legally been confirmed as belonging to the user.

Tree tenure

Tree tenure refers to the right of owning and using trees. Components of tree tenure include the right to own and inherit trees, the right to plant trees, the right to use trees and the right to cut down and sell trees.

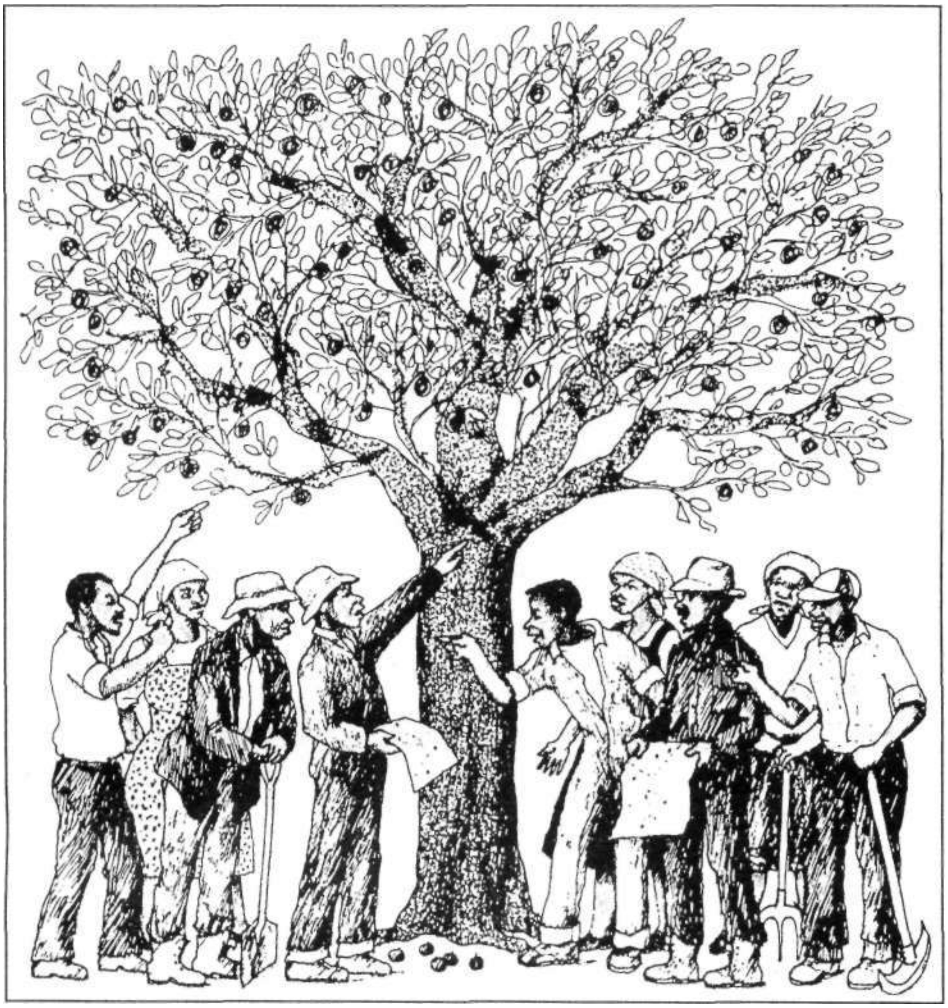


Figure 11.1 *The rights to the use of land and the trees that grow on it are not necessarily held by the same person*

Land and tree tenure do not always correspond. A certain person or group may well be recognized as having the right to cultivate or graze a piece of land, but this does not automatically give the same person or group full rights to use the trees on that piece of land. In this respect, traditional systems vary a lot from one community to another. As a general rule the systems with regard to both tree and land tenure are more complex and more community based among pastoralists than among farmers in high-potential areas where tenure is often almost exclusively individual.

Figure 11.2 Secure ownership and rights to use trees are strong incentives to increased tree growing by farmers

A factor that greatly complicates user rights to trees in high-potential areas is the regulations introduced by the state (see Section 11.5). Permits are required in many areas if a farmer wishes to sell or fell trees. Such demands for permits have been based on application of the Chief's Act.

Tree and land tenure are often complicated at the coast. The land and the coconut trees are often owned by people who do not live in the area. Sometimes, squatters grow annual crops under the coconut trees, but the owner comes to harvest and sell coconuts at harvest time. In other cases, squatters may plant coconut trees on land that does not belong to them. Eventually, when the owner of the land wants to use the land himself he is required to compensate the squatters for the coconut trees.

Traditionally, one person who plants coconuts can retain the ownership of the coconut trees even if he sells the land and moves to another place. A new land owner would not harvest the coconuts but would wait for the owner of the trees to do so. Nowadays buyers of land are encouraged to buy the coconut trees as well so that both trees and land belong to the same person.[1]

11.3 Gender

The gender factor in relation to tree growing covers the roles that male and female family members play in tree planting, tending and harvesting. In different societies there are differences in responsibilities, user rights, legal status, division of labour, decision making, etc., between men and women.

Much research has focused on the role of women in agriculture and resource management. It has been recognized that women in Kenya perform a large share of the farm work in addition to all the other duties that are traditionally the responsibility of women. Social changes such as most children now going to school and men being increasingly busy with off-farm work have added to women's workloads. Increased population pressure and settlements on former large-scale farms have often resulted in women having problems with access to

F.W. Mbote, Ministry of Agriculture, pers. comm.

fuelwood and other commodities. The disappearance of indigenous fruit trees has made children more dependent on "home food", also making women more busy.

Traditionally the man is the most influential member in Kenyan families, and he is also regarded as the owner of the land the family occupies. Traditionally, women and children own property only if the husband/father has died. In recent years, however, it has become common for single women to buy land for their children or for their own future use. Sometimes a father may also give land to his daughters who do not marry.

The situation regarding tree tenure and gender varies in different parts of the country: in some areas tree planting is clearly dominated by men (justified by the fact that men are the owners of the land), and trees are markers of ownership. In other parts, women have more freedom to plant, manage and even cut trees.

In Kakamega a lack of women's participation in tree planting is sustained through various taboos and beliefs. Examples are beliefs that if a woman plants trees her husband will die, or that she will be barren. Since traditionally childbearing is the only guarantee of stability in marriage, no woman would dare plant trees for fear of becoming barren. Similarly the life of a widow is difficult and no woman would plant trees if doing so is seen as a threat to her husband's life. Older women who already have the number of children they want can, however, plant trees and often do so (Chavangi, 1989).

Men and women may sometimes have different views with regard to the most favoured tree species. Since construction is mostly in the man's domain, he naturally has a strong interest in trees yielding good poles and timber, whereas women frequently show more interest in fruit trees and trees that yield fuelwood.

Figure 11.3 *It is always important to get the views of both men and women*

Division of labour according to gender also needs consideration in agroforestry extension. Women usually have longer work days than men, and the time they can devote to agroforestry may be limited. An agroforestry intervention that is recommended to alleviate women's burden in the collection of fuelwood, for example, may temporarily call for more work to plant additional trees near the house. Such an initiative may still be viable, however, if the long-term gain is clearly seen to outweigh the additional short-term work.

As a general conclusion, it is important to get the whole family involved in discussions on agroforestry. All family members have ideas and knowledge to contribute, and their individual needs and priorities should be taken into account in order to make the best use of available resources.

11.4 Other cultural factors

There are numerous other cultural factors that may influence the willingness to grow trees in an area.

Local perceptions and attitudes to trees can significantly affect tree growing. Trees may have social or spiritual roles that will affect whether they are planted and protected or not irrespective of their economic value. Knowledge about such intangible values is important for successful extension work.

11.5 Policy issues and legislation

Policy issues and legislation can have a great impact on tree growing. Compared to several other countries in eastern Africa the policy environment in Kenya has been favourable for tree growing. Secure and clear tree and land tenure and a relative freedom to harvest trees and selltree products have provided incentive, and the rural people have responded with intense tree growing on farms in many areas.

There are, however, some issues that have been repeatedly discussed in recent years and extensionists and farmers have argued that they are disincentives to tree growing and development.

One such issue is the application of the Chief's Act to the regulation of tree cutting. Even if the immediate intention is to prevent indiscriminate felling of trees, such restrictions may make farmers unsure of the benefit of growing trees and thus choose not to grow as many trees as they otherwise might.

Another issue relates to restrictions on production and trade in charcoal. Charcoal making and the sale of charcoal are restricted both by permit requirements and by price control. Charcoal is still an essential commodity that will tend to find its way to the customer regardless of regulations. It has been suggested that deregulation would make the growing of trees for charcoal more sustainable than at present.

A third issue is that of delays in the subdivision of farms and the issuing of title deeds. As noted earlier, insecurity of tenure is a major disincentive to all forms of investment.

A fourth issue is the permit requirement for production of fruit-tree seedlings. This requirement, if it were to be enforced, would make it too costly and cumbersome for individual small-scale farmers to raise and sell fruit-tree seedlings.

11.6 Economics of agroforestry

In several of the Case Reports in this book, farmers reported on the value of growing trees both for supply of products for their own use and to boost the family's cash income. A third aspect is the reduced need to spend cash on buying commodities which can be produced on farm if agroforestry systems are fully developed and adopted.

In a recent study in Vihiga Division, Kakamega District, on the socio-economic aspects of Eucalyptus growing on small-scale farms, Gustavsson and Kimeu (1991) found the following:

- An average farmer put 20% of his total land area under Eucalyptus trees for fuelwood, as a cash crop (selling poles) and as a source of building material. Each farmer saved Sh 5,000 annually when he was self-reliant in fuelwood.
- The products mainly harvested were poles, firewood, fencing posts and timber. These products were sold to dealers either from nearby Majengo market or from Kisumu town.
- Wood fetches an average of Sh 210 per cubic metre when the buyer does the harvesting.
- Fuelwood prepared for sale in small bundles fetches Sh 1,200 per cubic metre and dealers noted that the prices had doubled over the last few years.
- Timber fetches Sh 600 per cubic metre.

Gross-margin calculations showed that growing Eucalyptus was very profitable, with only tea exceeding it. The cash income from Eucalyptus is most important on farms that are less than 2 ha and where other crops cannot be produced on a sufficient scale.

Another recent study on the socio-economic aspects of Grevillea growing on small-scale farms in Kirinyaga District (M'Mutungi, 1991) concluded that:

- It is clear that the benefits outweigh the investment costs and therefore Grevillea can profitably be grown commercially
- Crop-yield loss was insignificant where pruning was done regularly
- Farmers growing Grevillea were found to be self-reliant in fuelwood
- The trees act as security during drought or periods of delayed payment for cash crops such as coffee. Trees are usually sold to cater for emergencies and pressing financial needs, e.g. school fees.
- There is a bright future market if farmers are educated on timber quality and the management needed.

One hectare with 150 Grevillea trees grown with crops was estimated to give the farmer a net income of Sh 2,800 annually from the Grevillea trees alone. In addition, the trees had many environmental and other benefits which cannot be quantified in monetary terms.

From these and other studies it is obvious that agroforestry is highly profitable and deserves continued attention in Kenyan agricultural and forestry extension, and in training and formal education.

12. EXTENSION

12.1 The role of the extension worker

What agroforestry extension is and is not

Extension can be described as a non-formal educational system aimed at improving the livelihood of people. Forestry extension has been used to mean "any program or activity that assists local people to be willingly involved in forestry activities from which they will derive some recognizable benefit within a reasonable period of time" (FAO, 1989).

"Extension should be regarded as a process of integrating indigenous and derived knowledge, attitudes and skills to determine what is needed, how it can be done, what local co-operation and resources can be mobilized and what additional assistance is available and may be necessary to overcome particular obstacles" (Sim and Hilmi, 1987).

It is important to stress that extension is basically a process of education, not necessarily involving heavy subsidies or material support. Furthermore it is a two-way educational process where local people and extension workers learn from each other.

"Agroforestry extension is *not* entirely a technical task of helping people to plant trees. It is, rather, a combined technical, psychological, sociological, institutional and political task" (Chavangi and Zimmermann, 1987).

Figure 12.1 *Extension is a process of educotion*

The role of the extension worker

Early agroforestry extension work tended to focus on the production of tree seedlings which were distributed to local people. If we regard extension as being strictly a process of education, then it can be questioned if that early work, should be regarded as extension at all.

More recently, extension policy of the Government departments involved has gradually shifted from the emphasis on nurseries to more education and facilitation of the farmers' own activities.

Chavangi and Zimmermann (1987) attempted to describe the role of the extension forester under the following points:

1. The primary role of the extension forester is to *help* people to express and communicate their problems and needs as they themselves perceive them. It is often said that a problem well defined and stated is a problem half solved.
2. As farm forestry (or agroforestry) is an integral part of rural development, the role of the extension forester is to explore how natural, human, and institutional resources in the community can be developed to bring about rural development through tree planting.
3. The role of the extension forester is to assist the people to come up with their own solutions to the problems that have been identified. This means that the role of the extension forester should be that of a motivator through participation. People should be given a chance to participate actively in the different aspects of planning and implementation.
4. The role of the extension forester is to provide individual and group encouragement and technical advice to farmers in their tree-planting efforts.
5. The role of the extension forester is to assemble and transmit existing knowledge, and to add his own knowledge. Farmers who have practised tree planting for a long time have considerable experience. This is knowledge that evolves over time; there is no substitute for it, and the extension forester will do well to make full use of this knowledge.
6. The role of the extension forester is, as noted earlier, to build on what already works well, but also to prevent farm forestry in all its aspects from remaining static.
7. The extension forester has the important role of organizing meetings. These various meetings are useful as a forum for creating mass awareness and for assessing general opinion or reaction to issues related to rural afforestation.

Figure 12.2 *One of the extension worker's roles Is to arrange meetings*

8. The extension forester has the important role of initiating projects which demonstrate the impact of rural afforestation.
9. With the initiation of projects that demonstrate the impact of rural afforestation in an area, the extension forester assumes the role of the organizer of visits to these projects.
10. The role of the extension forester is to develop satisfactory working relationships with the many other organizations which are involved in the promotion of rural afforestation in Kenya.
11. As research is an important component of extension forestry, the role of the extension forester is in this respect the vital one of acting as a link between researchers and the practical needs of the people.
12. The role of the extension forester is to make information available in a suitable form.

These roles of the extension forester apply to all extension workers dealing with agroforestry.

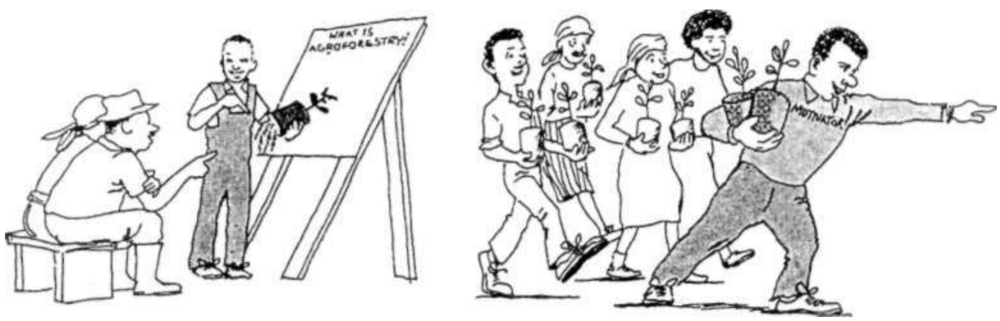


Figure 12.3 Focus on the extension worker's role as a knowledge builder and motivator

12.2 Extension planning and communication techniques

Successful extension depends upon a relationship in which the local people and the extension worker co-operate as equals. A method for participatory planning has been elaborated on in a publication which is complementary to this one (Tengnas, 1993). Communication techniques are also discussed in that publication.

12.3 Extension methods

Choice of method

There are several methods for extension work:
- The individual/household approach
- The group approach: meetings, field days, demonstrations, support to groups
- The school approach
- Mass extension methods.

None of these methods can be singled out as being the best one; all of them have their advantages and disadvantages. The choice of method depends on various factors such as:

- The tenure system in the area
- Community organization
- Resources available for extension.

A combination of extension methods is more effective than just one method. In an area where tenure is communal, or land management is based on communal efforts, a group approach is likely to be more effective than an individual approach. Meetings, field days and approaches to schools may also be good options. Usually decisions have to be made communally, and the best entry point may be through established decision-making systems, e.g. community meetings. Knowledge of traditional systems for making decisions is essential, particularly in pastoral areas where such systems are often still of great importance.

Even if the tenure is individual, communal management practices often exist. An obvious example is post-harvest grazing. Changes in behaviour in this respect may be very desirable since uncontrolled post-harvest grazing is a constraint to tree growing and soil conservation, and a change in this practice can best be achieved if the whole community is addressed. It may be difficult for an individual to introduce restrictions in this situation since the neighbours expect grazing to be free for all.

In communities where group work is common, and groups have already been organized for various tasks, a group approach may also be more feasible than an individual approach.

Figure 12.4 Local leaders play a vital role in the spread of extension activities

If an organization carrying out extension is rich in resources, a more costly approach can be chosen than if the organization is resource poor. It is, however, just as important for a resource-rich organization to carefully consider which method is best for the area, and how the extension work should be organized in order to prevent waste of resources. Cost-effectiveness should always be borne in mind, and past experience indicates, for example, that issuing free seedlings is rarely a sustainable approach since it creates dependency and discourages private commercial initiatives in tree-seedling production. An excessive level of material support generally creates dependence, and often proves to be counter productive in the long run.

The individual/household approach

This approach is most effective for activities to be undertaken by or within the full control of the individual farmer or household. Matters related to the individual farm should, as much as possible, be discussed with the whole family. If the whole family is involved, more problems are highlighted and more experience is brought to the discussion.

Figure 12.5 The individual approach

Advantages of the individual methods are:

- Unclear messages that have not been fully understood can easily be clarified
- The extension officer is able to secure co-operation and inspire the confidence of the family through personal contact
- It facilitates immediate feedback on the effectiveness of the measures discussed
- It may be the best way to ensure that everyone in the family participates in decision making.

Disadvantages of the individual method:

- It is expensive in terms of time and transport
- Only a few farmers may be visited, and sometimes they may be mainly the extension worker's friends
- The area covered is small since all the effort is concentrated on a few farmers.

The group approach

The group approach involves working with groups or the community at large. It is suitable when discussing matters related to the whole community (e.g. post-harvest grazing, protection and management of indigenous forests), and when there are activities to be undertaken by a group, e.g. group nurseries. It is also suitable when there is a need to address individual matters but more cheaply than can be done with the individual approach. The direct target group may be a women's group, a church organization, a co-operative society or the community in general.

Extension work can also be carried out at meetings, either organized specifically to discuss agroforestry issues, or by making use of meetings that were already organized for some other purpose but where some discussion on agroforestry can be accommodated. Meetings are effective venues for receiving information from the community, for discussing issues of communal or individual interest and for spreading new ideas.

Figure 12.6 Much information can be obtained during meetings

Field days and demonstrations are best organized on individual farms. There are two kinds of demonstration: result demonstrations and method demonstrations. Result demonstrations show farmers the results of a practice that has been in use for some time and are intended to arouse the farmer's interest in the practice. They can also be used to compare older practices or techniques with new ones. Method demonstrations show farmers how a particular activity or task is carried out, e.g. how to plant a tree. This type of demonstration is among the oldest methods of teaching. It is an effective method since the farmers can practise, see, hear and discuss during the demonstration.

The **catchment approach** is a special type of group approach that has been used since 1987 in the National Soil and Water Conservation Programme of the Ministry of Agriculture. All farmers within a certain area, normally some 200-400 hectares, are mobilized and trained for conservation efforts. A catchment committee consisting of, and elected by, the local farmers assists the extension staff in awareness creation, layout of contours, implementation and follow up. The group approach is combined with the individual approach since each farm is subject to specific advice and layout.

Training and visit (T&V) is not an extension method but rather a management system for extension work built on a combination of the individual and group approaches. In this system, the extension staff are trained every fortnight on the relevant extension issues for that time of the year and the staff then extend these messages to contact farmers who receive special attention. Field days and other visits are arranged on the farm of the contact farmer so that his neighbours can also benefit from the knowledge he has gained.

Advantages of the group approach:

- It is generally cheaper than the individual approach
- More people are reached within a given period of time

- There is an exchange of ideas and experiences among the group
- It is easy to monitor.

Disadvantages of the group approach:
- It may take a long time to arrive at a decision
- Influential people in the community may dominate the discussions
- It is sometimes difficult to get people to agree on issues and to work together
- Individual problems are not well addressed in a group
- People who are not members of the group will not be reached.

The school approach

The school approach is being used by both Government ministries and NGOs. Schools can be approached through headmasters or teachers. The extension work can be in the form of lectures, support for 4K Clubs, or discussions held during parents' days. The pupils can be used as a channel for reaching the community and will also be influenced themselves, thus changing the behaviour and attitudes of the new generation. Pupils can also be used to trigger discussions in their families.

Figure 12.7 Encouraging tree growing in schools

Advantages of the school approach:
- Schools can afford to make demonstration plots available and these be seen by many people
- It is possible to reach large numbers of people within a short time at minimal cost
- Pupils can be reached easily and are often very receptive to new ideas.

Disadvantages of the school approach:
- Children are not decision makers in the home
- It will be a considerable time before the children become influential in their society.

Mass extension methods

Mass extension methods involve the use of the mass media, e.g. radio, posters, drama, television, newspapers, films, slide shows, to inform the public. Mass media are mainly used to create awareness.

Advantages of mass extension methods:
- These methods can increase the impact of extension staff through rapid spread of information
- Many people can be reached within a short time, even in remote areas.

Figure 12.8 *Newletters can be used to create awareness*

Disadvantages of mass extension methods:
- The amount of information that can be transmitted is limited
- Radio and television reception is poor in some areas and the target group may not own sets, particularly TVs
- It is difficult to evaluate the impact since there is no immediate feedback
- Production of both programmes and printed materials is costly and requires special skills.

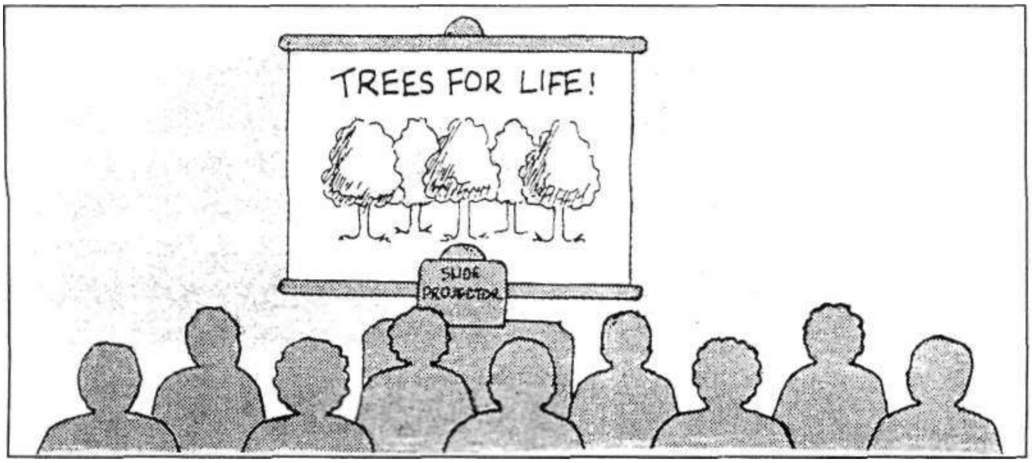


Figure 12.9 *Slide shows often create great interest in rural areas*

12.4 Agroforestry extension approaches in Kenya

Numerous organizations and projects have been involved in agroforestry extension in Kenya, and most, if not all, extension methods have been tried. This section will not attempt a full review or evaluation of these experiences, but will highlight a few past initiatives.

Ministry of Agriculture and Ministry of Environment and Natural Resources

Agroforestry extension in these two Ministries dates back to the 1970s, but initially with a strong emphasis on seedling production in central nurseries, and more lately with emphasis on training and education. In the Ministry of Agriculture, agroforestry extension is carried out through both the individual and the group T&V and catchment approaches. Schools are also addressed, and printed materials such as posters, calendars, and booklets for schools, have been produced. Thus these Ministries use all the major extension methods.

Ministry of Energy

This Ministry has been the host ministry for numerous projects. Agroforestry Energy Centres have been established for method demonstrations on how to grow trees, how to make improved *jikos* and how to produce biogas, and for result demonstrations on certain agroforestry technologies. Research was also part of that programme.

Figure 12.10 The direct impact of a demonstration plot

Kenya Woodfuel and Agroforestry Project KWAP

KWAP, formerly called KWDP, and run under the auspices of the Ministry of Energy, has been operating in Kakamega and Kisii Districts for a long time and has recently expanded its activities to other Districts in western Kenya.

Figure 12.11 KWAP has used drama as an extension technique

Various extension methods have been used, but the project has become most well known for its development of the so-called "mirror" technique. Based on traditional techniques for getting slightly sensitive issues discussed, KWAP developed techniques where drama, songs, role-plays, films and poems are used in *baraza* (public meetings) or field days, or on radio and television to depict a real situation in the community. The technique places a "mirror" in front of the community so that it is able to detect its own problems and find solutions to those problems. The drama, role plays, songs or films should be simple, clear and realistic to the community so that social barriers are identified and they will open opportunities for family discussions.

The issue of fuelwood shortage has been a focus, and the mirror technique has been used to make the community aware of the need for better co-operation between men and women in solving such problems.

Kenya Energy and Environment Organization, KENGO

KENGO has been active in extension for some time. Being an umbrella organization for other NGOs in Kenya, KENGO works mainly through the group approach and providing support for organizations working at the grassroots level. It also uses the mass-media approach and the school approach. KENGO has produced a significant number of publications, notably on improved stoves and tree seeds.

Kenya National Farmers Union, KNFU

KNFU has been promoting agroforestry among its members by supporting study groups and various other activities. Booklets on agroforestry have been produced.

VI Tree Planting Project

This project has operated since the mid-1980s in Trans Nzoia and West Pokot Districts. Nurseries have been established mainly as centres for demonstrations on how to raise tree seedlings of a wide range of species. The nurseries also play a significant role as centres for production of seedlings. Extension workers are working in the areas around the nurseries assisting farmers and groups. Schools can obtain some technical and material support from the project.

A demonstration and training centre has been established in Kitale where both methods and results are demonstrated. There is also an exhibition at the centre providing information on agroforestry and important species for the area, and a small arboretum where rare tree species have been established. The demonstration centre is a collaborative effort with Kitale Museum.

CARE

CARE has been working intensively in Western Kenya, mainly using the group approach.

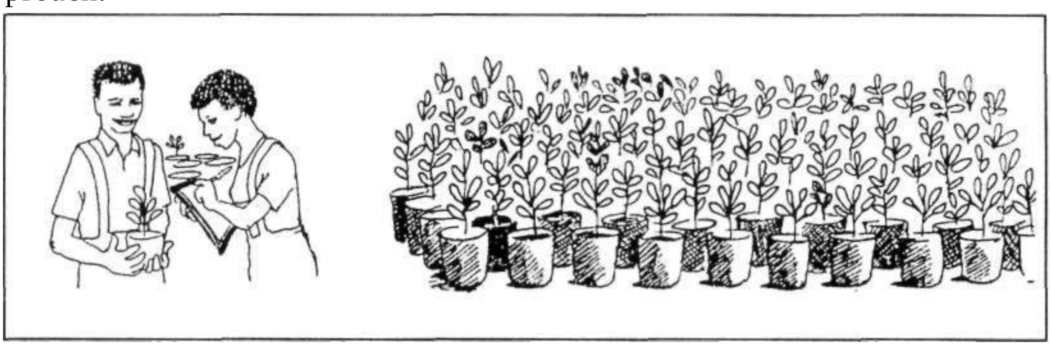


Figure 12.12 *Demonstration plots and nurseries*

13. MONITORING AND EVALUATION

In agricultural extension, which has been going on for a long time, extension workers normally have a set of "proven" messages based on results of extensive research. This situation is different from that of the extension worker promoting agroforestry. Agroforestry has only recently received attention in research, and simultaneously efforts in agroforestry extension have been intensified. Thus, the research information that extension workers can use to make recommendations on species, sites, arrangements and management techniques is limited. In addition, agroforestry technologies are usually complex and site specific. Hence, the extension worker usually has no "proven" technical packages to rely on but instead has to use the extension work itself as a method of technology development together with farmers.

Effective feedback of information from farmers to extension workers, and from them to researchers is, thus, even more important in agroforestry extension than in agricultural extension. Based on such feedback and on monitoring of field activities, recommendations have to be continuously modified.

Effective monitoring of progress is more important if new technologies are being introduced than if traditional practices are promoted since the risk of failure is generally greater with new or little-known technologies.

Extension is by definition aimed at improving the livelihood of the people, and it is of course the final impact of the efforts that will distinguish useful and successful extension work from failures. Different indicators can be used to evaluate impact depending on the nature of the activities and how long the extension work has been going on. In the early stages of extension, intermediate indicators need to be used, but eventually the "real", or so-called final indicators, should be used.

Figure 13.1 Evaluation is vital

IF, for example, the objective of the extension work in an area is to ease the burden of fuelwood collection for women by planting more trees nearby, in the initial stages of extension the number of tree seedlings planted must be used as an indicator of success. After a year or two it may be possible to make survival checks and see how many trees are actually growing on the farms. Both these indicators are intermediate ones giving only tentative indications of whether the objectives are likely to be met. It is not until the trees are actually in use for fuel that the final indicators can be used. In this example the final indicator may be how much less time women spend on firewood collection compared with the situation before the trees came into use. An even better final indicator would be how the women used the time saved due to the increased supply of firewood, what extra income they managed to earn as a result, how much more leisure time they had and what they thought of the improvement generally.

It is only by using such final indicators that the real success of extension can be measured, but due to the relatively long time required for trees to grow and mature, evaluation of forestry and agroforestry projects is often based on intermediate indicators.

It is important to treat results from evaluations based on intermediate indicators with caution. For example, the number of seedlings produced in nurseries is a poor indicator of success in agroforestry extension. There are many later pitfalls in the process of growing trees that may make the final outcome less satisfactory even if the early indicators were favourable.

In day-to-day extension work it is important to observe what is going on and how different combinations of trees and crops appear to be performing in the area concerned. Much can be learnt by careful observations, e.g. what kind of tree management seems to be most effective in a certain situation, or which spacing is most appropriate.

Another important way of monitoring day-to-day progress is to carefully **listen** to the reactions of the target group. Careful listening not only provides an excellent opportunity to learn more but also shows farmers that the extension worker is seriously interested in his task.

Finally, in day-to-day monitoring, **notes should be taken** regularly, both on direct observations made and on information provided by the rural people. It is always good to be able to go back to your notes and remind yourself of the details of a certain situation.

Figure 13.2 Activities in day-to-day extension work

If extension workers work, as a team in an area, which is strongly recommended, it is also essential once in a while to review the priorities and targets set, to scrutinize findings from any earlier data gathering, and jointly to discuss in more depth whether or not the priorities or targets need revision. These discussions should be held at least annually and, preferably, more often.

14. AGROFORESTRY RESEARCH IN KENYA: AN OVERVIEW

14.1 The development of agroforestry research in Kenya

Agricultural research in Kenya dates back, to before 1910 when small trial plots were laid out to test cash crops such as sisal, maize and cotton. Livestock experiments started around the same time. Forestry research was not organized in a coherent manner until 1934, and the Kenya Forestry Research Institute (KEFRI) was established as late as 1986.

Compared to that in agriculture and forestry, agroforestry research is very recent in Kenya. A major landmark was the establishment of the Headquarters of the International Council for Research in Agroforestry (ICRAF) in Nairobi in 1978. Gradually during the 1980s and 1990s agroforestry research progressed and a large number of institutions are now involved in various types of research. With ICRAF and its support for national institutions Kenya has in fact emerged as one of the global centres of agroforestry research.

In this chapter on-going research will be highlighted and some findings discussed.

14.2 ICRAF, AFRENA and collaborating national institutions

ICRAF

ICRAF was initially established as the International Council for Research in Agroforestry, and was aimed mainly at facilitating research carried out by other institutions. The headquarters had a small staff, and among the initial priorities were to create a documentation centre, to establish field demonstrations and to develop methods for agroforestry research. It was not until the late 1980s that ICRAF began its own research on a significant scale. In 1991 the institution's name changed from International *Council* to International *Centre* for Research in Agroforestry. During 1991, ICRAF became a member of the Consultative Group on International Agricultural Research with global responsibility for research in agroforestry. These developments marked a shift for ICRAF from being a body that gives advice to being a focal point for agroforestry research.

The institutional goal for ICRAF is "To mitigate tropical deforestation, land depletion and rural poverty through improved agroforestry systems". Research focuses on three agro-ecological zones: the humid, subhumid and semi-arid tropics. Although the mandate is clearly global, work in areas suffering from land depletion will continue to focus on Africa where these problems are most serious. Collaboration with national and other institutions, which has been a main feature of ICRAF's work, will continue. The four existing Agroforestry Research Networks for Africa (AFRENA) will continue receiving support through ICRAF.

ICRAF's own research has so far mainly been on-station, and focused on:

- Agroforestry technology design and management
- Species screening
- Soil fertility and soil conservation
- Fodder.

Most research has so far been applied and descriptive (trying to understand *what* happens) rather than process-oriented (trying to understand *why* it happens).

Collaborative research programme in the highlands of eastern and central Africa

Kenya is one of the countries participating in the AFRENA for the highlands of east and central Africa, which was initiated in 1986. The objectives of AFRENA are the development of appropriate agroforestry technologies and development of national capabilities to carry out agroforestry research. The participating countries in this AFRENA are Kenya, Uganda, Rwanda and Burundi. There are several research sites in each country, and the research focuses on the subhumid highlands at altitudes ranging from 1,000 to 2,500 m. The subhumid highlands in those countries have been designated as a zone since they share common features. Population density is high, farm sizes are small and land-use systems are among the most intense in Africa. Agricultural practices have not always kept pace with the increasing pressure on land, resulting in a decline in the natural-resource base.

A key consideration in the design of the research programme has been complementarity among activities in each country. Agroforestry technologies with potential for the zone as a whole are being tested at multiple sites under varying environmental conditions. The choice of technologies to be tested has been based on Diagnosis and Design (D&D), i.e. surveys of existing land use, with associated potentials and problems, have been used as a basis for setting research priorities.

Figure 14.1A D&D normally provides a basis for setting research priorities

Such D&D studies have been carried out at the national (macro) scale by teams constituted of ICRAF scientists and scientists from national institutions.

The main institutions with which ICRAF is collaborating in Kenya are the Kenya Forestry Research Institute (KEFRI), and the Kenya Agricultural Research Institute (KARI).

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14.3 ICRAF's research station at Machakos

In 1980 the Kenya Government gave ICRAF a 40-hectare site to be developed into a field station. Initially the field station was mainly developed for demonstrations of agroforestry technologies for extension personnel, policy makers and researchers. But gradually the station has turned into a research station with modest laboratory facilities. This field station in Machakos is the only such research facility that ICRAF manages on its own.

The demonstrations that were established during the 1980s were of three main types:

- Demonstrations of multipurpose tree species. Seven species were planted in macroplots *(Leucaena leucocephala, Acacia albida, Gliricidia sepium, Balanites aegyptiaca, Prosopis juliflora, Sesbania grandiflora, Acacia nummelaria),* and another 80 species planted in microplots.
- Demonstrations of agroforestry technologies, e.g. woodlots with *Grevillea robusta* and *Gliricidia sepium,* boundary planting, live fences, soil-conservation technologies (barrier hedgerows, bench terraces with trees on the edges of terraces, *fanya juu* with trees below the risers, trees with grasses on contours), alley cropping, windbreaks, and fodder banks.
- Demonstrations of experimental design (systematic designs, tree/crop interface, etc.)

Numerous visitors have benefited from these demonstrations, and the experience gained at the field station laid the foundation for the research which was developed within the AFRENAs.

From 1990 greater emphasis has been put on research. The collaborative research that began in the mid-1980s created a need for more scientific backing for strategic research issues and research methods. Most of the resources are now geared to research, aimed at answering the "how", "what" and "why" questions. Examples of research activities are:

- Demonstration plots have been converted to research plots where different soil-conservation measures are assessed with regard to run off, erosion, etc.
- Different species are investigated in component-oriented research with regard to spatial arrangement, cover versus barrier effects, agroforestry systems versus non-agroforestry systems, impact on long-term soil fertility, etc.
- Efforts to quantify the tree-crop interface with regard to factors such as water, light, and shelter
- Comparisons of annual and perennial legumes for soil-fertility improvement
- Studies of tree root systems and root competition
- Comparisons between use of prunings from hedgerows for fodder and for soil-fertility maintenance
- Water balance and the hydrology of agroforestry systems
- Provenance trials of *Gliricidia sepium* and *Cajanus cajan* while at the same time testing experimental design.

14.4 KEFRI/KARI/ICRAF Maseno National Agroforestry Research Centre

The Maseno Research Centre was established in 1987 with KEFRI as the lead institution and in collaboration with KARI and ICRAF. Maseno is located in a high-potential area in western Kenya. The station is a part of the AFRENA network, and research is carried out in the food-crop-based land-use system which dominates the area. The activities at Maseno include species-screening trials, farmer surveys, selection and breeding research on high-priority species, breeding biology and vegetative propagation studies, and work on tree-root symbionts. Research under the AFRENA programme includes on-station and on-farm experimentation to develop and evaluate agroforestry technologies for soil-fertility maintenance and fodder production.

Examples of on-station trials are:
- Species screening
- Vegetative propagation trials
- Flowering and fruiting of selected tree species
- Provenance trials of *Leucaena leucocephala, Sesbania sesban* and *Calliandra calothyrsus*
- Fodder production potential of grass and shrub combinations on contour bunds
- The effect of cutting frequency on biomass production of Leucaena hedges
- The effect of *Leucaena diversifolia* hedge architecture on hedge biomass production and crop performance
- The effect of Calliandra cutting height on fodder production in combinations of Calliandra and Napier grass on contour bunds
- Selection of MPTs for alley cropping with maize
- The effect of Leucaena mulch with different rates of application of DAP/CAN fertilizer on maize and maize/bean combinations
- Decomposition and nutrient uptake of selected MPTs.

The on-farm programme started in 1990. Informal surveys have confirmed the findings of the Macro D & D (Minae and Akyeampong, 1988). A decline in soil fertility is a major problem in the land-use system and shortages of fuelwood and livestock feed were also of concern. The communities were approached through women's groups in these surveys.

So far, on-farm activities have included:
- Assessment of the impact of hedgerow intercropping on soil fertility and soil-erosion control with emphasis on farmers' socio-economic requirements and benefits
- Studies of the biological performance of hedges on different soil types
- Investigation of on-farm supply and demand for tree products and marketing opportunities
- Testing of rotational hedgerow intercropping, fodder banks and boundary planting
- Studies of patterns of household decision making with regard to the adoption of agroforestry
- Development of appropriate on-farm research methods.

A number of other studies have also been conducted, e.g.:

- A farmer-designed tree-planting trial
- Soil-fertility management on small farms
- Soil-fertility status of farmers' fields
- Evaluation of hedgerow intercropping.

In a trial where 50 farms were involved, farmers designed tree planting with *Grevillea robusta, Casuarina cunninghamiana, Leucaena leucocephala, Leucaena diversifolia* and *Calliandra calothyrsus.* Two out of three farmers planted shrubs in hedgerows, 50% of the farmers planted Grevillea on external boundaries, 36% on internal boundaries and 11% around the homestead.

Neighbouring the agroforestry research station at Maseno is the site of the KARI Small Ruminant Collaborative Research Support Programme. This project is trying a number of fodder trees and shrubs in hedgerows and for improved fallows.

14.5 KARI/KEFRI/ICRAF Agroforestry Research Project, Embu

This project, which began in 1991, is also part of the AFRENA network The leadership is provided by KARI, and research is carried out in the coffee-based land-use system of the central highlands. The main emphasis is on on-farm research and only technology testing and development is carried out on station.

The main constraints to D&D in this land-use system were identified as:

- Decline in soil fertility
- Soil erosion
- Dry season fodder shortage
- Shortage of firewood and other wood products.

The team conducting the D&D also noted a need to intensify income-generating activities such as fruit production.

Activities carried out so far include:

- An ethno-botanical survey
- The establishment of on-farm fodder trees in fodder plots and multi-storey boundary planting
- Screening of *Flemingia macrophylla* for soil-erosion control and mulch in coffee
- On-station hedgerow intercropping for soil fertility
- D&D of agroforestry technologies for fodder production and soil fertility
- Monitoring and evaluation of production and marketing of fruit and wood products
- On-station MPT screening
- Establishment of MPTs in mature Napier grass plots
- On-station assessment of new Grevillea germplasm imported from Australia
- Study of the impact of homegardens on household economy
- Factors influencing labour productivity in hedge pruning.

14.6 KEFRI/KARI/NDFSRS/MIDP/ICRAF Dryland Agroforestry Research Project, Kakuyuni

The Dryland Agroforestry Research Project (DARP), is located in a semi-arid area of Machakos District. The project was initiated in 1983/84, and is a collaborative project between KEFRI, KARI, ICRAF, the National Dryland Farming Systems Research Station (NDFSRS), and Machakos Integrated Development Project (MIDP).

The main objective is to develop agroforestry technologies for semi-arid areas in Kenya. In the third phase that began in 1991 emphasis is being put on farmers' involvement in technology design.

A D&D was conducted in 1983, and some of the main constraints in the land-use system were found to be:

- Soil erosion and degradation of grazing land
- Decline in soil fertility
- Dry-season fodder shortage
- Poor cash flow for farmers
- A shortage of tree products (timber, poles, firewood).

Some examples of trials and experiments so far are:

- Hedgerow intercropping (on station, NDFSRS)
- On-farm trials of hedgerow intercropping with *Cassia siamea*, *Gliricidia sepium* and *Leucaena leucocephala*
- Rehabilitation of grazing land with indigenous species
- Fodder plots on farm
- Live fencing on farm
- Fruit-tree production on farm.

14.7 KEFRI and KARI

As noted earlier, the main national research institutions involved in agroforestry research are KEFRI and KARI. Most of their research is carried out in collaboration with other organizations at the various research stations. KEFRI is, however, also conducting important research on its own, mainly at Muguga. Among these activities, the National Tree Seed Centre deserves special mention. Research is conducted at the centre and it is also the most important institution involved in seed collection and sale of tree seeds.

Beside seed research there are also species screening trials, hedgerow intercropping trials, tree-grass combination trials, multi-storey boundary planting and fodder banks at Muguga, and there are plans to conduct a nation-wide survey of farmer-managed tree propagation techniques. Collaborative research between ICRAF and KEFRI at Muguga is currently being initiated.

KEFRI collaborates with the International Institute of Tropical Agriculture (IITA) under the Alley Farming Network for Africa (AFNETA) and with CARE (see below).

14.8 Other organizations involved in agroforestry research

A large number of other institutions conduct research or informal trials on agroforestry, often closely coupled with extension. Only a few of those organizations are mentioned here.

Ministry of Energy (KREDP, KWDP/KWAP)

The Ministry of Energy has been the parent ministry for both the KWDP/KWAP, which has already been described, and the Kenya Renewable Energy Development Project (KREDP). Both projects have contributed to agroforestry development, but research was a particular part of the agenda at KREDP. Agroforestry Energy Centres were established in the early 1980s. One of these centres is located at Mrwapa in the coastal zone. The main objective of the Centre is to address the problem of declining soil fertility and to find solutions to the shortages of firewood and poles in the coastal zone. Hedgerow intercropping trials with several tree species in combination with maize are continuing there. A large amount of data were collected from those trials, but unfortunately very little has been analysed.

International Livestock Centre for Africa

KARI and the International Livestock. Centre for Africa (ILCA) also carry out collaborative research in the coastal zone. The main focus is on fodder and milk. production, with special emphasis on how best to utilize available land and labour. Research is conducted both on station and on farm, with improved milk production as a main objective.

CARE

CARE and KEFRI have run a collaborative programme since 1985 in Siaya District. Activities include trials on hedgerow intercropping, soil-conservation measures, farm woodlots, boundary planting, intercropping and mulching of fruit trees, live fences and windbreaks.

Kenya Energy Non-Governmental Organizations (KENGO)

Although KENGO is not a research body, some of its activities have contributed significantly to knowledge and technology development. Of particular interest are KENGO's activities with regard to the development of fuel-saving stoves and documentation of indigenous tree species.

Universities

Egerton University, Moi University and the University of Nairobi are all conducting research on agroforestry or closely related issues.

fea *Research Foundation*

The Tea Research Foundation is conducting research on trees in relation to tea growing.

Coffee Research Foundation

The Coffee Research Foundation is conducting research on trees in relation to coffee growing, and in particular on the effects of shade trees on coffee.

The National Museums of Kenya/Freedom from Hunger Council Indigenous Food Plants Project (IFPP)

The East Africa Herbarium is a valuable institution for agroforesters. The Herbarium can often assist in tree identification, and in addition they are carrying out research on rare tree species.

The Indigenous Food Plant Project (IFPP), which is run in collaboration with the Freedom from Hunger Council, has contributed in documenting indigenous species and their uses for food.

14.9 Discussion of research findings

General

Both research and extension efforts over the last 15 years have revealed the extreme complexity of agroforestry systems. Research methods used earlier in agriculture and forestry are not applicable to agroforestry, and new and innovative research approaches are being developed. The importance of the socio-economic dimension of agroforestry has gradually become recognized.

One of the most important results to come out of agroforestry research and development has been the realization of the importance of involving the farmer both in designing research and in extension planning. The research conducted by ICRAF, and by national institutions supported by ICRAF, follows a logical sequence starting with diagnosis of the problems and potentials in the land-use system of an area, followed by the design of appropriate research studies and eventually the design of appropriate interventions to improve land use. The views expressed by farmers are the cornerstones in this process.

Ethno-botanical surveys have more recently become common as part of the D&D process. Understanding the local use of trees and shrubs paves the way for consideration of a wider range of species, including more indigenous species, than used to be common in agroforestry research. Biodiversity considerations have become part and parcel of agroforestry.

Recent research findings have shed new light on many aspects of agroforestry. For a deeper analysis of current knowledge on agroforestry, reference is made to other ICRAF publications. Only a few comments are made in this section.

Agroforestry and soil fertility

So far, much agroforestry research has aimed at evaluating the suitability of technologies like hedgerow intercropping. The potential of agroforestry for addressing problems of soil fertility and sustainability of production systems has been a focal point.

Research results on hedgerow intercropping have, however, been inconsistent. It has been realized that there is a need for more research aimed at quantifying the variables in tree-crop interactions in order to explain why hedgerow intercropping yields the desired results in some environments and not others.

Recent findings on the extent of shrub root systems indicate that the root systems extend much further than was thought earlier. These findings indicate a major weakness in much of the research carried out so far since the research plots have often been so small that roots from adjoining plots interfere with control plots and other neighbouring plots. Thus many of the experiments carried out would have lacked a proper control.

ICRAF scientists have recently proposed a tree-crop interaction (i) equation in order to quantify the effects of the various factors on alley cropped maize yield:

$$I = F - C + M \pm P + L$$

where F is the benefit of prunings (nutrients and mulch effects); C is the yield reduction due to interspecific competition; M the consequences of microclimatic changes in temperature, light and humidity; P the consequences of changes in soil physical properties; and L is the reduction in losses of nutrients or water (Akyeampong *et al.*, 1992).

It appears that F and C are the most important of these factors. The limited evidence so far suggests that in a dry environment C (yield reduction as a result of competition) is greater than the benefits of mulching (F).

Tentative conclusions from the research on hedgerow intercropping are that:

- Hedgerow intercropping may not be a feasible technology in dry areas (less than 800 mm rainfall a year)
- Hedgerow intercropping with certain species, e.g. Leucaena, is not a feasible technology on acidic soils (most soils in the high-potential areas in Kenya are more or less acidic)
- Hedgerow intercropping may not be feasible where labour is a constraint
- There is a need for further research on hedgerow intercropping before the technology is taken up for extension to farmers.

Fodder production from agroforestry systems

The role of fodder shrubs and trees has been subject to research at several sites in Kenya. Studies carried out by KARI and ILCA in the coastal zone have shown that Leucaena fodder supplemented with Napier grass results in higher milk production if the Napier grass is mature (150 cm high) and hence low in protein. With cross-breed cattle there is a potential for increasing milk production, both during early lactation if the Napier grass is low quality and later during the lactation. Leucaena supplements also result in weight increases except during early lactation when the animal's weight is bound to drop anyway. A general recommendation is to cut Napier grass when it has reached a height of 100 cm rather than 150 cm.

With regard to labour, it was observed that some farmers were reluctant to grow Napier grass due to the amount of labour required. An alternative was then developed using cassava to meet energy needs and Leucaena to meet protein needs. This combination requires less labour.

ICRAF scientists have analysed the potential value of prunings from leguminous shrubs (Hoekstra and Darnhofer, 1992). Their analysis indicates that the potential value is considerably higher if the prunings are used for fodder than if they are used as a source of green manure.

The focus of future research

Based on the experiences and results from the research carried out so far the following areas are likely to be priorities for research over the next few years:

- Continued focus on on-farm research and farmer involvement in research planning and implementation
- Concentration on tree products, e.g. fodder, poles/timber, and fruits and other food from trees and shrubs
- Process-oriented research on soil fertility in relation to a few agroforestry technologies
- The role of trees and shrubs for livestock production
- Development of predictive models for studying the tree-crop interface
- For drier areas: More emphasis on managing and improving the utilization of existing vegetation rather than on introduction of new practices. The focus will be on livestock but not necessarily fodder production for zero-grazing systems
- Research on soil fertility in relation to agroforestry is likely to shift from an emphasis on hedgerow intercropping to block planting of trees for fertility, improved fallows, etc., in order to seek appropriate technologies for dry areas and acidic soils
- Studies on the effects of incorporation of trees with a litter rich in phosphorus as a complement to nitrogen-fixing species
- Studies on the use of lime and green manure.

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