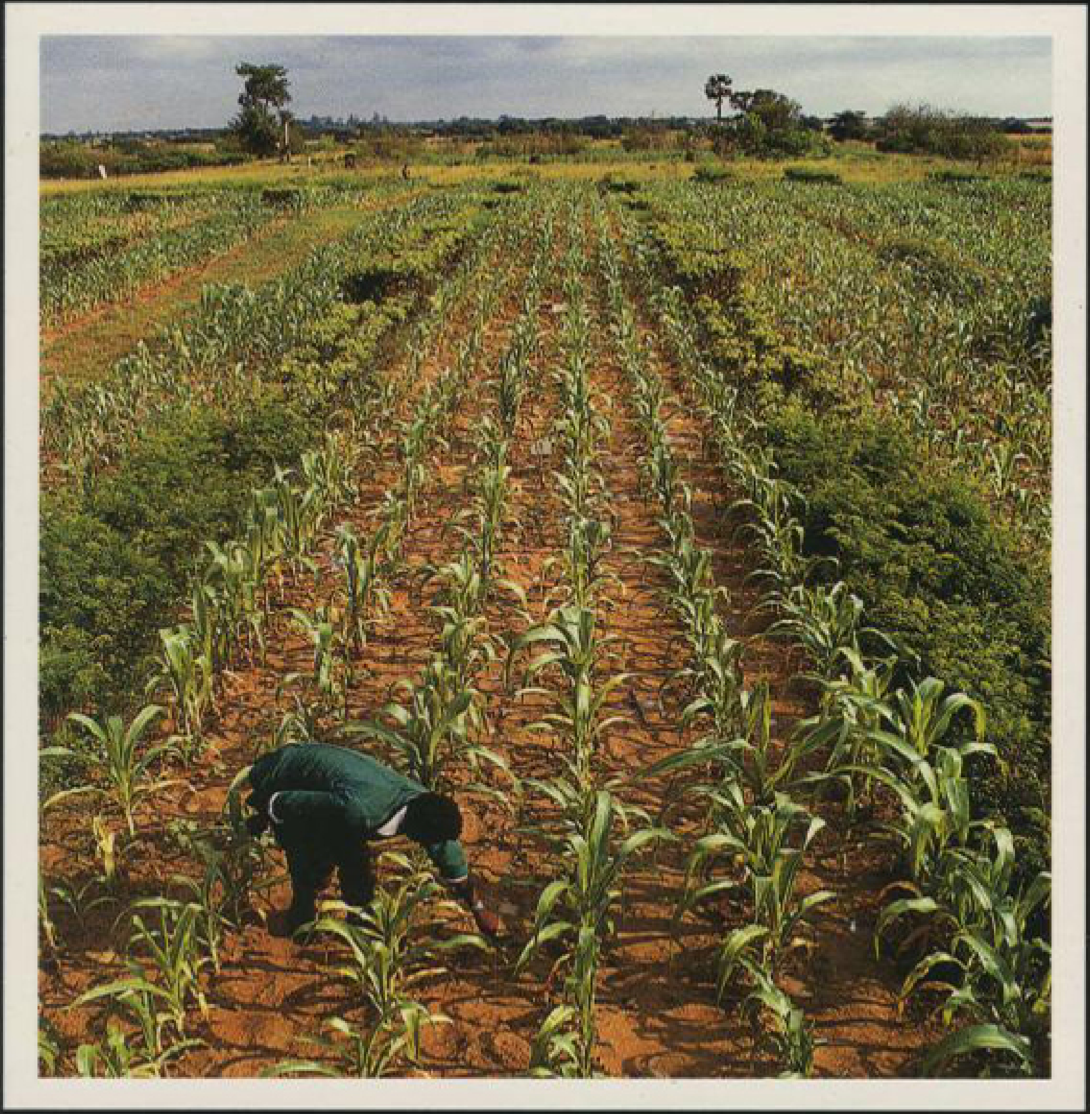
The Tropical Agriculturalist



ALLEY FARMING

CTA

MACMILLAN

IITA

THE TROPICAL AGRICULTURALIST

Series Editor
René Coste
Formerly President of the IRCC

Alley farming

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IITA

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Technical Centre for Agricultural and Rural Co-operation (ACP-EU)

The Technical Centre for Agricultural and Rural Co-operation (CTA) was established in 1983 under the Lomé Convention between the African, Caribbean and Pacific (ACP) States and the European Union member States.

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CTA, Postbus 380, 6700 AJ Wageningen, The Netherlands.

Agency for Cultural and Technical Co-operation (ACCT)

The Agency for Cultural and Technical Co-operation, an intergovernmental organisation set up by the Treaty of Niamey in March 1970, is an association of countries linked by their common usage of the French language, for the purposes of co-operation in the fields of education, culture, science and technology and, more generally, in all matters which contribute to the development of its Member States and to bringing peoples closer together.

The Agency's activities in the fields of scientific and technical co-operation for development are directed primarily towards the preparation, dissemination and exchange of scientific and technical information, drawing up an inventory of and exploiting natural resources, and the socio-economic advancement of young people and rural communities.

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Associated States: Cameroon, Egypt, Guinea-Bissau, Laos, Mauritania, Morocco, St Lucia.

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IITA

The International Institute of Tropical Agriculture (IITA) was founded in 1967 as an international agricultural research institute with a mandate for major food crops, and with ecological and regional responsibilities to develop sustainable production systems in tropical Africa. It became the first African link in the worldwide network of agricultural research centres supported by the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

IITA is governed by an international board of trustees and is staffed by approximately 80 scientists and other professionals from over 30 countries, and approximately 1,300 support staff. A large proportion of the staff are located at the Ibadan campus, while others are at stations in other parts of Nigeria, and in Benin, Cameroon, and Uganda. Others are located in work sites in Côte d'Ivoire, Ghana, Malaŵi, Mozambique, Tanzania, Zambia and Zimbabwe. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

IITA conducts research, training, and germplasm and information exchange activities in partnership with regional bodies and national programmes in many parts of sub-Saharan Africa. The research agenda addresses crop improvement, plant health, and resource and crop management within a farming systems framework. Research focuses on smallholder cropping systems in the humid and subhumid tropics of Africa and on the following major food crops: cassava, maize, plantain and banana, yam, cowpea and soybean.

The goal of IITA's research and training mission is to improve the nutritional status and well-being of low-income people of the humid and subhumid tropics of sub-Saharan Africa.

Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP), the CGIAR is an informal association of over 40 governments, international organizations, and private foundations. The CGIAR provides the main financial support for IITA and 15 other international centres around the world, whose collective goal is to improve food security, reduce poverty, and protect the environment in developing countries.

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Preface

Much of humid and subhumid tropical Africa suffers high rates of deforestation, caused by traditional slash-and-burn cultivation and the extraction of timber and firewood. Even in areas that no longer have primary forest, the over-exploitation of natural vegetation and soils continues, leading to widespread erosion and degradation. The African continent loses an estimated 5.1 million hectares of productive land yearly – a figure well beyond the regenerative capacity of both natural processes and reforestation.

The pressure on the region's natural resources can only intensify in the years ahead. Population continues to rise at over 3 per cent per year (or annually) in many African countries, with the result that urban markets for crops such as rice, vegetables and fruit, meat and dairy products are expanding rapidly. Besides supplying these markets, small-scale farming families will need to meet their own subsistence requirements. With the opportunities for expanding agriculture limited – much of the remaining unused land has valuable forest resources or is marginal for cropping – the rising demands for food and other products will have to be met by increasing yields on land that is already cultivated.

Many smallholders find it difficult to justify the use of chemical fertilizers and other inputs to increase or maintain their crop yields. Either they cannot obtain fertilizers when they need them, or else the returns to farming are too insecure to make such investments sensible. And even if they were to use more fertilizers, this might not be enough to sustain production on the acid and highly-leached soils characteristic of many humid lowland areas. These soils are highly sensitive to the unbalanced use of high levels of inputs.

Under these circumstances, it is vital to develop alternative low-input farming systems that will safeguard the long-term productive potential of farmers' land by maximizing the use of biological nutrient sources and organic materials developed on or near the farm.

One such system is alley farming. Originally developed in Southeast Asia, this system has been researched and promoted in Africa by the International Institute of Tropical Agriculture (IITA), in cooperation with the International Livestock Research Institute (ILRI), the International Centre for Research in Agroforestry (ICRAF) and national research partners. The best results obtained so far with alley farming have been on relatively fertile soils where soil moisture is not a limiting factor, but efforts to adapt the system for more difficult acid soils continue.

We hope that this book will help make alley farming better known. Its widespread adoption would reduce the threat to the world's remaining tropical forests and transform the prospects for sustainable agriculture in the fragile lowland tropics.

Lukas Brader
Director General
International Institute of Tropical Agriculture

1 Introduction

This book has been written to help readers understand the concept of alley farming and its potential as a sustainable farming technique for the rainfed areas in the humid and subhumid tropics. It is written in a concise and practical format for agricultural research and extension specialists and farmers working in the developing countries, who are interested in practising alley farming. The book discusses the advantages and limitations of alley farming as an alternative 'low external input', and environmentally friendly farming method for farming rainfed areas, particularly on sloping lands. Alley farming, like any other agroforestry land-use systems that involve crop, tree and animal production, is therefore a more site-specific technology as compared to single-commodity production systems. Suitability of the farming method depends on the biophysical and prevailing socioeconomic factors of the area. Although results of field observations have shown that alley farming has the best potential in the humid and subhumid zones, the concept of alley farming can also be applied to wider agroecological zones. Since a good understanding of the principles and practices of managing soils in the humid and subhumid tropics is needed to make alley farming work, this topic is also included in this book.

The book is divided into various chapters that deal with: the historical development of alley farming; practical guidelines for establishing and managing alley farms; its benefits for crop and livestock production; economic benefits; and problems of adoptability. A selected list of references is given at the end of the book, which provides more in-depth information on some of the topics presented in this book.

Sustainable production systems

Sustainability, in the simplest sense, is defined as the ability of the production system to produce a stable yield of a desired crop(s) over a long period of time with minimal soil degradation. However, the scope and perceptions of sustainability vary with different people.

The concept of agricultural sustainability has received much attention during the past few decades due to environmental concerns in relation to agricultural production. In the humid and subhumid tropics, under rainfed conditions in diverse and risk prone environments, a wide range of different farming and land-use systems have evolved with time, each adapted to local ecological and socioeconomic conditions and cultures. These practices include, among others, the bush fallow or slash-and-burn system. The bush fallow system, characterized by short cropping and long fallow periods, is no longer sustainable in many areas, as extensive reserves of land needed for the long fallow period and the high amount of labour required to clear these lands are no longer available.

The overexploitation of natural resources, or use of inappropriate farming techniques, has resulted in deforestation and land degradation in the tropics, with a consequent increase in environmental problems. The move from traditional to market-oriented production during the last few decades has led or forced the smallholder farmers in some areas in the tropics to seek more short-term profits from their crops rather than maintain their conservation farming practices. Increased intensification of land use and the adoption of improved crop varieties which remove more nutrients without any external chemical inputs, reduce soil fertility, and result in a sharp decline in soil productivity and increased weeds and pest infestations. The simple addition of fertilizers to the system, even if farmers can afford them, might be insufficient to sustain crop production on the fragile, rainfed areas of the humid and subhumid tropics on a long-term basis. The arbitrary application of exotic, high input, food crop production technologies to these fragile soils often only leads to rapid chemical, physical and biological soil degradation, as soil organic matter declines with continuous cultivation if no proper soil management measures are taken.

In developed countries people are more concerned with pollution from overuse of agricultural chemicals and loss of biodiversity, which are the unfortunate by-products of modern agricultural progress. In designing our resource management systems, we should therefore adapt our production systems to take advantage, where possible, of our natural resources and avoid overexploitation or overuse of agrochemicals. While such a strategy is often less profitable in the short term, it is more sustainable and less environmentally damaging in the long term. Considering farming systems are heterogeneous in the tropics, a large number of alternative soil management technologies should be made available for farmers to select from, based on their needs to sustain long-term soil productivity with intensive cropping. Alley farming is one of the many technologies that can be promoted.

Agroforestry systems

Trees and shrubs featured prominently in traditional farming systems in the tropics because of their many uses and their environmental and socioeconomic benefits. Woody species form a major component of the bush fallow system and are also widely grown in permanently cropped land. The collective name for land-use systems in which woody species are grown with annual agricultural crops and/or pasture and livestock on the same unit of land is *agroforestry*. Alley farming is a form of agroforestry. In agroforestry the various components may be present either in a spatial arrangement or a time sequence. There is both an economic and ecological interaction between the woody and non-woody components of the system. It is both an old practice and a recent science.

When nutrient supplies in the soil are limited, agroforestry and tree-based systems are known to be more efficient than the herbaceous mono-cropping system in the utilization of nutrients to sustain modest levels of agricultural production. This is mainly due to the presence of woody species that can contribute more to nutrient cycling than the shallow-rooting food crops. In traditional agroforestry practices, farmers have also incorporated woody perennials that have multipurpose functions or uses for soil fertility improvement, for weed suppression and as sources of timber, fodder, food and other auxiliary products for their own use or the market. Because of their multiproduce functions, agroforestry systems also have the advantage of minimizing the risk of crop failure. When considering the different production systems on the fragile uplands, agroforestry systems are also known to be more sustainable than annual crop-based systems in the humid and subhumid tropics.

There are many types of agroforestry systems, based on whether they combine with trees, crops, livestock or both. Three types can be distinguished as follows:

- *Agrosilvicultural systems*, consisting of mixtures of annual crops and woody perennials. Included in this group are: the bush fallow system, multistorey cropping, shade trees for plantation crops, a mixture for plantation crops, taungya and shelterbelts.

- *Silvopastoral systems*, consisting of a combination of pasture land, livestock and woody perennials, with no crops. Included in this group are: fodder banks, living fences of fodder hedgerows, trees and shrubs on pastures, the integrated production of livestock and wood products.
- *Agrosilvopastoral systems*, consisting of a combination of annual crops, pasture/livestock and woody perennials. Included in this group are: tree-livestock-crop mixtures around the homestead/ compound farms or in integrated production systems of trees, pasture and livestock.

Alley farming can be grouped under any of the above systems, as will be described in subsequent chapters.

The most commonly used criteria in classifying agroforestry systems are based on the spatial and temporal arrangements of the plant components of the system. *Spatial* arrangements of plants in agroforestry mixtures can result in a mixed and dense stand of plant species as seen in compound farming or in mixed stands of trees with crops or pasture as commonly observed in farmer's fields. The intercropped plant species can also be grown in zones or strips of varying widths. There are various forms of *zonal* agroforestry, varying from microzonal (such as alternating rows) to macrozonal (wide strips) arrangement or a combination of both as observed in alley-farming fields. An extreme form of zonal arrangement is the boundary planting of trees on edges of plots for fruits, fodder, fuelwood, fencing, soil protection, shelterbelts and windbreaks. Alley farming can be classified as zonal agroforestry and will be described in Chapter 3.

Temporal arrangements of plants in agroforestry can also take various forms. An extreme example is the bush fallow system, involving a short cropping cycle and a long fallow cycle or the relay cropping of trees and annual food crops, as in the taungya system. These systems, where crops are separated from the woody species for part of the time, are also called *rotational* agroforestry systems. This is in contrast to the *simultaneous* agroforestry systems, where crops and woody species are grown together on the same land, as observed in alley farming.

Agroforestry systems can also be classified based on their *service functions* or socioeconomic roles. Despite its importance for production, agroforestry has service functions such as for soil erosion control or shelterbelts, which can augment the sustainability of the production system. Based on scale and level of technology input and management, three groups can be distinguished: commercial, intermediate and subsistence systems. In *commercial* agroforestry the production output is the major aim of the system. This includes commercial plantations with underplanting of food crops. *Intermediate* agroforestry systems are those intermediate between commercial and subsistence scales of production and management. *Subsistence* agroforestry systems are those where the use of land is directed towards satisfying the farmers's basic needs and are managed mostly by the owner/occupant and his or her family. Alley farming can be managed at any of these three levels.

Agroecological zones and soil types

Based on the moisture regime and the length of the growing period, the rainfed areas in the tropics are divided into four major agroecological zones: the humid, the subhumid, the semi-arid, or arid zones. The alley farming technique has the most potential in the humid and moist subhumid zones. The humid zone is characterized by a forest vegetation, a length of growing period of over 270 days and an annual rainfall of over 1300 mm. This zone has reliable and in some parts even excessive rainfall with less than four months of dry season. The subhumid zone has a length of growing season of 150–269 days and is subdivided into: the wooded moist savannah zone with an annual rainfall of 1000–1300 mm and fairly reliable distribution, and the dry savannah zone with an annual rainfall of 600–1000 mm. The semi-arid zone has a length of growing season of 75–149 days and an annual rainfall from 250–600 mm. The arid zone has a length of growing season of less than 75 days and an annual rainfall of less than 250 mm.

In the humid and subhumid tropics, the most widely distributed groups of upland soils are the alfisols, ultisols, and oxisols and associated soils (Table 1.1). Other important soil groups in these zones are also the entisols and inceptisols.

The alfisols (luvisols, FAO legend; *sols ferrugineux*, French classification) and associated soils are found mainly in the subhumid zone, covering about one-third of the zone. They are moderately leached red and yellow soils, with a distinct clay horizon in the subsoil. Sometimes included in this group are the nitosols. These are red soils developed from basic parent materials. Alfisols are widely distributed in the subhumid zone of Africa, including large areas in western, eastern, central, and south-eastern Africa. In Asia, they are most abundant in the Indian subcontinent, in Sri Lanka, Thailand and Kampuchea. They also cover large areas in north-eastern Brazil and are found in Bolivia, Colombia and Mexico.

The ultisols (acrisol, FAO legend; *sols ferallitiques*, French classification)

Table 1.1 Geographical distribution ($\times 10^6$ ha) of major soil order in the humid and subhumid tropics

Soil order	Asia	Africa	America	Total	Per cent
Humid					
Oxisols	14	179	332	525	35
Ultisols	131	69	213	413	27
Inceptisols	90	75	61	226	15
Entisols	90	75	61	226	15
Alfisols	15	21	18	54	4
Others	39	10	11	60	4
Total	379	429	696	1504	100
Subhumid*					
Alfisols	121	466	107	694	33
Entisols	–	255	17	272	13
Inceptisols	28	38	–	66	3
Ultisols	20	24	8	52	3
Others	150	679	181	1010	48
Total	319	1462	313	2094	100

NOTE: * Also included are soils from the semi-arid or dry savannah zone.

are strongly-leached red and yellow soils with a distinct clay horizon in the subsoil. Ultisols are the second most abundant soil in the humid zone, covering an estimated 28 per cent of the zone. The oxisols (ferralsols, FAO legend; *sols ferrallitiques*, French classification) are highly-weathered red and yellow soils, with no formation of a clay horizon in the subsoil. These soils are mainly found in the humid zone. Oxisols are the most abundant soils in the humid zone, covering an estimated 35 per cent of the land area. About half of the ultisols and 60 per cent of the oxisols are located in humid tropical America. They are the dominant soils in the Amazon and Orinoco basins and the Atlantic coast of Central America and humid coastal Brazil. In South-east Asia they cover large areas of Malaysia, Sumatra, Kalimantan, Sulawesi and Mindanao. They also cover considerable areas of humid tropical Africa, including the eastern Congo basin bordering the lake region and the forested areas of Sierra Leone, Liberia, Côte d'Ivoire and Cameroon. Both the ultisols and oxisols require a higher amount of nutrient inputs than the alfisols and also correction of soil acidity to increase and sustain their long-term productivity with intensive cultivation, including alley farming. This will be elaborated in Chapter 2.

2 Soil management

Soil characteristics

Vast areas of the rainfed areas in the humid and subhumid tropics that are currently used for traditional farming are covered by low-activity clays (LAC) alfisols, ultisols and oxisols and associated soils. These are soils having an effective cation exchange capacity (ECEC) less than 16 meq/100g of clay measured in the subsoil horizon. Examples of the chemical characteristics of surface soils of LAC alfisols and ultisols are shown in Table 2.1. Because of the predominant nature of the clay minerals and the low cation exchange capacity, these LAC soils have a low ability to retain nutrients and

Table 2.1 The chemical composition of the surface layer (0-7.5 cm) of an alfisol and an ultisol under secondary forest and following forest clearing and burning

	pH-H_2O	Organic C (%)	Exchangeable cations (meq/100g)				ECEC	Extr. P (rmg.kg)
			Ca	Mg	K	Al		
Ultisol (Typic paleudult) from humid zone of south-eastern Nigeria								
UF*	4.3	1.73	1.32	0.34	0.16	1.44	3.91	108
AB**	5.0	1.82	2.96	0.85	0.33	0.08	4.32	123
Alfisol (Oxic paleustalf) from subhumid zone of south-western Nigeria								
UF	6.0	1.58	5.97	1.57	0.33	–	7.86	4.7
AB	6.3	1.37	7.48	1.94	0.97	–	10.45	20.7

* Under secondary forest.

** Following forest clearing and burning.

C = carbon, Ca = calcium, Mg = magnesium, K = potassium, Al = aluminium.

meq/100g = milli-equivalents/100 grams of soil.

ECEC = Effective Cation Exchange Capacity.

Extr. P (rmg/kg) = Extractable Bray I phosphorus (rmg/kg).

also have a low *buffering capacity*. Soil organic matter can contribute a major portion of the cation exchange capacity of the surface soil by contributing more adsorption sites for plant nutrients and reducing their losses through leaching.

The alfisols mainly found in the subhumid zones are less leached, with low acidity and a high content of bases (calcium, magnesium and potassium) or a high base saturation of the soil. These soils have low to moderate fertility. Surface soil pH-H_20 under natural vegetation is slightly acid and ranges from 5.5–6.5. The alfisols require nitrogen, phosphorus and potassium applications for intensive crop production. These soils have low phosphorus fixation capacity and added phosphorus tends to be more easily absorbed. In addition, the presence of vesicular-arbuscular (VA) mycorrhizal fungi are common and they are also effective on these soils. The VA mycorrhizal fungi that live in association with plant roots increase the plant root ability in the uptake of less available phosphorus from the soil. This can lower the crop requirement for phosphorus fertilization. Continuous cultivation and nitrogen fertilizer application can significantly alter the chemical properties of alfisols, by lowering soil pH, soil organic matter and levels of potassium, calcium and magnesium. Lowering soil pH to below 5.0, may increase the soluble aluminium and manganese to toxic levels that can be harmful for sensitive crops such as maize and grain legumes. Except for the nitisol, the alfisols with sandy to sandy-loam surface soil texture are known to have low structural stability, making them susceptible to soil compaction and erosion.

The ultisols and oxisols have a low nutrient reserve and consequently nutrient levels in the soil solution are usually inadequate to provide for the nutrient needs of the crop(s). In addition, toxic aluminium and manganese levels, low calcium, magnesium and potassium levels and multi-nutrient deficiencies severely limit crop growth and yields. To correct soil acidity some of these soils require only a small amount of lime (500–1000 kg/ha of ground limestone or dolomite) to reduce toxic levels of aluminium and manganese. They are often deficient in phosphorus. Ultisols have a moderate phosphorus-fixing capacity and added phosphorus tends to be more easily adsorbed. The oxisols have a high phosphorus-fixing capacity.

The physical properties of the ultisols are similar to those of the alfisols, but differ from the oxisols. In the oxisols the clay is highly resistant to dispersion by water. The oxisols have, therefore, more stable aggregation throughout the soil profile. This results in good water infiltration and water transmission, and low erodibility. Alley farming will have more impact on the ultisol than on the oxisol for controlling soil erosion.

Soil management

Soil management is concerned with managing the chemical, physical and biological properties of the soil for crop production. In soil management we are concerned with soil fertility and productivity. *Soil fertility* is a measure of the ability of the soil to supply essential nutrients for plant growth without toxic amounts of any elements. The goal of good soil fertility management is to provide an adequate and balanced supply of nutrients to satisfy the needs of the plant. *Soil productivity* encompasses soil fertility plus all the other biophysical factors affecting plant growth. It is a measure of the soil's capacity to produce a particular crop or sequence of crops under a specified management system. The aim of a good soil management system is to sustain soil productivity for crop production using socially and economically acceptable means.

In the traditional system, farmers practise the bush fallow rotation or slash-and-burn cultivation system. In this system, soil fertility and productivity exhausted during the cropping phase are biologically rejuvenated during the long fallow phase. The secondary forest vegetation extracted the remaining nutrients in the soil, especially from lower soil layers, and brought them to the surface. The secondary forest is a closed nutrient-cycling system and the amount of nutrient losses is negligible compared to a crop production system. Nutrient replacement during the fallow phase is a slow process and will not add much additional nutrients to the system, except in the presence of nitrogen-fixing legume species.

Woody species can play an important role in soil productivity regeneration through: 1) nitrogen input by nitrogen-fixing legume species, 2) pumping up nutrients from below the rooting zone of the crops, and 3) reduction in nutrient leaching and erosion losses by plant roots. In addition, the presence of woody species also improves the soil physical conditions and the soil biotic and faunal activities by adding plant litter and influencing the microclimatic conditions under the trees or shrubs.

In the traditional system, during seed bed preparation the fallow vegetation is cleared and burnt. Burning serves several functions, for example, for clearing excessive plant biomass to obtain a reasonably clean seed bed, to expedite the release of plant nutrients held in the plant biomass, or to reduce soil acidity. The effect of burning varies with the soil type and amount of biomass burnt. On the alfisol the main nutritional effect of burning is to supply additional phosphorus for the crop. On the acid ultisol and oxisols, however, burning of plant residues not only increases the supply of available phosphorus, potassium, calcium and magnesium levels, but also reduces soil acidity (Table 2.1). The beneficial effects of burning are short lived, though, and usually last for only one cropping season due to rapid leaching losses of nutrients by rain. Burning also results in the loss of much needed organic matter and volatilization loss of nitrogen and sulphur. Repeated land clearing, burning, and cropping with ever shorter fallow periods may lead to disruption and rapid loss in soil productivity. Although light burning is sometimes necessary for reducing plant biomass during seed bed preparation, retention of plant residues as mulch or green manure is preferred. Results of trials conducted in the last three decades in the humid and subhumid tropics have shown that for sustaining long-term soil productivity the following practices are essential for managing the LAC soils:

- Good biological surface soil cover to prevent soil particle detachment or loosening due to rain and wind.
- Minimum tillage seed bed preparation.
- Judicious and balanced fertilization and liming for acid soils.
- Frequent additions of organic matter.

On these LAC soils, soil organic matter plays an important role: 1) as a source of nutrients, particularly nitrogen, phosphorus and sulphur; 2) for enhancing soil cation exchange capacity; 3) to increase soil moisture retention; and 4) to increase soil microbial and faunal (e.g. earthworm) activities. On acid soils application of plant residues can also contribute in the amelioration of soil acidity, by neutralizing toxic levels of aluminium and manganese in the soil solution or by reducing the phosphate-fixing capacity of the soil. The neutralizing effect of plant residues varies with the cations (potassium, calcium and magnesium) contents of the plant material. Plant materials with high cation contents (e.g. *Leucaena leucocephala* and *Gliricidia sepium* prunings) tend to be more effective than those with lower cation contents (e.g. grasses).

To sustain soil productivity in the humid and subhumid tropics, each production system has a minimal requirement for annual organic matter input. Results of trials in the forest-savannah transition zone of west Africa, have, for example, shown that for sustaining a no-tillage maize production system, yearly application of at least 4t /ha of maize stover mulch is required. Since it is well known that organic matter decomposes rapidly in the humid and subhumid tropics, the split application of organic matter during the cropping season is better than applying the same amount as a single dose at the beginning of the season.

Organic matter can be applied as a mulch, green manure, compost or animal manure. For convenience and economic reasons, *in* *situ* production of organic matter is preferable to that from external sources. This can save transport and application costs. As green manure, organic material is mainly applied as a source of plant nutrients. Incorporation of the green manure in the soil in many instances is also more effective as a nutrient source. High-quality organic materials, such as those with high nitrogen and low lignin contents and low C/N (carbon/nitrogen) ratios, are good sources of green manure. These materials have high decomposition rates and can release nutrients quickly to meet crop demands. High-quality green manure sources are, for example, plant materials of cover crops such as velvet beans (*Mucuna pruriens* var. Utilis), *Psophocarpus palustris* and *Pueraria phaseoloides,* and prunings of *L. leucocephala* and *G. sepium*. Mulches are fresh or dried materials that are applied to the soil surface and that will decompose slowly. Eventually it will also supply plant nutrients to the crop. Mulches are applied mainly to protect the soil surface. The application of mulches has several advantages for crop production in the humid and subhumid tropics, for example:

- Protecting the soil surface from the impact of raindrops.
- Lowering surface soil temperature.
- Increasing soil moisture infiltration and retention.
- Improving soil physical properties.
- Stimulating higher levels of soil microbial and faunal activities.
- Suppressing weeds.

Low-quality materials, with low nitrogen and high lignin contents and high C/N ratios can still make suitable mulch materials. These materials decompose slowly and can provide a longer lasting soil surface protection. They include, for example, rice straw, maize stover, and prunings of woody species such as *Dactyladenia barteri* and *Senna siamea*. Some high-quality materials, such as residues of velvet beans, can also be used as a mulch in a no-tillage crop production system if produced *in situ* in large quantities. Farmers usually do not have any preference on the quality of the mulch material, and use what is most easily available.

Soil erosion

In the humid and subhumid zones, soil erosion is mainly the result of soil particle detachment caused by raindrops and by overland water flow or runoff. In the drier zones, such as in the semi-arid tropics, soil detachment and transport is caused by wind erosion. The extent of water erosion is affected by:

1 rainfall erosivity, which depends on rainfall energy and intensity. Rainfall erosivity is about twice as high in the humid than in the subhumid zone, and about twice as high in the subhumid than in the semi-arid zone,
2 soil erodibility or susceptibility of the soil to erosion, which depends on the soil characteristics,
3 slope length and gradient of the land, and
4 soil and land cover.

The removal of native vegetative cover (as in deforestation) or excess and improper soil tillage and crop husbandry are major causes of soil erosion. Increasing population pressure in some highly-populated areas in the tropics has resulted in the cultivation of hill slopes and marginal lands, which aggravate the process of soil erosion and land degradation.

The alfisols and ultisols and related soils, because of their weak soil structures, are extremely susceptible to soil erosion when exposed. High-intensity raindrops that are common in the humid and subhumid tropics can easily disperse the soil particles when exposed, resulting in the formation of a surface soil crust when the soil dries up. Because of the low structural stability of these soils, they can be compacted easily if tilled with heavy implements or when over-cultivated. Soil crusting and compaction can reduce water infiltration and increase water runoff and soil erosion. Erosion will result in a loss of surface soil and soil fertility and exposure of the less productive subsoil.

Reducing raindrop impact by the maintenance of an effective soil cover and decreasing runoff volume and peak runoff rate are important ways of controlling soil erosion. This can be done by biological means, such as intercropping, the use of live mulch, mulching, or a combination of these practices. Traditional intercropping systems provide a higher canopy cover and better erosion control than do monocropping systems. The presence of a single layer canopy cover as observed, for example, in mono-species forest or a well-established cassava plot, is inadequate in controlling soil erosion. In the forest or agroforestry systems, it is the combination of: 1) the multistorey canopy cover (that reduces the energy of raindrops) and 2) particularly the presence of undergrowth cover and plant litter, that effectively controls soil erosion.

Because of the weak structure of the LAC alfisols and ultisols, the amount of soil disturbance needs to be minimized. Use of no-tillage or minimum-tillage practices during seedbed preparation can reduce runoff and erosion. Tractorized cultivation without accompanying soil conservation measures increases the risk for soil erosion in the humid tropics due to the prevalence of high intensity rains during the rainy season. Traditional farmers in some parts of the humid and subhumid tropics have already developed ingenious ways of cultivating the soil. In south-western Nigeria, for example, traditional farmers use locally-made short handle and narrow angle small hoes for soil cultivation. These hoes are well adapted for scraping the surface of the soil to remove weeds and also for shallow and reduced tillage. This minimum and shallow tillage system as practised by traditional farmers on acid soils also has the advantage of not mixing the acid and less productive subsoil with the less acid surface soil, a condition that can occur with mechanized tillage. In some areas traditional farmers have already used animal traction for land cultivation, the preparation of ridges, and for weeding to control runoff and soil erosion.

On hilly lands, soil erosion is a major problem and is affected by the length of the slope and the gradient of the land. On these lands, soil erosion can be controlled by reducing the effective slope length. This can be done by: 1) the construction of physical structures such as earthen banks, stone walls and cut-off ditches, or 2) by planting biological barriers such as vegetation strips or barrier hedges. On relatively gentle slopes widely-spaced barriers can be effective in controlling soil erosion, while on steep slopes, barriers have to be closely spaced to be effective in reducing erosion to acceptable levels.

The adoption of appropriate surface soil tillage measures, such as reduced tillage and adequate biological surface soil cover, and the use of biological soil conservation measures such as vegetative hedgerows on sloping lands, can minimize soil losses to permissible levels. These practices, combined with the application of chemical soil amendments as needed, are essential elements for conserving and maintaining the long-term productivity of rainfed areas dominated by LAC soils for intensive crop production in the humid and subhumid tropics. They can also form an integral part of the design of an appropriate alley farming system.

3 The practice of alley farming

Rapid increases in population and food demands since the 1960s in developing countries in the tropics, have resulted in an expansion of cultivated rainfed area and an increase in land use intensification. Various attempts undertaken by agricultural research centres or institutions working in the humid tropics to replace the bush fallow subsistence food crop production system with 'modern agriculture' have, in many instances, produced discouraging results. The promotion of mechanized and high chemical input rainfed food production systems have limited success in the humid and subhumid tropics. Although the use of fertilizers is well known to be essential for sustaining the productivity of the rainfed areas, availability and cost still prohibit their extensive use in much of tropical Africa. To assist farmers in the transfer from subsistence to intensive farming, investigations have been carried out since the early 1970s at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, to develop more sustainable and productive agricultural systems for managing fragile rainfed areas in the humid and subhumid zones. Investigations into planted fallow and agroforestry has led, among others, to the development of the 'alley cropping' concept and to further research on this system.

The concept

'Alley cropping' is an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees and shrubs, preferably nitrogen-fixing species (Fig 3.1). The hedgerows are cut back at planting and periodically pruned during cropping to reduce shading and competition with crops for light, nutrients and moisture. The hedgerows are allowed to grow freely to cover the land when there are no crops. The International Livestock Centre for Africa (ILCA) (now the International Livestock Research Institute [ILRI]) extended the concept of 'alley cropping' to include live-

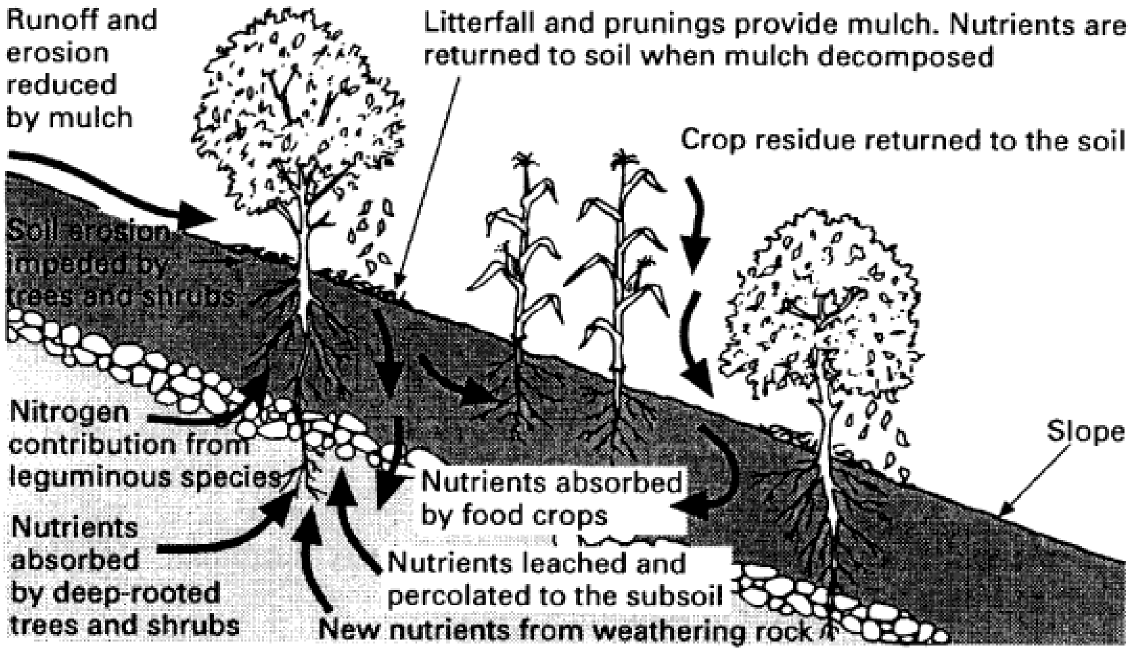


Fig 3.1 Schematic representation showing the various components and benefits for nutrient cycling and erosion control of an alley farming system.

stock by using a portion of the hedgerow foliage for animal feed, calling the system 'alley farming'. Although certain authors make a distinction between 'alley farming' (livestock component included) and 'alley cropping' (no livestock component), no distinction will be made in this book, and the term 'alley farming' will be used. Alley cropping/alley farming is also known under several other names. In Sri Lanka it is known as 'avenue cropping' while the International Centre for Research in Agroforestry (ICRAF) calls it 'hedgerow intercropping', and some other institutions call it 'contour hedgerow system'.

Fig 3.1 illustrates the various components observed in an alley-farming plot. Growing the multipurpose trees or shrubs in hedgerows and crops in the alleys allows more flexible management than in mixed agroforestry systems. It also allows the integration of a wider choice of woody species, and for tractor or animal traction for cultivation where appropriate. Alley farming is based on the following principles:

- The woody hedgerow species which have been selected for their deep rooting characteristic still retain the same basic functions as in the bush fallow system, i.e. for nutrient cycling from deeper soil layers which are beyond the reach of the crop roots, for better soil stabilization and subsoil moisture utilization.
- Nutrients retained in the hedgerows are made available to the

associated crops through pollarding or leaf prunings, which are applied as mulch or green manure. The inclusion of nitrogen-fixing leguminous hedgerow species will contribute biologically-fixed nitrogen to the system.

- During the period when there is no cropping, the undisturbed regrowth of the hedgerows also helps suppress weeds through a shading effect.
- The presence of leaf mulch and litter protects the surface soil against raindrops and soil erosion.
- The hedgerows provide a physical barrier that can greatly reduce soil erosion, particularly on sloping lands.
- The inclusion of browse hedgerow species can provide supplementary fodder for ruminants and allows the integration of livestock in the production system.

In addition, the hedgerows can provide auxiliary products such as stakes and firewood. The alley farming system can, therefore, be regarded as a bush fallow production system in the sense that tree foliage is used to maintain and improve soil fertility. However, land use efficiency is higher than in the traditional bush fallow system, because the cropping and fallow phases are carried out simultaneously on the same plot of land instead of being separated. It also allows a more rapid and effective soil fertility regeneration, and the inclusion of nitrogen-fixing leguminous hedgerow species also reduces requirements for the external input of nitrogen fertilizer. As an improved system, alley farming has various advantages over the bush fallow system (Table 3.1), but may require more

Table 3.1 Differences in management practices between traditional bush fallow and alley farming systems

Traditional bush fallow	Alley farming
• Mixed native woody species are retained.	• Selected woody species, preferably fast-growing legume species, are used.
• Irregular planting pattern is used.	• Hedgerow pattern is used.
• Before cropping, trees and shrubs are cut back and burnt to release nutrients.	• Trees and shrubs are pruned and prunings used as mulch and green manure.
• Fire is used for controlling growth.	• Periodic prunings are required to control hedgerow growth.
• Short-term cropping is allowed.	• Continuous cropping is allowed.

labour input at critical cropping periods. However, on-farm research results have shown that with timely operations, the total labour requirements for managing alley farming fields can be lower than that for managing fields under the traditional slash-and-burn cultivation system. The timing of hedgerow pruning can be a constraint as it may conflict with other farm operations.

Traditional alley farming and its historical development

The principles of alley farming have been practised for generations by farmers in various regions of tropical Africa and Southeast Asia. Traditional farmers have adopted these measures for sustaining crop production in rainfed areas, particularly on sloping land.

In the humid zone of south-eastern Nigeria traditional farmers in the village of Mbaise, close to Umahia, have incorporated 'Ichieko' (*Dactyladenia barteri*), a multipurpose shrub species, in their food crop production system. Farmers planted hedgerows of *D. barteri* at 2–3 m spacing (Fig 3.2) using seeds or seedlings collected from the farms. In this area farmers practised a rotational land-use cycle, consisting of one to two years of cropping followed by two to three years of fallowing. At the start of the cropping cycle, the hedgerows are cut at about ground level with the exception of some stems which are retained for use as live stakes for white yam (*Dioscorea rotundata*). This is followed by light burning, and cropping with

Fig 3.2 Traditional alley farming using *Dactyladenia barteri* hedgerows on an ultisol at Mbaise in south-eastern Nigeria. This is a plot where hedgerows were pruned close to the ground in preparation for planting. (Foliage biomass was burnt and stakes were collected and piled in the background).

food crops such as maize, cassava, and white yam in the alleys. During the cropping phase, hedgerows are periodically pruned and then allowed to regrow during the fallow period. The hedgerows are planted for the purpose of rejuvenating soil fertility exhausted during the short cropping cycle, for weed control, as a source of browse for small ruminants, and for staking material for yam. This production system has sustained soil and crop productivity at subsistence levels for generations in the area.

Traditional farmers in the subhumid zone of north-central Nigeria, around Zaria, practised alley farming with *Moringa oleifera*. *Moringa* hedgerows are planted at inter-hedgerow spacings of over 2 m using cuttings or seedlings. Since *Moringa* has a light canopy it is pruned at irregular intervals at less than 1 m in height. Foliage prunings are usually sun dried and sold as fodder during the dry season. The alleys are planted with traditional intercrops of maize, sorghum, millets, grain legumes or vegetables. No data exist as to the effect of alley farming with *Moringa* on crop yield and soil productivity.

An interesting development of traditional alley farming within the context of modern science has taken place in the lesser Sunda Islands of south-eastern Indonesia. During the early 1930s the then Dutch colonial rulers in Amarasi, a western district on the island of Timor in south-eastern Indonesia, forced the traditional farmers by law to plant hedgerows of *L. leucocephala* at 3 m spacing for erosion control and soil fertility improvement before the land reverted to fallow. This measure was initially unpopular among farmers in the district, since it was soon discovered that, without proper accompanying management practises, the *L. leucocephala* plants in a short time colonized the entire land. In the 1950s *L. leucocephala* planting was reintroduced with the main purpose of suppressing *Lantana camara*, a shrubby and unproductive weed, difficult to control and which had invaded the island and spread everywhere in a few years. *L. leucocephala* was soon found to be suitable for controlling *L. camara*. After four to six years of *L. leucocephala* fallow followed by slashing and burning, the fields could be cultivated again.

During the early 1970s farmers in west Amarasi modified the method of managing the *L. leucocephala* hedgerows. Prunings from the hedgerows were not burnt but instead used as green manure and mulch. Crops such as maize and beans were grown in the alleys and the hedgerows were regularly pruned during the cropping period and the loppings applied to the growing crops. This new management system allowed the development of a more permanent cropping system. Traditional farmers who had practised this system continuously for a few years have reported that their crop yields were only slightly lower than those grown on newly-cleared *Leucaena* fallowed plots.

During the mid 1970s, through the combined efforts of the local agricultural extension service and the Catholic mission, the contour terracing concept using *L. leucocephala* was successfully introduced in the Sikka district of the neighbouring island of Flores for erosion control and rehabilitation of degraded steep lands. The new contour hedgerow crop production system using *L. leucocephala* with its accompanying management package, locally known as the 'Lamtoronisasi' programme, was rapidly adopted by traditional farmers in the district and covered an area of over 40 000 ha in the 1980s. The system allows farmers to practise more permanent and productive agriculture on the otherwise very degraded and highly erodible steep lands. In addition, the by-product of the system also allows farmers to raise more domestic farm animals by using prunings of the *L. leucocephala* hedgerows as a supplementary source of browse. The use of *Leucaena* hedgerows, however, has declined since the 1980s due to the entry of the psyllid (*Heteropsylla cubana*) insect that has caused widespread defoliation and damage to the plants. Various other leguminous species, such as *Gliricidia sepium* and *Calliandra calothyrsus*, have in the meantime been planted to replace *Leucaena*.

In the southern Philippines, farmers of the Nalaad tribe have for some time practised some aspect of alley farming by incorporating *L. leucocephala* hedgerows in their crop production system. However, the first recorded report of alley farming in this area was made by the Philippines Soil Conservation Service in Alabang, Rizal, in 1953. Here, by continuously intercropping maize with *L. leucocephala* hedgerows, which were grown 1 m apart and pruned bi-monthly for four years, soil erosion on sloping land was reduced to less than 2.5 per cent of the control and the maize yield was more than tripled compared to the control. The work on alley farming in the southern Philippines was later expanded by the Mindanao Baptist Rural Life Centre at Davao del Sur in Mindanao in the mid-1970s to cover wider aspects of crop, fruit trees and forest production on sloping land. The technique is widely known as the 'Sloping Agricultural Land Technology' (SALT) programme.

Since the introduction of the alley farming concept about two decades ago, variations of the above techniques have been observed in traditional farmers' fields in several areas of Asia and Africa. The main variations are that farmers tend to use hedgerows of natural vegetation that require less labour for establishment and maintenance. Other farmers planted hedgerow species with economic value for fodder, vegetable, fruit or timber production. For example, in the Benin Republic some farmers prefer to plant hedgerows of *Acacia auriculiformis* for timber production. At Alabata village in south-western Nigeria some farmers intercropped some of the leguminous hedgerows with plantain (*Musa* spp.) and particularly oil palm (*Elaies guineense*), which is much preferred by farmers of the area because of its commercial value. Some farmers in east and west Africa prefer to plant *Cajanus cajan* hedgerows that can also produce some grains. In the southern Philippines planting of cash crops such as coffee or tea bushes or timber hedgerows of *Gmelina arborea* and *Eucalyptus* spp. is a popular practice because of the high local demand for timber.

4 Field establishment and management

A farmer establishes an alley farming field with certain goals in mind. He or she may use the alley farming fields for:

1 sustaining crop production,
2 maintaining or increasing soil productivity,
3 erosion control,
4 fodder production,
5 timber production, and
6 a combination of these and other purposes.

The farmers' success in obtaining his or her goals and the full benefits from establishing the alley farming fields will depend on careful planning and the following technical factors:

- *Correct choice of woody species*, which depends on soil and climatic factors, farmer's needs and market opportunities.
- *Successful hedgerow establishment*, including hedgerow orientation and methods of establishment which can greatly affect early rate of growth, uniformity, future biomass production of the hedgerow and hedgerow functions.
- *Efficient hedgerow management*, in which timely operations and appropriate management can reduce labour requirements and cost, and increase benefits from the system.

Choice of species

Criteria

Many multipurpose tree species (MPTs) and shrubs are potentially suitable for use as hedgerows in alley farming, but only a small number have been tested. Leguminous MPTs that can biologically fix nitrogen are preferred over non-nitrogen-fixing legumes or non legumes. Species that have more than one useful attribute are advantageous as they give the system more flexibility and raise its productivity.

Ideally the MPTs used in alley farming should meet the following criteria:

- Can be established easily.
- Grow rapidly.
- Have a deep root system with few lateral branches near the soil surface.
- Have a suitable branching pattern, including high branches.
- High above-ground biomass, particularly leaf biomass production.
- Foliage has moderate to high and balanced nutrient content.
- Foliage has desirable quality for use as mulch or as green manure.
- Regenerate readily after pruning.
- Contain no toxic or alelophatic chemicals in shoots and roots.
- Provide useful by-products such as fodder, food, stakes, fuelwood and timber.
- Some degree of resistance to fire.
- Are resistant to (and will not serve as hosts to) pests and diseases, particularly those of crops grown in the alleys.

A high number of MPTs can meet some of the criteria, but only a few species are able to meet all of them (Tables 4.1 and 4.2). Occasionally, it may be desirable to choose a species that is excellent for certain specific purpose(s), for example, *L. leucocephala* is chosen because of its high biomass production and the high chemical quality of the prunings, although it has the disadvantage of slow early growth, and *D. barteri* is chosen for its slowly decomposing mulch. Some species have many desirable qualities for use as hedgerows, but have serious pest problems. *Sesbania sesban*, for example, harbours root knot nematodes and cannot be grown in combination with root, tuber and other crops that are sensitive to these nematodes.

The same characteristics needed for trees in cropping systems are required for livestock systems, with the addition of palatability, high digestibility, and freedom from toxic or anti-nutritional factors. Several of the tree species widely used do contain harmful metabolites, but these can be broken down by rumen microbes to render them safe for the animals, as will be discussed in Chapter 6. Most attention has been paid to the *Leucaena* species as a forage source, but the psyllid insect attacks observed in some areas of South-east Asia and East Africa have highlighted the danger of reliance on a single species. *Gliricidia, Sesbania, Prosopis, Erythrina, Paraserianthes* and *Acacia* species have all been grown for forage with varying degrees of success, depending on the local environment.

Table 4.1 List of potential multipurpose tree and shrub species for alley farming on non-acid soils in the humid and subhumid zones

Environment	Humid zone (annual rainfall > 1300 mm)	Subhumid zone (annual rainfall, 1000–1300 mm)
Low-altitude (0–800 m)	*Acacia auriculiformis* (A,B,C,E and F)*	*A. auriculiformis*
	Alchornea cordifolia (B,C,D)	
	Cajanus cajan (A,B,C,D and F)	*C. cajan*
	Gliricidia sepium (A,B,C,D,E and F)	*G. sepium*
	Leucaena leucocephala (A,B,C,D,E and F)	*L. leucocephala*
	Senna siamea (B,C,E and F)	*S. siamea*
Mid-altitude (800–1200 m)	*Cajanus cajan*	*C. cajan*
	Calliandra calothyrsus (A,B,C,D,E and F)	*C. calothyrsus*
	Flemingia macrophylla (A,B, and C)	
	Gliricidia sepium	*G. sepium*
	Leucaena diversifolia (A,B,C,D,E and F)	*L. diversifolia*
	Highland *Leucaena* species and hybrids (A,B,C,D,E and F)	Highland *Leucaena* species and hybrids
	Senna spectabilis (B,C,E and F)	*S. spectabilis*
	Sesbania sesban (A,B,C,D and E)	*S. sesban*
High-altitude (> 1200 m)	*Paraserianthes* spp. (A,B,C,E and F)	*Paraserianthes* spp.
	Erythrina poeppigiana (A,B,C,D,E and F)	*E. poeppigiana*

* A = nitrogen-fixing; B = source of mulch; C = source of green manure; D = fodder; E = source of stakes; and F = source of firewood.

Table 4.2 List of potential multipurpose tree and shrub species for alley farming on highly acid soils in the humid and subhumid zones

Environment	Humid zone (annual rainfall > 1300 mm)	Subhumid zone (annual rainfall, 1000–1300 mm)
Low-altitude (0–800 m)	*Acacia auriculiformis*	*A. auriculiformis*
	Cajanus cajan	*C. cajan*
	*Dactyladenia barteri*** (B,C,D,E and F)*	
	Flemingia macrophylla	
	Paraserianthes falcataria	*P. falcataria*
	Tephrosia candida (A,B and C)	*T. candida*
Mid-altitude (800–1200 m)	*Calliandria calothyrsus*	*C. calothyrsus*
	Flemingia macrophylla	
	Paraserianthes spp.	*Paraserianthes* spp.
High-altitude (> 1200 m)	*Erythrina* spp.	*Erythrina* spp.
	Paraserianthes spp.	*Paraserianthes* spp.
	*Tithonia diversifolia*** (B and C)	
	Desmanthus virgatus (B and C)	

* A = nitrogen-fixing; B = source of mulch; C = source of green manure; D = fodder; E = source of stakes; and F = source of firewood.
** non-legume species.

Environmental adaptation

The selection of woody species greatly depends on their adaptability to the local climatic and soil characteristics and limitations. Information on altitude, amount and distribution of rainfall, and soil characteristics of the locality can be used as a guide in selecting the desired species.

In Tables 4.1 and 4.2 are shown those hedgerow species which have good potential or have been tested for use in alley farming in different environments. Some woody species perform well at low-altitudes (< 800 m) and high annual rainfall (> 1000 mm) conditions, such as *D. barteri* or *L. leucocephala*, while others such as *C. calothyrsus* and *S. sesban* perform better at high rainfall and mid-altitude (> 800 m) elevation. Species such as *C. cajan* are also well adapted to lower rainfall limits of 800–1000 mm. In addition to the climatic factors, soil characteristics also affect species' suitability for a particular location. The dominant soil type and soil drainage conditions affect the choice of the species for the locality. Nitrogen-fixing leguminous woody species usually perform better on slightly acid soils (with pH-H_2O, 5.0–6.5), for example, species such as *G. sepium* and *L. leucocephala*. When grown on highly acid soils the species show poor plant growth due to poor and restricted root development, and poor nodulation. Growth of these species on acid soils can, however, be improved by liming the soil, combined with fertilizer application. Some species, such as *D. barteri* and *F. macrophylla*, are adapted to acid soils where they perform well. Further research and exploration of nitrogen-fixing woody species and provenances, particularly those of indigenous origin, are needed to find new and better adapted materials, especially for the acid soils. The following is a short description of the characteristics of some of the widely-tested species.

Acacia auriculiformis

This is a resilient, vigorously growing, small leguminous tree, 8–12 m in height, heavily branched with a short bole. On fertile soil it can reach a trunk diameter of 60 cm and a height of 30–40 m. This species occurs near sea level to 400 m, although it is also found in areas of up to 600 m, but it is most common at an elevation of less than 80 m. The mean annual rainfall in its natural range varies from 700–2000 mm and the species grows best in the humid zone with annual rainfall from 1500–1800 mm. It can also survive in the dry savannah, as its thick and leathery leaf can withstand heat and desiccation. *Acacias* commonly grow in riparian areas and on a wide variety of soils, including clay and calcareous soils. It has a high tolerance to saline, alkaline and acid soils. It usually nodulates profusely and fixes nitrogen. Plants can be propagated using seedlings. Because of its fast early growth, it can compete with weeds. The tree coppices poorly when cut at a low height. Coppicing is better when the stem is cut at over 50 cm in height and some branches left uncut on the trunk. Planted at 4 m inter-hedgerow and 0.5 m intra-row spacings and pruned at 0.75 m height, it can produce more than 5.0 tons of dry foliage biomass/ha/year. Uncut, it can produce up to 15–20 m^3 of wood/ha with 10–12 years rotation.

Alchornea cordifolia

This is a shrub that can reach a height of 4–6 m. It occurs in humid lowland forest at altitudes up to 300 m with at least 1200 mm annual rainfall and a temperature range from 20–34^{0}C. Plants grow best in low-lying areas, and grow well on acid and low-fertility soils. They are volunteer plants, widely used in traditional systems for soil fertility regeneration and fodder. They can be propagated using seedlings. Plants have dense and shallow root systems and may compete with crops in simultanous agroforestry systems on poor soils. *Alchornea* coppices well with intensive pruning. Planted at 4 m inter-hedgerow and 0.25 m intra-row spacings and pruned to 0.75 m height, it can produce about 4.0 tons of dry foliage/ha/year on soils with moderate fertility in the forest/moist savannah transition zone. Prunings decompose slowly and make a good source of mulch.

Cajanus cajan
This is described as a perennial leguminous shrub. It is a hardy and widely-adaptable plant that can tolerate drought and high temperatures, and is grown from sea level to 3000 m. Plants cannot withstand frost or waterlogging. True annuals are not known but it is widely grown as an annual crop with a single harvest or perhaps allowed to ratoon after harvest. Because of their perennial habit, pigeon pea plants remain vegetative at fruit maturity. There are short-, medium- and late-maturing cultivars that vary in growth habit, biomass and grain yields. Most of the late-maturing types are indeterminate. The late-maturing cultivars have a higher biomass yield than the short stature grain types. Plants are grown in the humid, and especially in the subhumid, lowland tropics. Some cultivars have a high tolerance to soil acidity. Traditional farmers in humid and subhumid tropical Africa plant the shrubby or erect genotypes with medium- to late-maturity that grow 2–4 m tall in intercropping systems. These are the types suitable for use in the alley farming system. Pigeon peas are cultivated for grain production and also for soil fertility improvement. High-quality prunings of pigeon peas can be used as fodder, mulch or green manure. Plants nodulate profusely. Planted at 4 m inter-hedgerow and 0.25 m intra-hedgerow spacings, a local perennial shrubby type, pruned to 0.75 m height produces 4.5 tons of dry foliage/ha in the first year and about 2 tons/ha in the second year. Biomass yield was negligible during the third year because of the high percentage of plant mortality.

Calliandra calothyrsus
This is a versatile shrub or small leguminous tree, which can reach 4–6 m in height. It grows in areas with a mean temperature from 22–28°C. The species grows best between 250–800 m, in areas with an annual rainfall of 2000–4000 mm, although in some areas it still grows well at altitudes of up to 1500 m. It can withstand dry

periods of 2–6 months with a rainfall of less than 50 mm. It grows well on a variety of soils from fertile to relatively infertile acid to slightly alkaline soils, but it grows poorly on waterlogged soils. Plants nodulate profusely, and are usually also well-infested with *mycorrhiza*. *Calliandra* can be propagated by direct seeding, the use of seedlings or by cuttings. The plant is a good source of green manure, fodder and firewood. Plants coppice well and can be pruned to 25 cm in height. Planted in hedgerows at 4 m inter-row spacing and 0.25 m intra-row spacing and pruned to 0.75 m in height, it can produce over 6 tons of dry foliage /ha/year on moderately fertile soil in the humid/subhumid transition zone. Too frequent pruning may result in die back of the plants. Uncut plants on moderately fertile soil can produce 5–20 m^3/ha/year of fuelwood.

***Dactyladenia barteri* (syn. *Acioa barteri*)**

This is a climbing shrub or small tree, up to 12 m tall. It occurs in humid lowland forests at altitudes up to 300 m with at least 1200 mm annual rainfall and a temperature range between 20°–34°C. Plants are well adapted to sandy, acid and low fertility soils. Propagation is mainly done by direct seeding. Seeds germinate readily and seedlings have vigorous growth. Juvenile stem cuttings also root quickly. Known to be deep rooting, roots can reach depths of over 10 m in acid soils. Plants have only a moderate rooting density in the surface soil and will compete less with crops so it is particularly suitable for simultaneous agroforestry systems. Plants are widely planted or protected as fallow vegetation for soil regeneration in various parts of humid west Africa. The leaves are used for fodder and stems provide good quality poles for staking crops or for construction work. Plants are fire resistant and coppice well, even at a low pruning height. Grown on acid and infertile soil at 4 m inter-hedgerow spacing and pruned to 0.75 m height, it can produce over 6 tons of dry foliage /ha/year in the humid zone.

Erythrina poeppigiana

This is a leguminous tree native to the humid and subhumid lowland tropics. Naturalized trees are found to 2000 m elevation. It grows well in areas with a mean annual rainfall ranging from 1000 to 4000 mm, but in the subhumid zone it can tolerate 5–6 months of dry season. Some local provenances can tolerate low soil fertility and high soil acidity (pH-H_20 of 4.3). Plants can be propagated using seedlings or cuttings. Although seedling survival is generally good, weeding may sometimes be needed. *Erythrina* plants nodulate abundantly with nitrogen-fixing bacteria, but inoculation is required when introducing the species to new areas. Plants are normally also infested with mycorrhizal fungi. *Erythrina* is widely used as a shade tree, living fence posts, and for forage and fuelwood production. The high-quality pruning biomass can be used as green manure or mulch. Unpruned plants will shed some of their leaves during flowering or long dry periods. Pruning trees periodically will prevent complete leaf fall, even during the dry season. Although plants coppice well, too frequent prunings can cause die back because of the slow recovery of carbohydrate reserves in the plants. Planted at 6 x 6 m spacing with three prunings it can produce over 4 tons of dry foliage/ha/year and 3.5 tons of stems/ha/year.

Flemingia macrophylla (syn. _F. congesta_)
This is a woody leguminous shrub that can grow up to 2.5 m in height. It can be found in the humid and subhumid zones, from sea level up to 2000 m. The minimum rainfall required is about 1100 mm and plants thrive well in areas with an annual rainfall of up to 3000 mm. *Flemingia* is a hardy plant that can withstand long dry spells, and is capable of surviving on very poorly-drained and occasionally waterlogged soils. Plants have a high adaptation to acid and infertile soils with high levels of extractable aluminum. It is also tolerant to light shade and has some degree of fire resistance. Plants have a deep root system and nodulates well with nitrogen-fixing bacteria. *Flemingia* is widely used as planted fallow to suppress weeds and for soil improvement, for stabilization of sloping lands and grown as a cover crop in coffee, cocoa and clove plantations. Prunings of *Flemingia* have intermediate quality; it decomposes slowly and forms a good source of mulch and green manure and is also used as dry season browse, but digestibility is low. It can withstand repeated prunings and coppices well. Grown on low-fertility ultisol and planted at 4 m inter-row spacing, it can produce about 1.5 tons of dry foliage/ha/year. Densely planted, it can produce about 12 tons of foliage/ha/year.

Gliricidia sepium
This is a small deciduous tree up to 12 m tall, with a short trunk and often branching at the base. It grows in areas with mean annual temperatures from 20–29° C. Light frost is tolerated. It grows well in the humid and subhumid zones with an annual rainfall of 900–1500 mm. It can tolerate a wide range of soil types, both acid and alkaline, and prefers well-drained soils as it cannot tolerate waterlogging. It is more tolerant to acid and low fertility soils than *L. leucocephala*. Plants have a moderate rooting depth and density. Roots are commonly well nodulated with nitrogen-fixing rhizobium and infested with mycorrhiza. *Gliricidia* can be propagated by direct

seeding, the use of seedlings and by cuttings. It is the most widely-cultivated multipurpose tree after *L. leucocephala* and is planted as shade trees in agroforestry systems, live stakes and fences, and improved fallows. It is also planted to stabilize the soil for erosion control, for reclamation of denuded land or on land infested with noxious weeds such as spear grass (*Imperata cylindrica*). The wood is often utilized as firewood, for charcoal production and for the construction of buildings and farm implements. *Gliricidia* provides useful forage in the form of leaves, green stem and bark, and is commonly used to supplement poor quality and low-protein roughage. During the dry season it may become a major source of feed for goats and cattle in the subhumid zone. Ruminants unaccustomed to *Gliricidia* forage may not eat the foliage initially. However, once initial aversion has ended, they will eat a high proportion. Leaf meal can also be fed to poultry and rabbits. Because of its high quality, *Gliricidia* prunings are a good source of green manure. During the flowering period and long dry season unpruned plants shed their foliage. Pruning trees periodically will prevent complete leaf fall, even during the dry season. Plants coppice well and can be pruned to 25 cm in height. However, too frequent prunings may result in die back of the plants because plants do not produce a sufficient reserve of carbohydrates. Planted at 4 m inter-hedgerow and 0.25 m intra-hedgerow spacing on soil with moderate fertility in the forest/moist savannah transition zone, it can produce about 5.0 tons of dry foliage/ha/year and 1.8 tons/ha/year of wood. Grown in woodlots, the first wood harvest can be done after 3–4 years, yielding 8–15 m^3/ha. Coppicing is done every 2–3 years, yielding 40 per cent more than the first harvest.

Leucaena leucocephala

A versatile and most widely grown multipurpose tree, there are two major types of *Leucaena*: the 'common' shrubby form that grows up to 8 m tall, and the arboreal 'Salvador' type that grows up to 16 m. Widely-grown giant cultivars are 'K8', 'K29', 'K67' and 'K636'. Due to the widespread damage caused by psyllid in some areas, new interspecific hybrids such as 'KX1', 'KX2' and 'KX3' which are psyllid tolerant are becoming popular in Asia. It is found up to 1000 m elevation, but new hybrids such as 'KX3' greatly extend this range to cooler climates. For optimal growth, *Leucaena* requires warm conditions, with mean temperatures ranging from 20–26°C. Some cultivars are sensitive to frost damage. Frost causes defoliation and severe frost can kill all the above-ground parts, but below-ground parts survive and plants will regrow vigorously. It requires an annual rainfall of 650–1500 mm, but occasionally can be found in wetter or drier locations. *Leucaena* favours deep, well-drained soils with pH-H_20 greater than 5.0. It has a low tolerance to soluble aluminum in the soil solution and is therefore unsuitable for acid soil conditions. It performs optimally on calcareous soils, but can also be found on saline and alkaline soils with pH-H_2O of up to 8.0. Plants can be established easily by direct seeding or the use of seedlings. Using cuttings gives a low percentage of establishment. Plants are normally deep rooting, but have shallow roots when grown in acid soils. Plants nodulate profusely in areas where *Leucaena* has been planted. Rhizobium inoculation may be required for establishment in new areas. Generally plants are well infested with mycorrhiza. *Leucaena* is widely grown as a source of timber, fuelwood and staking material. Leaves and prunings have a high chemical quality and are suitable for use as fodder and green manure. It is also widely grown as planted fallow for suppression of difficult to control weeds such as *L. camara*, for soil regeneration, and for stabilization of sloping land. *Leucaena* plants can withstand frequent prunings and still coppice well, even with mechanized pruning at ground level. It also regenerates quickly from the base after fire damage. Planted at 4 m inter-hedgerow and 0.25 m intra-hedgerow spacing on soil with moderate fertility in the forest/moist savannah transition zone with 0.25 m pruning height, the giant type can produce over 7.0 tons of dry foliage/ha/year and 4.0 tons/ha/year of dry stakes. The wood yield varies widely with cultivars, planting density, location, age of plantation and management practices. The arboreal type has annual height increments of 3–5 m and annual wood increments of 20–60 m^2/ha.

Paraserianthes falcataria **(syn. *Albizia falcataria*)**

This is a large leguminous tree that can reach 20–30 m in height and 0.8 m stem diameter. In its natural habitat, it grows from sea level to 1200 m altitude in areas with a temperature range of 22–34°C. It grows well in the humid zone with an annual rainfall of 2000–4000 mm and less than two months of dry season. Plants grow well in well-drained and fertile soil, and it has a tolerance to soil acidity. *Paraserianthes* is one of the fastest growing trees, and is used for pulp and other wood products, fuelwood, as a shade tree in coffee and tea plantations and also in silvopastoral systems. Plants can withstand pruning and coppice well. Planted in 4 m inter-row spacing on an acid soil it can produce on average 2–3 tons of dry foliage/ha/year. *Paraserianthes*, however, cannot withstand repeated prunings. If the plants are pruned too often it will result in die back.

***Senna siamea* (syn. *Cassia siamea*)**

A tree, 6–12 m tall, with spreading branches forming a dense rounded crown, this is a leguminous plant that does not fix nitrogen. It grows in a range of climatic conditions, but is particularly suited to the lowland tropics with mean annual temperatures of 20–31°C and a mean annual rainfall of 500–2800 mm. In the dry savannah it grows only in areas where its roots have access to ground water. It is susceptible to cold and frost and does not do well at altitudes above 1300 m. *Senna siamea* grows best on deep, well-drained and fertile soil and grows poorly on infertile soil. It has reasonable tolerance to acid soils. Roots grow to considerable depth, with a dense mat of roots at shallow (0–20 cm) depth that grows extensively, reaching a distance of up to 15 m away from the stem. The extensive root system may prove to be a disadvantage in simultaneous agroforestry systems. Propagation is mainly by direct seeding or seedlings. Since, seedlings grow slowly, it is susceptible to competition from weeds. Plants are tolerant to coppicing, although too frequent prunings may result in die back. When planted at 4 m inter-hedgerow spacing it can yield over 5 tons of dry biomass/ha/year on moderately fertile soil. It is particularly suited to the forest/moist savannah transition zone. Prunings have a low chemical quality and decompose moderately well. They are very suitable as mulch material. Plantations can be harvested every 5–7 years, yielding 10–15 m^3/ha/harvest of timber, poles and fuelwood.

***Senna spectabilis* (syn. *Cassia spectabilis*)**

A small shrub, 4–6 m tall, this is a leguminous plant that does not fix nitrogen. It grows in a range of climatic conditions, but is particularly suited to the lowland tropics with mean annual temperatures of 20–31° C, and a mean annual rainfall of 1000–2000 mm. It grows best in deep, well-drained, and fertile soil, and is tolerant of acid soil conditions. The roots grow to a moderate depth, but with a dense mat of roots at shallow depth it will require root pruning to reduce competition with annual crops. *Senna spectabilis* can be propagated either by direct seeding, by seedlings or alternatively by cuttings. Plants are tolerant of coppicing, although too frequent prunings may result in die back. Prunings have low chemical quality, decompose moderately and are suitable as mulch and green manure. Plants also produce staking material and firewood. Planted at 4 m inter-hedgerow and 0.25 m intra-hedgerow spacings and pruned to 0.50 m height, *Senna spectabilis* can produce on average about 6 tons of dry foliage/ha/year and 2 tons/ha/wood.

Sesbania sesban

This is a small tree that grows to 8 m in height. Occurring in semi-arid to humid areas with annual rainfall from 500 to 2000 mm, it does well under bimodal rainfall distributions. It grows from sea level to 2000 m elevation. It does not tolerate frost, but it can withstand periodic waterlogging and flooding. While *Sesbania* can tolerate to a considerable degree alkalinity and salinity, some research results indicate that certain types can grow well on acid soils. Plants nodulate well, but they require inoculation with specific rhizobium if planted at a new location where *Sesbania* has not been grown previously. Propagation is generally from seed, although it has been rooted from cuttings. Seed scarification usually improves germination. Plants establish and grow quickly and they are often allowed to grow scattered throughout annual crop fields in Africa for the nitrogen they provide. Because of its fast growth, *Sesbania* is used as planted fallow to improve soil fertility and to control weeds. It is also used as a shade tree in coffee plantations. Since the plants are relatively short-lived, and come under intensive browsing or pruning, they will not last more than 3–5 years. If planted as hedgerows in alley farming it is recommended that 10–25 per cent of the foliage is left on the plants to increase longevity. Prunings are of high chemical quality and are mostly used as fodder and green manure. Plants are infested with root-knot nematodes and are not recommended for intercropping with crops sensitive to these nematodes. The wood is of low quality and not durable, and branches are used as poles in temporary structures and for staking. *Sesbania* has high potential for fodder or pulpwood production. Planting at about 10 000 plants/ha can produce 15–20 tons of dry, woody biomass/year.

Hedgerow establishment

Various factors need to be taken into consideration for successful hedgerow establishment to save time and avoid waste of effort. After determining the purpose and suitability of the area for establishing the alley farm, it is important to obtain the most suitable *planting material* and select the most cost-effective way to establish and manage the hedgerows and fields. The recommendations made here are based on research and on-farm experiences, and allowances need to be made to fine tune practices according to prevailing local conditions. Local variations in soil types, microclimate and other physical factors have to be considered, together with local availability of labour.

Planting material

Trees and shrubs can be established from seeds, seedlings or stem cuttings depending on the species. For direct seeding, high-quality seed with a high germination percentage (over 75 per cent) is needed, which can be obtained from development agencies or reputable seed suppliers. If seed germination percentage is low the seeding rate has to be adjusted accordingly. Since seeds of many legumes have hard, water-resistant seed coatings, they exhibit seed coat dormancy that must be broken to allow maximum germination rates. This is done by seed scarification and is required for species such as *L. leucocephala* and *S. siamea* to obtain a high germination rate, but is not needed for others such as *C. cajan* and *G. sepium* (Table 4.3). Seed pre-treatment can be done using one of the following methods:

1 *Mechanical*: this is done by rubbing seeds against an abrasive surface such as sandpaper or by mutilation of part of the seed coat. Care should be taken not to damage the seed embryo.
2 *Hot water treatment*: this is the simplest and most cost effective way to treat a large quantity of seeds, but can give erratic results if not done properly. Boiling water (100°C) is poured into a container containing seeds, and these are stirred for three to four minutes. The seed to water ratio should be 1 : 2 by volume and the minimum amount of water should not be less than one

Table 4.3 Requirements for seed treatment and inoculation for certain tree and shrub species used in alley farming

Species	Seed treatment*	Inoculation requirement
A. auriculiformis	A,B	No
C. cajan	None	No
C. calothyrsus	A,B	No
F. macrophylla	A,B	No
E. poeppigiana	A,B	No
G. sepium	None	No
L. leucocephala	A,B	Yes
L. diversifolia	A,B	Yes
P. falcataria	A,B	No
S. siamea	A,B	Does not nodulate
S. spectabilis	A,B	Does not nodulate
S. sesban	A,B	Yes
T. candida	None	No

* A = hot water treatment; B = concentrated sulphuric acid.

litre for the heat treatment to be effective. The water should be poured off after it has cooled and the seeds can be air or sun dried for storage afterwards.

3 *Acid treatment*: this gives consistent and reliable results, though it is more costly. Seeds are treated for 60 minutes with concentrated (commercial grade) sulphuric acid (98 per cent) using a seed to acid ratio of 10 : 1 by volume. During seed treatment the seeds are occasionally stirred. Following treatment the seeds are rinsed with water to remove traces of acid and then air or sun dried.

Not all species can be propagated vegetatively by using cuttings. Species such as *E. poeppigiana* and *G. sepium* can be propagated successfully using cuttings, while *L. leucocephala* shows poor establishment from cuttings. Use of long cuttings (≥ 0.5 m) and the woody part of the stem results in a higher establishment percentage.

When direct seeding and vegetative propagation are not feasible, the use of seedlings is necessary. For example, seeds of certain species such as *D. barteri* have a short viability of 3–4 weeks and seed only for a short period during certain times of the year. Potted seedlings in small black polythene bags or bare-root seedlings can be used. Potted seedlings are kept for 8–10 weeks before transplanting. For bare-root seedlings, the seeds are planted in nursery beds. When transplanting, seedlings are carefully removed from the beds and carried in bundles to the field where they are to be planted out. The success rate of field establishment with bare-root seedlings is lower, but can be practised successfully with certain species such as *L. leucocephala*.

Seed inoculation with rhizobium

Nitrogen fixation characterizes most woody legumes (over 92 per cent of mimosoids and papilionoids, but 34 per cent of caesalpinoids). Nitrogen-fixing legumes preferred in alley farming, such as *G. sepium* and *L. leucocephala*, rely on rhizobium bacteria to fix atmospheric nitrogen. Seed inoculation will be needed only when suitable rhizobium is not present in the soil, usually when a species is introduced for the first time into an area or site. Table 4.3 shows a list of the rhizobium requirements of a number of species.

A simple and inexpensive way to introduce rhizobium is to mix the seeds before planting with soil collected from around well-established and nodulated trees or shrubs of the same species growing nearby. Alternatively, seeds may be treated with rhizobium culture, available from local institutions or commercial companies.

Direct seeding is the cheapest and most practical way for establishing the hedgerows. However, for most species, including *L. leucocephala* and *G. sepium*. this method is recommended only in areas with an annual rainfall of over 1200 mm and a growing period of at least six months. Unreliable and poor rainfall after planting can result in patchy establishment.

With direct seeding special attention has to be given to planting depth. Some species, such as *G. sepium*, require a shallow planting depth of 1.0 cm, others, such as *L. leucocephala*, can tolerate a deeper planting depth of 1.0–2.0 cm. The seeding rate for establishing the hedgerows depends on species and seed availability. If plenty of seed is available, seeds can be drilled in a furrow and will result in dense establishment. If the seed supply is limited, they can be planted at 0.20–0.25 m spacing in the hedgerows, with two to three seeds planted per hole. For planting at 4 m inter-hedgerow and 0.25 m intra-row spacings, using three seeds per hole, 1.7 kg of *L. leucocephala* seeds and 2.5 kg of *G. sepium* seeds per hectare are needed. For seed drilling, between 10 and 15 kg of seeds/hectare are required for both species.

A problem with direct seeding is that the seedlings need to be protected against weeds during early growth, increasing the labour requirement. Hedgerows can be established economically by planting at the same time as the food crops or shortly afterwards, in which case both crops and trees can be weeded at the same time (Fig 4.1). Precautions also need to be taken to protect the small seedlings against rodents and foraging animals. This can be done by keeping the animals away from the fields or by fencing, both of which are measures also needed to protect the food crops.

The use of seedlings or cuttings is desirable for quick establishment or where there are limitations for direct seeding. Seedlings are preferred for drier areas with a short rainy season. The advantages of planting with seedlings and cuttings are: 1) plants are tall enough to compete successfully with weeds and require less care and protection during their early development, 2) plants attain a large size quickly to allow early pruning, and 3) plants have already established a deep root system before the end of the rainy season and can therefore withstand a prolonged dry season. Disadvantages with the use of seedlings include the need to establish a nursery, with the additional expense of transporting and planting the seedlings. The use of cuttings can also be costly, especially if parent trees from which cuttings could be obtained are not available locally. Even if they are, there is still the expense of gathering and

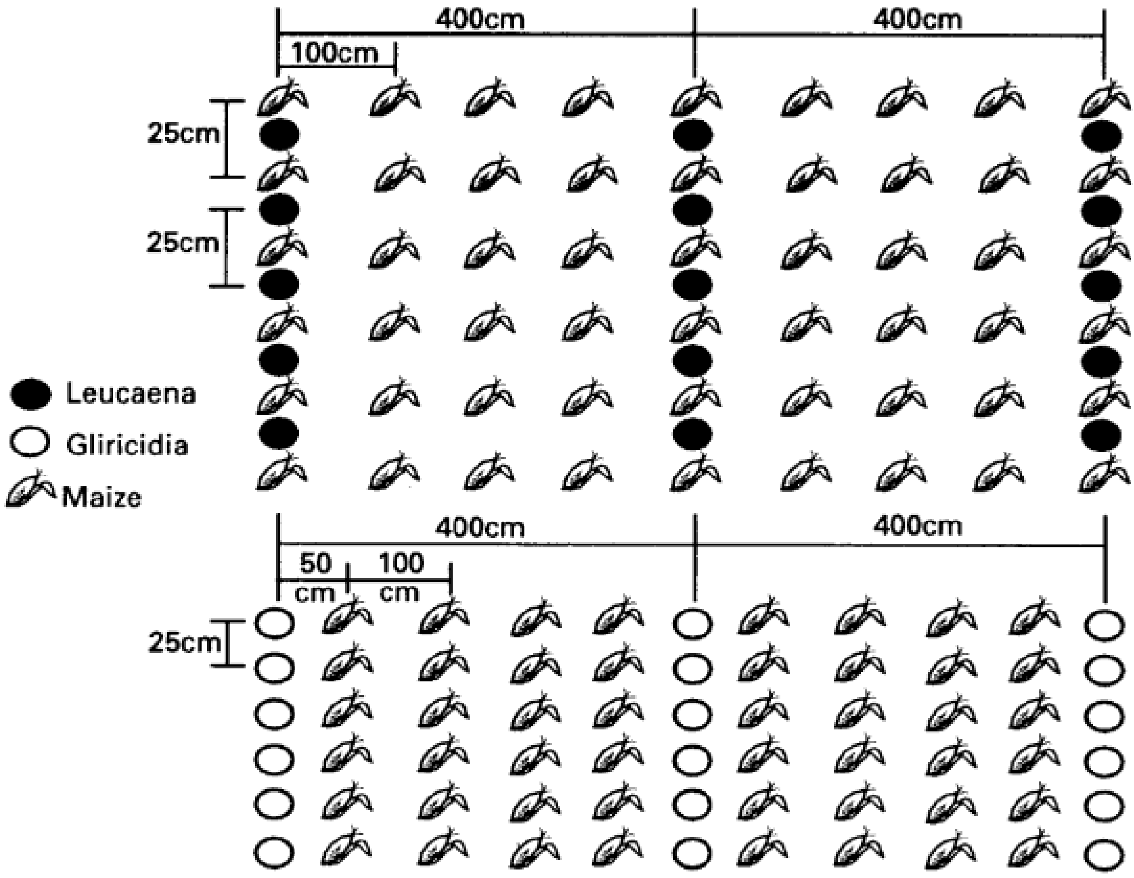


Fig 4.1 Arrangements for establishing an alley farming plot with *Gliricidia sepium* and *Leucaena leucocephala* hedgerows with a maize crop to create a 4 m wide alley.

transporting the cuttings over a short distance. One additional disadvantage in the use of cuttings is the absence of tap roots and the fact that plants develop more lateral roots, so can increase competition for nutrients with the food crops. This will reduce plant anchorage for certain species such as *G. sepium*, and plants can be easily uprooted.

Hedgerow orientation

The orientation of hedgerows and crops in an alley farming system depends on plant species, climate, slope, soil conditions and the space required for the movement of people and tillage implements. In the field the orientation of the hedgerows in many instances is determined by the location and the slope of the land.

On sloping land hedgerows need to be planted on the contour lines (lines which connect points of exactly the same elevation) to reduce runoff and subsequent soil erosion (Fig 4.2). Because water does not flow along a contour line, the hedgerow barrier that is planted along the contour line will have the maximum impact in

Fig 4.2 *Leucaena leucocephala* hedgerows on sloping land in Sikka, Flores, Indonesia.

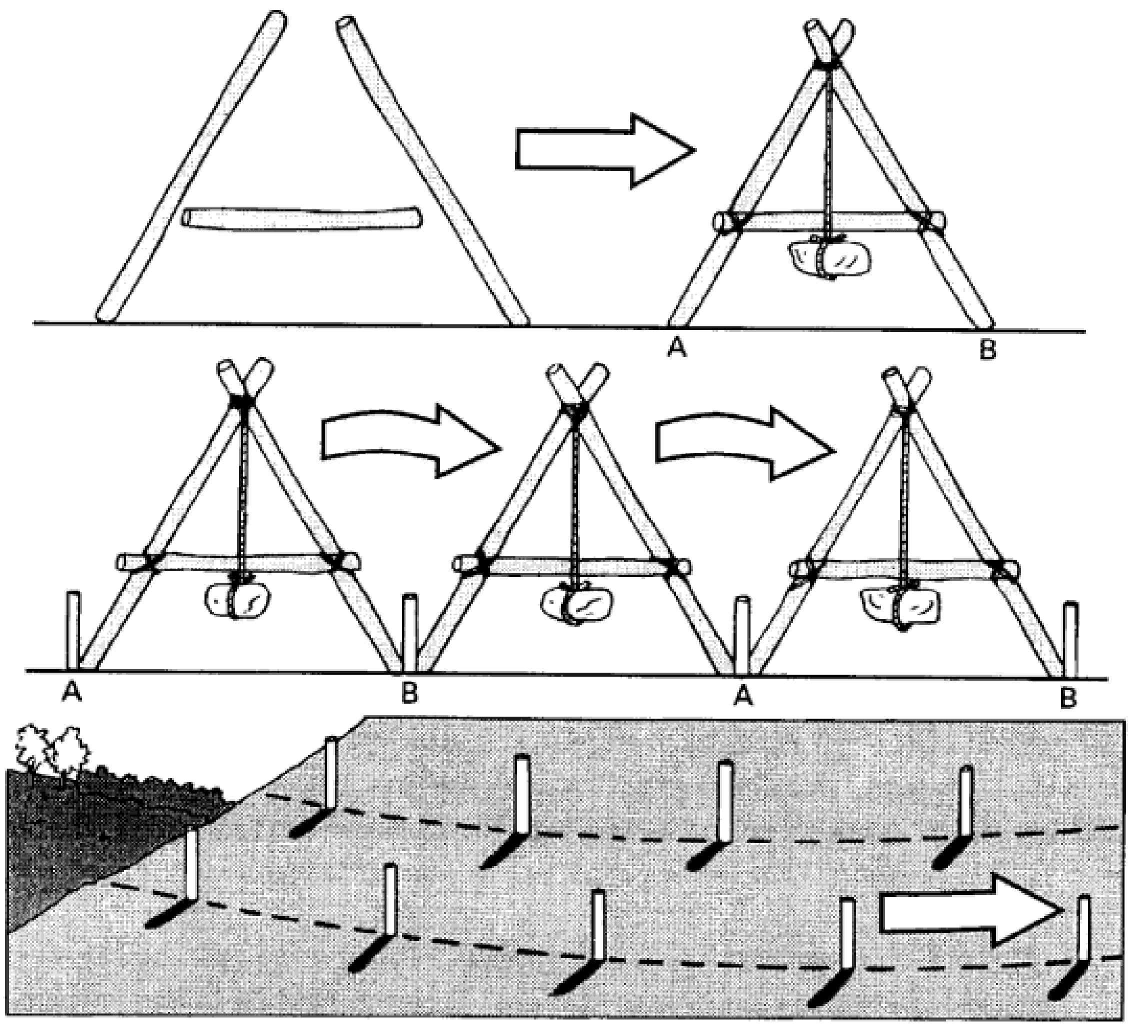


Fig 4.3 Making the A-frame, finding the contour and staking the contour line.

preventing water or soil moving down the slope. The contour lines can be located by various means. The most widely-used method is using the A-frame (Fig 4.3). It consists of three 2–3 m-long poles tied in the form of a letter A, two tied up at the top and the third one tied horizontally across the two poles about 1 m from the bottom. A string is hung from the top where the two vertical poles are tied and a stone tied to the end of the string. The stone should hang just below the horizontal pole. Calibrate your frame by placing it on level ground and mark the spot where the string crosses the horizontal pole. This is usually the centre. In the field, place one of the legs of the A-frame at the spot where you wish to start the contour line. Hold this pole in place and move the other leg around until the string hangs down exactly over the mark on the cross pole. Place wooden pegs into the soil next to each of the legs. The line connecting the pegs will form the contour line. Ideally, on flat lands located in areas close to the equator, where possible hedgerows should also be positioned in an east-west direction, so that plants on both sides of the hedgerows receive full sunlight during the day.

The inter-hedgerow spacing used in the field usually ranges from 4 to 6 m, with intra-row spacing varying from very close spacing to 0.25 m. On sloping land, the inter-hedgerow spacing depends on the gradient of the land. On very steep lands and hillsides, the hedgerows need to be spaced closer together and double hedgerows can also be used if needed. Wider inter-hedgerow spacing is suitable for very humid areas where solar radiation limits crop growth and farmers need a larger area for their food crops. In the drier areas, where soil moisture limits crop growth, wider inter-hedgerow spacing of over 12 m is also recommended. Observation from years of experimentation with systems based on *G. sepium* and *L. leucocephala* show that farmers have adopted an inter-hedgerow spacing of 4–6 m for the humid and subhumid zones. Fig 4.1, on page 00, illustrates planting arrangements for establishing an alley farming plot with *G. sepium* and *L. leucocephala* using 4 m inter-hedgerow and 0.25 m intra-hedgerow spacings. As described in the previous section, the food crop maize, for instance, can be planted earlier. A few days after the maize seedlings have emerged, *G. sepium* and *L. leucocephala* can be seeded using the arrangement shown in Fig 4.1.

In Fig 4.4 the various stages for establishing and managing the *L. leucocephala* hedgerows are shown. During the first year rainy season, *L. leucocephala* hedgerows are planted at the same time as maize. During the first year second growing season, and the following dry season, the hedgerows are allowed to grow uninterrupted.

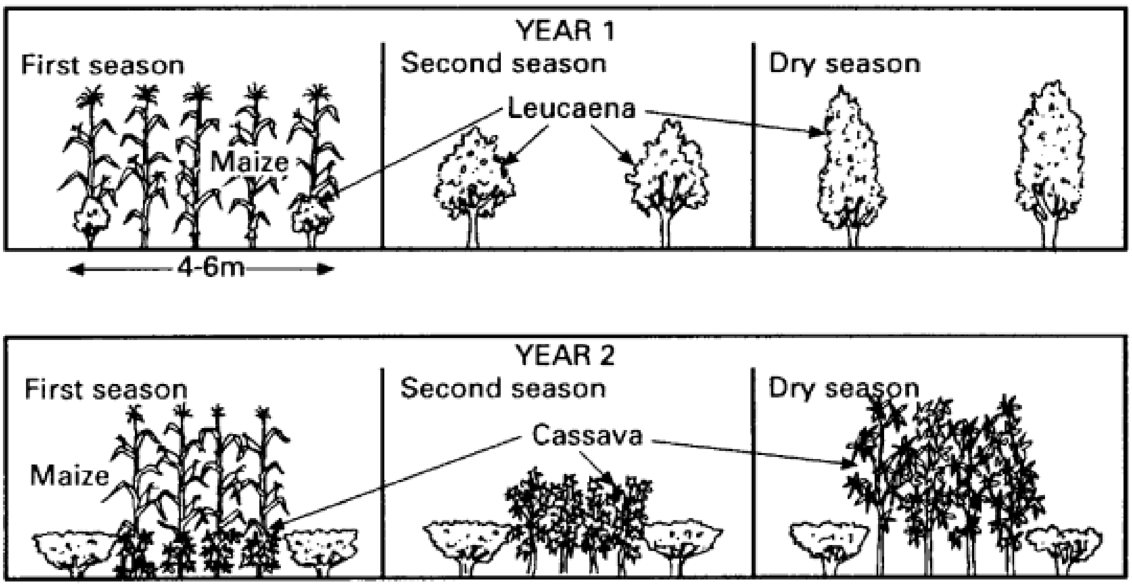


Fig 4.4 Schedule for establishing and managing an alley farm with *Leucaena leucocephala* hedgerows with 4–6 m wide alleys during the first two years of cropping.

Table 4.4. Recommended inter-hedgerow spacings for various environments and operations

Scale of operation/environment	Inter-hedgerow spacing
Smallholder operation	
Humid zone	4–6 m
Subhumid zone	5–6 m
Semi-arid	> 12 m
Tractorized operation	
Humid and subhumid zones	> 9 m

In the second year the hedgerows can be pruned or foraged if they have already reached the desired size, and the alleys can again be cropped, in this case with cassava. Recommended inter-hedgerow spacing arrangements for the different climatic zones and for mechanized operations are shown in Table 4.4.

Farmers' rationale for establishing alley farms varies with agroecological zones. An important point is that in drier areas where there is a need to minimize water competition, farmers are compelled to establish hedgerows at wide spacings. The resulting low density of trees diminishes the value of the hedgerows as a source of mulch and there may not be a sufficient amount of prunings to make a significant impact on food crop yields. However, hedgerow prunings could still provide an important source of supplementary fodder for livestock production, which is commonly an important farm activity in the drier and semi-arid zones. The widely-spaced hedgerows could also serve as windbreaks and provide excellent protection against wind and/or soil erosion. If the alley farms were also established for fruit tree or timber production, wider intra- and inter-hedgerow spacings are needed, depending on the hedgerow species planted.

Hedgerow management

To maximize the benefits to the associated crops, the hedgerows need to be managed in such a way that it will minimize competition with the crops. This can be achieved by using proper hedgerow pruning methods and schedules, depending on the associated food crops grown. The major management issues are concerned with:

- Pruning regime.
- Pruning utilization.
- Fallowing.

Pruning regimes

Once established, the hedgerows need to be pruned occasionally. Pruning serves two purposes: 1) it minimizes shading of the companion crop(s), and 2) it makes leaves and branches available for mulch, green manure, fodder, staking material, and firewood. Hedgerow pruning is a pivotal activity in alley farming. It is, however, the most labour- and management-intensive component of the system.

A pruning regime refers to the technique and schedule of pruning practised at a site. The choice of pruning regime depends on several factors:

1 the associated crops and hedgerow species,
2 the relative importance and type of products and by-products,
3 services expected from the hedgerows, and
4 the amount and timing of labour available for hedgerow management and harvesting.

The choice of an optimal pruning regime will often be a compromise between keeping the woody hedgerows in good condition for long-term production, providing adequate mulch or green manure, avoiding short-term yield reduction to the crops and the economic value of the hedgerows. Low pruning height and high pruning frequency reduce biomass yield, while higher pruning height and lower pruning frequencies increase biomass yield of hedgerows (Fig 4.5).

Pruning regimes, besides having an effect on biomass yield, also affect the quality of prunings and yields of hedgerow wood and associated crops. Higher pruning heights and lower pruning frequencies favour wood yield of hedgerows and reduce the associated yield of crops (Fig 4.5). Frequent prunings produce less biomass but higher quality of prunings.

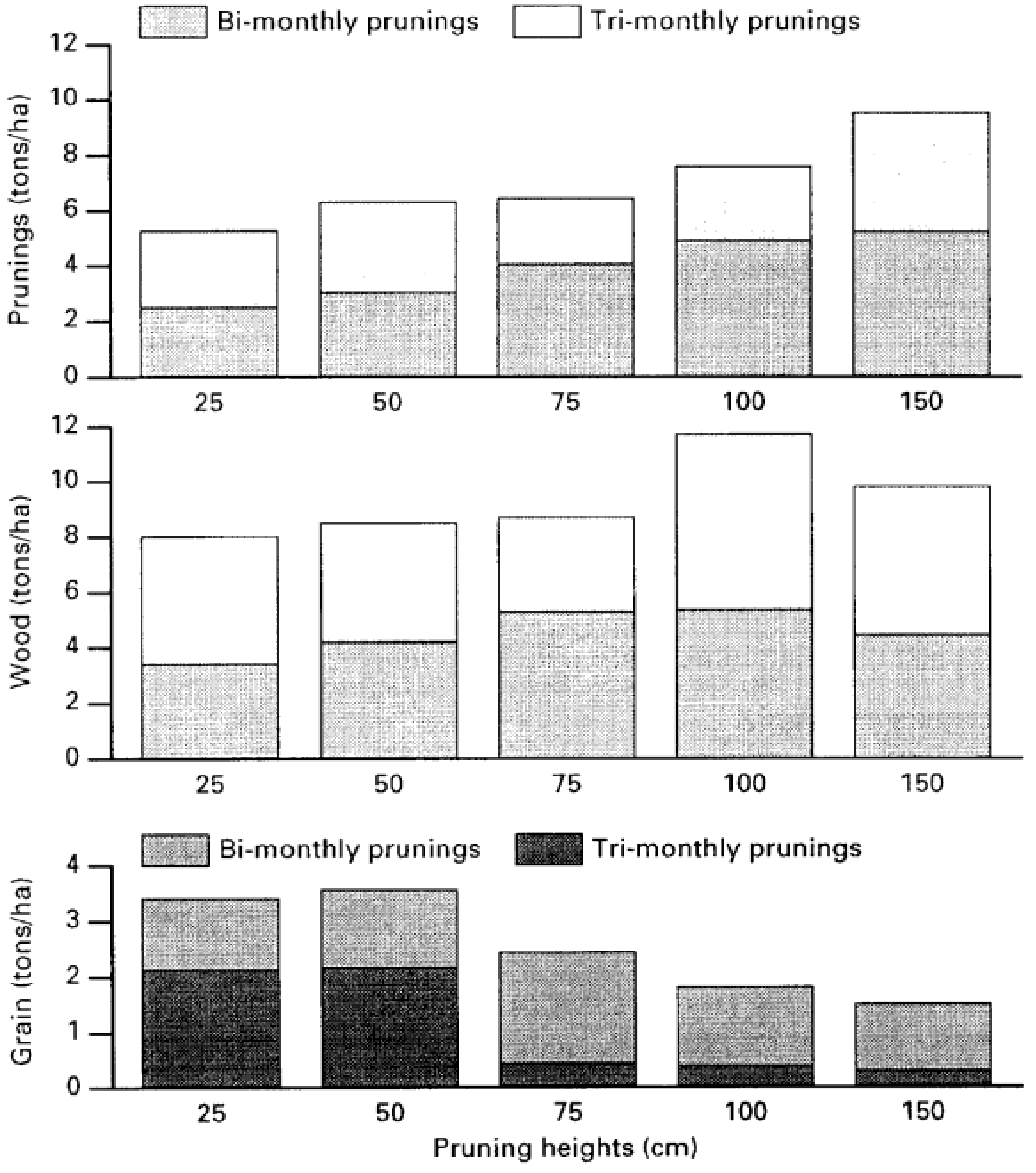


Fig 4.5 Relationships between pruning regimes with pruning biomass and wood yields of *Leucaena leucocephala* hedgerows grown at 2 m inter-hedgerow spacing and grain yield of alley-farmed maize.

Pruning techniques

There are two types of pruning techniques: coppicing and pollarding. In coppicing, which is the preferred technique, the hedgerows are cut at a desired height of 0.25 to 1.0 m above the ground. Regrowth will be produced from the stump. In pollarding, the crown of a tree is cut back to a height of about 2 m. A lower pruning height requires fewer prunings (Table 4.5), though it can increase physical back strain with manual prunings.

Hedgerow prunings can be done manually (Fig 4.6) with a sharp cutlass or mechanically using a small 2.5-horsepower backpack brush cutter. For certain species, such as *L. leucocephala*, the hedgerows can be pruned down to slightly above the soil surface using a grass mower with Howard rotary blades mounted on a tractor. For a tractorized operation, the plant stem diameter should be kept below 5 cm. The time required for doing hedgerow pruning can be

Table 4.5 Recommended pruning frequencies for *Leucaena leucocephala* hedgerows planted at 4 m inter-hedgerow spacing. Greater pruning height requires more frequent pruning to prevent shading of sequentially and alley cropped maize and cowpea

Pruning height hedgerows	Maize (1st season)	Cowpea* (2nd season)
0.25 m	2 prunings	1 pruning
0.60 m	3 prunings	2 prunings

* Cowpea is a shorter stature and duration crop than maize.

Fig 4.6 A farmer in Zaki-Biam, Benue State, Nigeria, prunes his hedgerow manually.

sharply reduced using mechanization. Coppicing *L. leucocephala* hedgerows planted at 4 m inter-hedgerow spacing, with a plant diameter of 2–3 cm, requires 2, 8, and 45 hours/ha respectively with a grass mower, brush cutter or by hand.

Pruning schedule

The initial pruning of the hedgerows can be done when the tree reaches a height of 2-3 m or a stem diameter of 2–3 cm. This is usually after 12 months of growth for well-established *G. sepium* or *L. leucocephala* hedgerows. Pruning trees too early can cause growth stagnation or die back. During each and subsequent cropping seasons, hedgerows are pruned at the time of planting the crops. Regrowth of hedgerows is rapid in species such as *G. sepium* and *L. leucocephala* in the humid and subhumid tropics. Regrowth of *G. sepium* and *L. leucocephala* can reach 1 to 2 m in about six weeks during the rainy season and 2 to 3 m in 8–12 weeks during the dry season. Thus, the farmers will need to cut back the hedgerows once or twice as the maize crop matures (Table 4.5).

Less frequent pruning is needed for short-season crops such as cowpeas (Table 4.5). For a long-season crop such as cassava, following initial pruning at planting, subsequent prunings at about 10–12 week intervals are required. When prunings are used for livestock fodder, hedgerows may be pruned when the shoots are of a suitable length. For fruit and wood production, only the side branches of the trees are removed.

Uses of pruning material

Hedgerow prunings can be applied as a mulch and green manure. In mulching, hedgerow prunings are distributed and left on the soil surface in the alleys before planting and while the crops are growing. Applied as green manure, these can be incorporated in the soil to reduce nitrogen loss through volatilization, in which case they serve more as a nutrient source for the associated crops.

Prunings can also be used as fodder for livestock or as sources of staking material and firewood. These uses will be discussed in later chapters. Unlike the *in situ* uses of prunings as mulch or green manure, in the case of fodder and auxiliary uses, prunings are usually taken away from the field. In a cut-and-carry system, precautions need to be taken that the export of prunings will not result in over-exploitation of plant nutrients. Efforts should be taken to compensate nutrient removal by returning the animal manure to the field or by applying fertilizer.

Fallowing

Alley farming allows long periods of continuous cultivation on one field. For agriculture with no chemical inputs, practised in areas where long fallow periods have become a luxury, alley farming provides clear benefits over the traditional systems. Yet the question arises, as to whether an established alley farm can be cropped indefinitely.

Results have shown that when farmers can afford an occasional short fallow in the farming cycle, this will enhance the sustainability of the alley farm. The benefits of short fallowing have been demonstrated on slightly acid soils. Such fallows show positive effects on:

1 the growth, vigour and productivity of hedgerows,
2 soil productivity and fertility improvements, and
3 crop yields.

The fallowed fields can also be utilized for grazing by small ruminants and cattle. Short fallow periods on the alley farms also allow the satisfaction of farmers' requirements for fodder, stakes and firewood. The practice of fallowing is highly recommended in areas where farmers cannot afford the use of chemical inputs. To augment soil fertility improvement during the fallow period, farmers can also plant nitrogen-fixing cover crops in the alleys.

One additional important effect of short fallows is for suppressing noxious and problem weeds such as *Imperata cyclindrica* and other grasses. Moreover, alley farming provides a means to recover cropland that has been taken over by problem weeds. If the hedgerows are allowed to grow to close their canopies, most troublesome weeds will be shaded out. *Dactyladenia barteri* and *G. sepium* have proved to be particularly effective for this purpose. However, long-term fallowing of the alley farms can become a problem with certain species such as *L. leucocephala*, in which volunteer seedlings can pose a major weed problem. Volunteer *L. leucocephala* seedlings growing in the alleys therefore need to be controlled early, before they develop an extensive root system.

5 Benefits for crop production

In this chapter the potential benefits and limitations of alley farming for crop production as compared to mono-cropping systems is discussed. In contrast to mono-crop systems, intercropping woody species and crops in alley farming can provide higher and year-round biomass production. An important aspect of alley farming is its environmental impact and the stabilization of crop production, especially on sloping lands.

Biomass production and effects on soil properties

It is known that the amount of soil organic matter in surface soil declines rapidly with cultivation, and applied organic matter also decomposes rapidly in the humid and subhumid tropics. To retain the productivity of the rainfed areas, there is a need to incorporate production systems that can provide a high amount as well as year-round supply of organic matter. This can be met with alley farming, where the combination of woody species and crops allows the year-round production of plant biomass. Because of their deeper root system, woody species are able to extract soil moisture from deeper soil layers beyond the reach of annual crops. This enables them to grow or be coppiced even during the dry season. Since the perennial woody hedgerow component of the system can or is allowed to produce biomass during the dry or off seasons when there are no crops, higher plant biomass production per unit land area is feasible compared to sole cropping, as illustrated in Table 5.1. The annual pruning biomass produced by *Gliricidia* and *Leucaena* hedgerows as shown in Table 5.1, is more than adequate to meet the annual organic matter requirement for sustaining the productivity of alfisol, as discusssed in Chapter 3. There are reported instances where alley farming did not perform well. In a number of cases this was due to the poor performance of the hedgerows, resulting from the use of unsuitable species and/or planting at very

Table 5.1 Dry pruning biomass yield (tons/ha/year) of *Gliricidia sepium* and *Leucaena leucocephala* hedgerows planted at 4 m inter-row and 0.25 intra-row spacings, and the alleys were sequentially cropped with maize and cowpea, grown on an alfisol in the sixth cropping year of a long-term trial. The site has bimodal rainfall distribution

Parameters	*Gliricidia*	*Leucaena*	Control*
Main season			
Prunings**	3.69	5.37	–
Wood	2.47	3.41	–
Maize	5.39	5.77	2.63
Minor season			
Prunings	2.10	2.70	–
Wood	2.08	2.21	–
Cowpea	1.14	1.20	1.03
Plot total	16.87	20.66	3.66

* No hedgerows.

** Leaves + green branches.

poor site conditions. The result was very low hedgerow biomass production. Under these circumstances the alley farming system will be ineffective for maintaining soil productivity.

In addition to the above ground biomass production, plant roots, particularly roots of woody species, can also contribute substantial amounts of organic material to the soil. The roots of woody species can make up about 20–30 per cent of total plant biomass. With woody species there is also the process of year-round annual root turnover, particularly of fine roots, that can serve as a source of soil organic matter and nutrients. However, data on these contributions from the roots of woody species is lacking, because of measurement difficulties.

The benefit of alley farming to maintain a higher surface soil organic matter level than the control (no hedgerow) plot is shown in Table 5.2. In this trial, following five years of continuous alley farming, the microsite under the hedgerows maintained the same soil organic matter level that was observed at the start of the experiment, while in the control plot the level declined to less than half. Mulching and better micro-climate conditions with alley farming also stimulated higher faunal activity such as earthworms, that increased the soil biological tillage. This resulted in higher soil porosity and lower soil bulk density in the alley-farmed plots than in the control (no hedgerow) plots (Table 5.3). Soils with a higher amount of soil pores and lower bulk density will allow: 1) better annual crop root growth than in compacted soils with high soil bulk density that can restrict root growth, and 2) better soil moisture infiltration rate. Increased wormcast activity also resulted in a higher amount of mixing of the surface soil (Table 5.2). The amount of wormcast produced in this study were 117 in the hedgerows, 24 in the alleys and 28 in the control in tons/ha. As wormcasts retain a higher nutrient content than the surface soil, they also help to increase and retain plant nutrients in the soil.

The higher biomass production with alley farming as compared to crop production only, is environmentally also desirable. The presence of woody species contributes to a higher carbon sink, and

Table 5.2 Chemical properties of surface (0–15 cm) soil of an alfisol and earthworm casts after five years of alley farming with *Leucaena leucocephala* hedgerows in south-western Nigeria

Chemical parameter	Alley-cropped plots Hedgerows	Alleys	Control (no hedgerows)
pH-H_2O	5.3 (5.8)	5.1 (6.0)	5.3 (6.1)
Organic C (%)*	1.23 (3.88)	0.94 (3.11)	0.59 (1.78)
Total N (%)	(0.34)	(0.30)	(0.17)
Exchangeable cations (meq/100 g)			
K	0.39 (0.93)	0.58 (0.88)	0.52 (0.62)
Ca	2.94 (8.45)	2.47 (5.98)	2.73 (4.08)
Mg	0.92 (1.73)	0.74 (1.22)	0.89 (0.96)

* Soil Organic C level at the start of the experiment was 1.21% in alley-farmed plot and 1.05% in control plot. Figures between brackets are for corresponding *Hyperiodilus africanus* earthworm casts.

Table 5.3 Effect of hedgerow species on soil bulk density in the 0-5 cm depth and water infiltration rate of an alfisol in alley-farmed plots in south-western Nigeria

Hedgerow species	Bulk density (Mg/m^3)	Infiltration rate at 2 h (mm/min)
A. cordifolia	1.37	1.96
D. barteri	1.34	2.87
G. sepium	1.33	2.53
L. leucocephala	1.31	1.59
Control (no hedgerow)	1.41	0.79

thereby removes more carbon dioxide from the atmosphere, contributing to the reduction of the greenhouse effect.

The mulching and green manuring effects of hedgerow prunings on soil properties and as a source of plant nutrients depend on the quantity and quality of the prunings added. Low-quality prunings, such as *D. barteri* prunings that have a high C/N ratio of 28, decomposes slowly and is a good source of mulch (Fig 5.1). Applied as mulch in the humid zone, in three months only half the prunings decompose. These low-quality mulch materials have the additional advantage as a slow nutrient source and also for building up soil organic matter content. *Leucaena leucocephala* prunings, because of their high quality with a low C/N ratio of 13, decompose faster with a half-life of about 20 days. High-quality mulches contribute more to soil nutrient level but less to soil organic matter content. The intended use of prunings in some instances will determine the choice of hedgerow species. If the aim is to obtain a long-duration mulch, for example for plantain and banana (*Musa* spp.) production, two crops which have shallow roots and require constant mulch cover to sustain root growth, then hedgerows that produce low-quality mulches such as *D. barteri* or natural vegetation are preferred.

Soil conservation

An important advantage of alley cropping as compared to a monocropping system is for soil conservation, especially on sloping lands.

Fig 5.1 Prunings from *Dactyladenia barteri* hedgerows make a suitable source of mulch for a maize crop.

Table 5.4 The effect of soil conservation practices on soil loss (tons/ha) on sloping lands in East and South-east Asia (IBSRAM,1993)*

Site	Slope	Treatment	Soil loss
China	30–46	Farmers' practice	70.9**
		Alley farming	28.6**
Indonesia	8–18	Farmers' practice	56.6
		Alley farming	10.3
Philippines	15–25	Farmers' practice	57.7**
		Alley farming (low input)	1.1**
		Alley farming (high input)	0.6**
		Banana hedgerow	1.1**
Thailand	20–50	Farmers' practice	146.4
		Alley farming	48.2
		Bahia grass strips	29.6
		Hillside ditches	9.8
Vietnam	5–7	Farmers' practice	2.2
		Alley farming (low input)	1.1
		Alley farming (high input)	1.1

* Adapted from International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand, report highlights 1993.

** Mean of two years, others mean of three years.

The combined effects of: 1) better surface soil cover with the intercropping of woody species and crops, 2) year-round surface soil cover by the woody species, 3) mulch cover from plant residue and hedgerow prunings, and 4) the barrier effect of hedgerows, can increase soil protection against soil erosion. This is well illustrated by the results observed in East and South-east Asia as shown in Table 5.4. This beneficial effect of alley farming for erosion control has been widely adopted by farmers in many Asian, African and Caribbean countries, for example in Indonesia, the Philippines, Kenya, Rwanda, Kenya and Uganda. This principle is widely promoted and has been adopted in recent development projects in a number of countries such as in Haiti, where over 140 km of hedgerows were planted for conservation purposes in 1988. Where hedgerows have been planted they have contributed significantly to increased slope stability and improved microsite soil enrichment between the hedgerows.

Even on relatively flat land the effect of hedgerows on soil conservation can be observed, as shown in Fig 5.2. The presence of

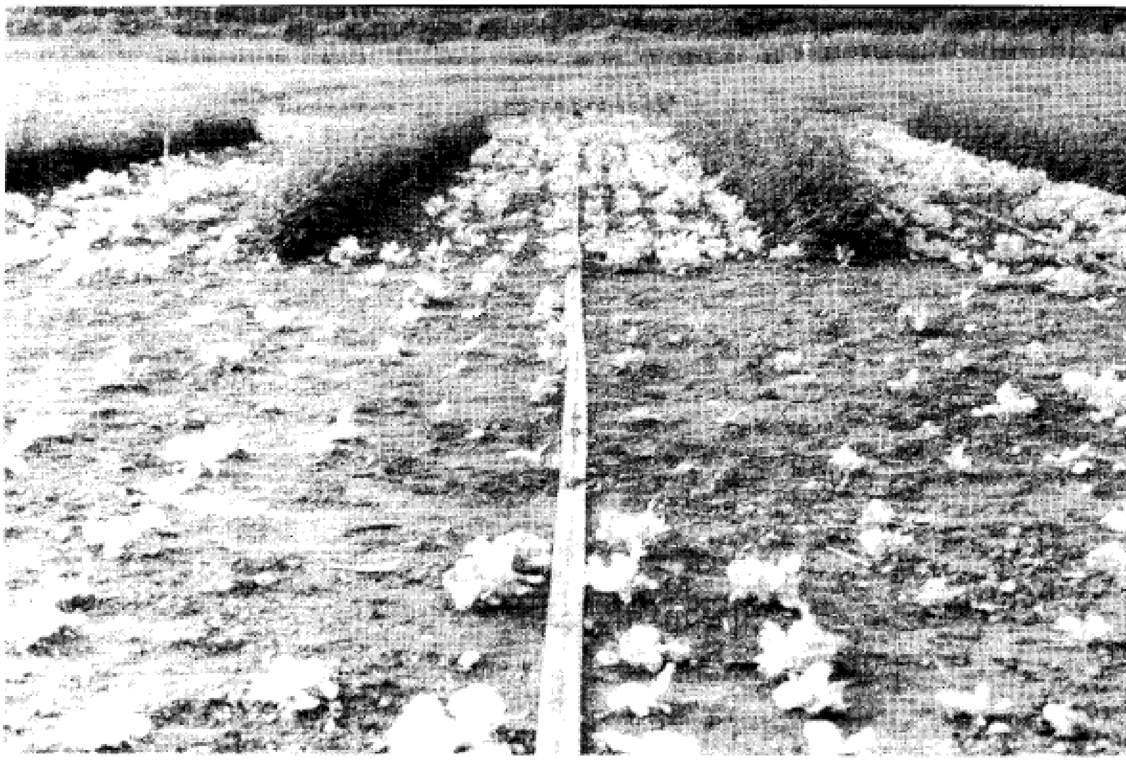


Fig 5.2 Growth of patsai (*Brasica chinensis*) with and without alley farming with *Leucaena leucocephala* hedgerows. Eroded control plot with no hedgerows in the foreground showed poor stand and growth of crop.

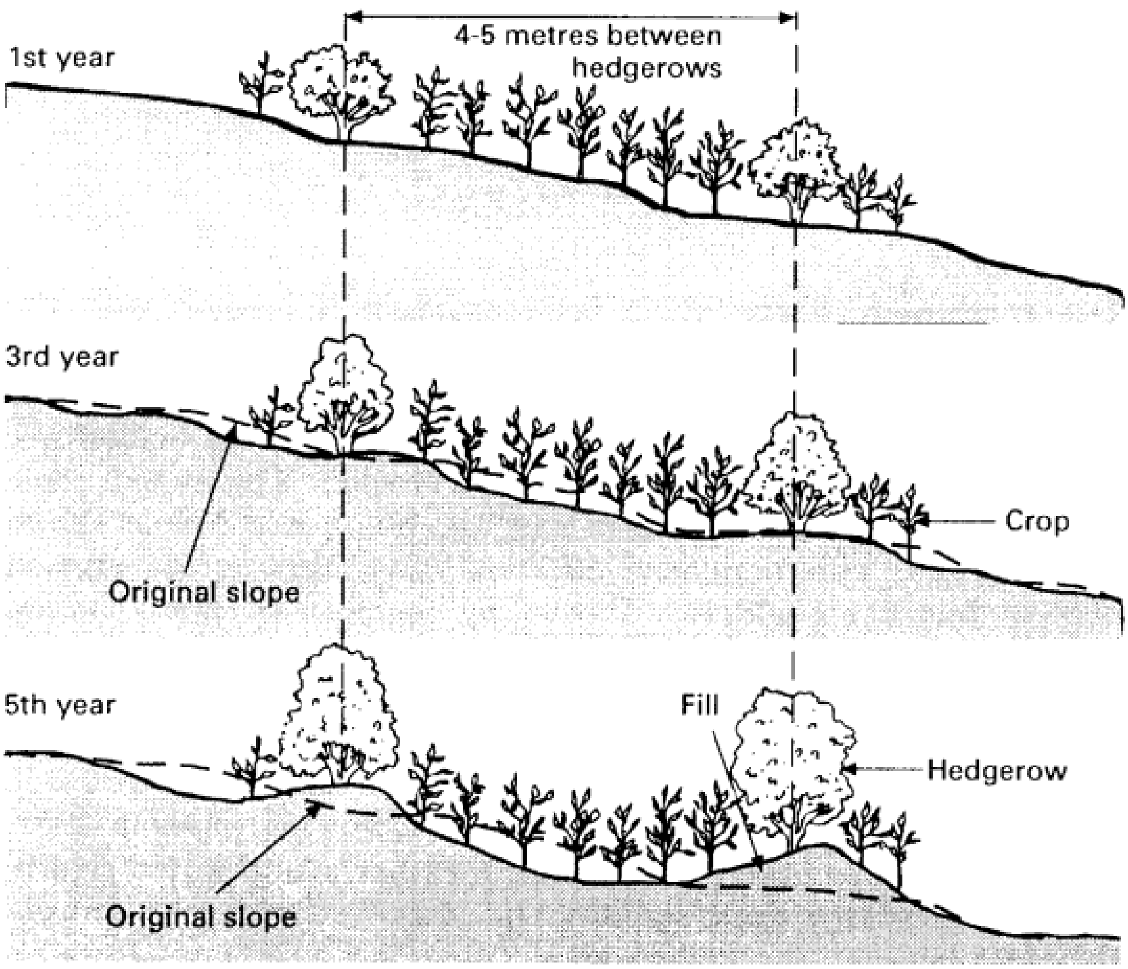


Fig 5.3 Minibench terracing resulting from contour hedgerow planting.

L. leucocephala hedgerows and the addition of prunings reduced runoff and soil erosion and resulted in higher plant stand and better growth and yield of direct seeded patsai (*Brasica chinensis*).

Contour hedgerows are known to be a very effective and low-cost method for the biological terracing of sloping land. As illustrated in Fig 5.3, alley farming and tillage and the resulting across-terrace down-slope movement of the soil will create natural or minibench terraces in a short period. Although these terraces may create plot heterogeneity, resulting in better crop growth in the lower than the upper part of the terrace due to the soil movement, they will add further stability to the slope. The effect of soil heterogeneity can be reduced with the application of fertilizers and organic manures. To further increase the stability of the slopes farmers can practise ridging on the terraces.

The hedgerows can also serve as shelter belts or windbreaks, especially in the dry savannah or semi-arid zones, to control wind erosion.

Weed control

It is well known that in the forest the soil carries a high seed load. Because of this, weeds in the forest are mostly pioneer species that colonize a site after the canopy is opened and light provided. A similar situation also occurs in cultivated plots. Since weeds are usually intolerant of shade, an effective way of controlling them is through canopy closure and shading of the undergrowth. Mulching is therefore an effective way of reducing weed incidence and the effect is more apparent with low-quality mulches that decompose slowly. Mulching confers benefits in terms of reducing weed competition between crops and weeds and also in reducing labour requirements for weeding. Uncut hedgerows during fallow periods also suppress weed establishment. These fallow periods can also be used to suppress the growth of weeds that are difficult to control. Uncut *Gliricidia sepium* hedges can be used effectively in suppressing the growth of a well-established field of speargrass, mainly due to their shading effect.

Long-term observations have also shown that in addition to weed suppression, alley farming brings about a change in the weed species in the plots. These changes, however, vary with the hedgerow species. With *L. leucocephala* hedgerows fallowing tends to increase the establishment of *L. leucocephala* volunteers. Therefore, for mechanized alley farming using *L. leucocephala* hedgerows it is necessary to prune the hedgerows periodically to avoid the trees from seeding. In general with alley cropping, there is an increase in shade-tolerant broadleaf weed species at the expense of other species. With nitrogen-fixing legume species (such as *L. leucocephala* and *G. sepium*) the broadleaf weed species that emerge are found to be less competitive to the crops, and at the same time also easier to control than the original grass weed species. This greatly reduces the labour requirements and cost for managing the alley farmed plots.

Nutrient contribution

Nitrogen and phosphorus are most frequently the limiting nutrients in tropical soils. Nitrogen response usually occurs first, followed by that of phosphorus after a few years of cultivation. Potassium is generally not limiting, except after many years of intensive cultivation. Sulphur deficiency is more common in the subhumid zone, while micronutrient problems occur locally. These nutrients in the soil are derived from weathering parent materials, except nitrogen which is also derived from symbiotic and non-symbiotic nitrogen fixation and deposition from the rain. To sustain crop production, nutrients removed with the harvest have to be replenished. The inclusion of nitrogen-fixing woody species in the production system such as in alley farming can partially supply nitrogen. The remainder of the nutrient requirement has, however, to be added from other organic or fertilizer sources. Woody species growing in association with mycorrhizal fungi are also known to better utilize less available phosphorus levels in the soil, as discussed earlier.

Biological nitrogen fixation in legumes occurs through the symbiosis of plant with nitrogen-fixing bacteria that live in root nodules. Tropical woody legumes may nodulate with two types of *Rhizobium*: fast-growing strains which belong to the genus *Rhizobium* (*senso stricto*) and slow-growing strains designated as *Bradyrhizobium*. Nitrogen-fixing trees with potential for use in alley farming and other agroforestry systems can be divided into three groups as follows:

1 Those that nodulate with strains of *Rhizobium* (*senso stricto*). This group includes *Acacia nilotica, Acacia senegal, L. leucocephala, Sesbania grandiflóra, S. punctata*, and other *Sesbania* spp.
2 Those that nodulate with *Bradyrhizobium*. This group includes *Acacia holocerica, A. mearnsii, Faidherbia albida* and *Tephrosia vogelii*.
3 Those that nodulate with either *Rhizobium* or *Bradyrhizobium*. This group includes *Calliandra calothyrsus* and *Gliricidia sepium*.

The first group of plants is considered specific and has a narrower symbiotic range than those in the other two groups. In the absence of a compatible fast growing strain of *Rhizobium*, the first group requires inoculation with the strain. On the other hand, most tropical soils harbour the typical *Bradyrhizobium* and inoculation is not needed.

Despite the recognized potential of nitrogen-fixing trees in alley farming, there is still a lack of knowledge on the amount of nitrogen fixed and the effect of tree management on nitrogen fixation. The percentage of total nitrogen in plants, derived from biological fixation, varies considerably among species and provenances. With the exception of a few species, such as *L. leucocephala* and *G. sepium*, the actual nitrogen-fixation capacity of most of the nitrogen-fixing trees is not precisely known. It can range from as high as 65 per cent in *G. sepium* and *L. leucocephala* to as low as 20 per cent in *F. albida*. Based on the limited data available on the amount of actual nitrogen fixation, three groups of nitrogen-fixing trees are recognized as follows:

1 High nitrogen-fixing trees, fixing 100–300 kg N/ha/year or more. This includes *Albizia lebbeck, Acacia mangium, C. calothyrsus, G. sepium* and *L. leucocephala*.
2 Intermediate nitrogen-fixing trees, fixing 60–120 kg N/ha/year. This includes *Albizia lebbeck*.
3 Low nitrogen-fixing trees, fixing less than 20 kg N/ha/year. This includes *A. senegal, F. albida* and *Sesbania sesban*.

The amount of nitrogen fixation can be affected by various soil and management factors. Soil moisture deficit, soil acidity and phosphorus deficiency all reduce nitrogen fixation. As phosphorus deficiency is common in soils in the tropics, this has to be corrected to get the full benefit from nitrogen fixation. Frequent and heavy pruning of hedgerows can cause considerable dying of roots and shedding of nodules and so reduce nitrogen fixation. Although information is still rather sparse, available data show that moderate pruning can stimulate nitrogen fixation, while the addition of large quantities of nitrogen-rich prunings may depress nitrogen fixation by the hedgerows.

With the hedgerow prunings large quantities of nutrients are added to the plots (Table 5.5) during the cropping season. The amount of nutrient yield in the prunings corresponds closely to pruning biomass, and varies with hedgerow species and management practices. Despite the high nitrogen yield from the prunings, however, the effective nitrogen contribution from the prunings to the associated crops is known to be low, ranging from 20 to 30 per cent.

Table 5.5 Above-ground nutrient cycling in alley farming with *Gliricidia sepium* and *Leucaena leucocephala* hedgerows on an alfisol in the sixth cropping year. (Hedgerows planted at 4 m inter-row and 0.25 m intra-row spacings. Alleys were sequentially cropped with maize in main season and with cowpea in minor season. Plots received 12P and 25K in kg/ha).

Treatments	Amount of nutrients (kg/ha)				
	N	P	K	Ca	Mg
A *Alley farmed with* G. sepium					
Prunings					
Biomass*	225.6	14.5	160.2	71.8	25.3
Wood	45.9	2.3	39.6	44.1	5.5
Total	271.5	16.8	199.8	115.9	30.8
Crops					
Maize grain	49.4	24.3	29.2	1.6	5.1
Maize stover	24.2	3.2	46.7	6.2	3.4
Cowpea seed	28.3	3.9	14.2	0.5	0.7
Cowpea plant	11.9	1.8	14.3	2.6	0.7
Total	113.8	33.2	104.4	10.9	9.9
Plot total	385.3	50.0	304.2	126.8	40.7
B *Alley farmed with* L. leucocephala					
Prunings					
Biomass*	300.6	19.3	156.4	67.0	35.9
Wood	28.6	1.7	33.1	18.0	3.9
Total	329.2	21.0	189.5	85.0	39.8
Crops					
Maize grain	49.8	22.4	24.5	1.2	5.1
Maize stover	20.0	2.9	47.7	4.8	3.5
Cowpea seed	22.5	2.6	9.5	0.3	0.5
Cowpea plant	12.3	1.8	14.7	3.0	1.0
Total	114.6	29.7	96.4	9.3	10.1
Plot total	443.8	50.7	285.9	94.3	49.9
C *Control* (no hedgerow)					
Maize grain	19.3	10.5	12.9	0.4	2.9
Maize stover	10.2	1.3	20.8	3.4	2.0
Cowpea seed	25.0	4.5	17.2	0.5	0.7
Cowpea plant	9.2	0.9	8.1	2.6	1.0
Plot total	63.7	17.2	59.0	6.9	6.6

* Includes leaves + green branches.

This low nitrogen utilization is attributed to various factors such as:

- Nitrogen loss due to leaching, denitrification, and volatilization.
- Nitrogen reabsorption by the hedgerows.
- Nitrogen incorporation in soil organic fractions.
- Poor synchronization of nitrogen release from pruning decomposition with crop demand.
- Lower use efficiency of nitrogen from prunings when applied as a mulch rather than when incorporated as green manure.

The ability of plants to respond to an application of prunings varies with age (a similar pattern of response is also seen with the application of inorganic fertilizer). Between maize planting and harvest times, trees need to be pruned three times to prevent shading (Table 4.5, page 42). The first application of prunings – at maize sowing time – is known to have a greater effect on maize growth and yield than later prunings (Fig 5.4). By the time the third pruning is applied, the maize plant is almost too mature to benefit.

Older materials and the drying of prunings are also known to lower rates of decomposition and nitrogen release. In addition, mixing high-quality prunings (from e.g. *L. leucocephala*) with low-quality prunings (from e.g., *D. barteri*) can slow the decomposition rate of the high-quality prunings. This can be used as a management option to reduce nitrogen loss. In alley farming with *G. sepium* and *L. leucocephala* the nitrogen contribution to the associated maize

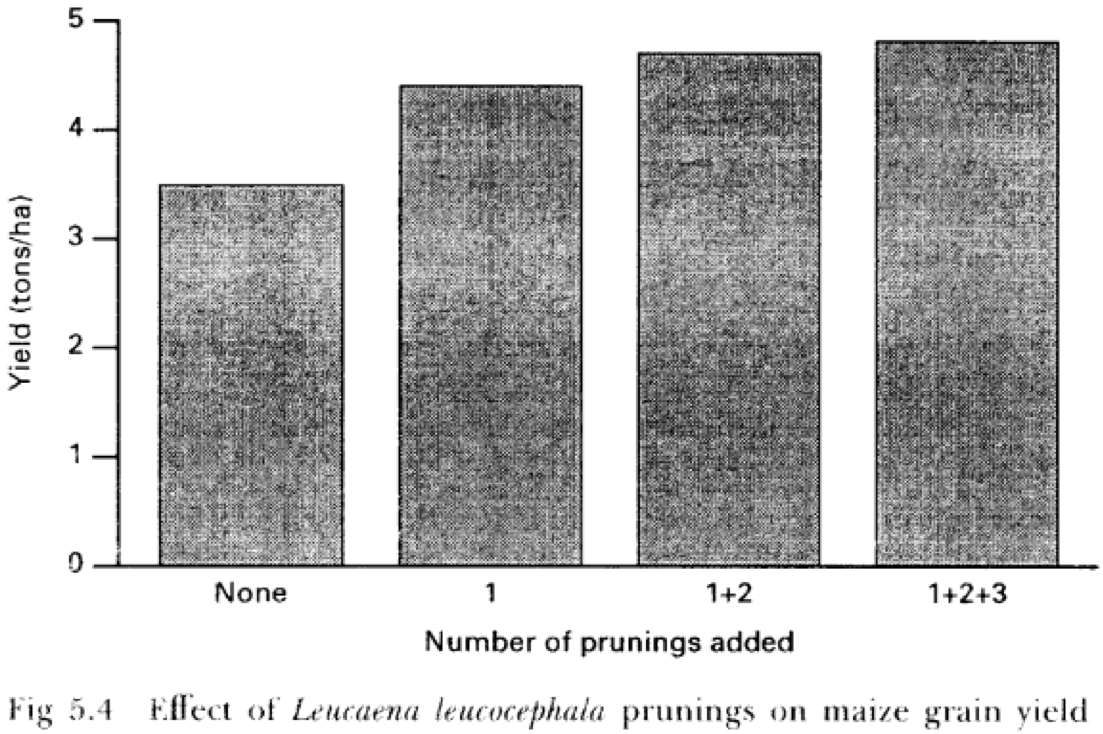


Fig 5.4 Effect of *Leucaena leucocephala* prunings on maize grain yield over two cropping seasons during 1988 in the humid zone of southwestern Nigeria.

crop in one season may range from 30 to 60 kg N/ha. Further research is still underway to seek management options that can increase nitrogen use efficiency from hedgerow prunings. In addition to the prunings, annual root turnover from woody species can contribute a substantial amount of nitrogen to the production systems. Precise data on the total amount of nitrogen contribution from roots are still unavailable. Besides nitrogen, hedgerow prunings also contain large quantities of other nutrients, particularly potassium, calcium and magnesium.

The advantage of alley farming to mono-cropping is that the system, due to the presence of the woody hedgerows, can cycle higher quantities of nutrients, as illustrated in Table 5.5. This higher ability of the woody species to recycle more nutrients is attributed to: 1) their deeper rooting system that can explore a larger soil volume, and 2) their longer growing period compared to the crops. Hedgerows of non-nitrogen-fixing legumes such as *Senna siamea* and non-legumes such as *D. barteri* can also cycle substantial amounts of nutrients with the prunings. Using these species will, however, require a larger level of nitrogen input to sustain long-term crop production. *Senna siamea* hedgerows, because of its extensive and shallow rooting system, is also known to compete more for nutrients with the associated crop. The depressing effect of unpruned *S. siamea* hedgerows on the crops can extend over 6 m distance away from the plant base.

Crop production

There is increasing information available on the effect of alley farming using various hedgerow species on crop production from different parts of the tropics. The alley farming technique has been tested with a number of crops. These include cereals (maize, upland rice), grain legumes (cowpea, soybean, Phaseolus bean), root and tuber crops (cassava, yam, cocoyam and sweet potato), plantain (Fig 5.5), banana and vegetable crops grown in mono- or inter-cropping systems. Fig 5.6 shows an alley-farmed field of intercropped maize and cassava with *Leucaena* hedgerows.

The impact of alley farming on crop performance and yield have been variable and differ greatly in different agroecological zones. Results vary with crops, hedgerow species and management practices. On high base status soils, with few exceptions, positive effects were reported for (mono- or intercropped) maize alley farmed with *Gliricidia* and *Leucaena*. Investigations at Maseno in western Kenya showed that the yield of alley-farmed maize was higher in

Fig 5.5 A farmer alley farming a plot of plantain (*Musa* spp.) with *Leucaena leucocephala* hedgerows on an alfisol at Alabata village in south-western Nigeria.

association with *Gliricidia* and *Leucaena* than with *Calliandra*, *Sesbania* and *Senna*. Positive effects of alley farming were reported for plantain and vegetable crops. However, results of alley farming with cowpea, soybean and groundnuts in West Africa have shown no or small yield increases. In contrast, investigations in Costa Rica showed consistent increases of yield of *Phaseolus* beans alley farmed with *Erythrina poeppigiana*. Alley farming with cassava and other root and tuber crops also gave mixed results. The observed lower cassava tuber yield with alley farming is mainly related to hedgerow management problems, as will be further discussed in this section.

An investigation of alley farming of upland rice with various

Fig 5.6 An alley-farmed field of intercropped maize and cassava with *Leucaena leucocephala* hedgerows in south-western Nigeria.

hedgerow species on acid soils in South-east Asia and Latin America also gave mixed results. Observations in Peru gave negative results, even with additional chemical inputs, mainly due to root competition. While observations on a farmer's field in Thailand gave a positive effect on rice yield (Table 5.6), there was no yield effect in fields in Indonesia. The results of an investigation in southern Philippines showed that upland rice yield was affected by hedgerow species. Competition was higher with grass (*Vertiver* and *Panicum)* hedgerows than with leguminous forage (*Stylosanthes*) and woody species or natural vegetation hedgerows. In one alley farming trial with *Gliricidia sepium*, the yield of upland rice was increased by 132 per cent.

In alley farming, crops and woody species are grown in close association, consequently the potential for below- and above-ground growth resources competition exists between them. Minimizing negative competition and maximizing crop and tree productivity is the main goal of hedgerow management options. The following are some commonly observed instances of competition:

1 *Light competition* takes place above ground. Light competition can be a serious problem in the humid zone, where solar radiation is low during the cropping period due to overcast skies. In alley farming, crops growing adjacent to the hedgerows usually

Table 5.6 Upland rice and maize yields (kg/ha) in farmers' fields using farmers' practice and alley farming without fertilizer application in South-east Asia*

Site	Crop	1989	1990	1991	1992	1993
Indonesia						
Farmers' practice	Rice	—	900	50	58	0
Alley farming	Rice	—	400	67	120	100
Philippines						
Farmers' practice	Maize	98	2102	341	861	1825
Alley farming	Maize	325	3057	978	1514	3600
Thailand						
Farmers' practice	Rice	1100	486	1095	566	535
Alley farming	Rice	1150	1396	1156	136	611

* Adapted from Adisak Sajjapongse and J. K. Syers, 1995, 'Tangible outcomes and impacts from the ASIALAND management of sloping lands network', in *Proceedings International workshop on conservation farming for sloping uplands in southeast Asia: Challenges, opportunities and prospects*, pp. 3–14. Proceedings no. 14, IBSRAM, Bangkok, Thailand.

show less growth and lower yield compared to those growing further away, due to hedgerow shading. The amount of shading depends on:

- Hedgerow species. Fast-growing species tend to cause more shading than slow-growing species.
- Inter-hedgerow spacing, as shading increases with narrower alleys.
- Hedgerow pruning height and intensity. Higher pruning heights will require more frequent prunings. For cowpea and maize production a hedgerow pruning height of 0.25–0.60 m is recommended (see Table 4.5, page 42). Frequency of pruning has to be adjusted to the hedgerow species and the associated crop grown. Slow-growing hedgerows will require less frequent pruning.

In traditional systems, where food crops are normally grown as intercrops, the shading effect can be very complex. For example, in a maize/cassava intercropping system the effect of hedgerow shading is more pronounced on the cassava crop than on the maize crop because cassava initially grows slowly. Delayed prunings of the hedgerows, as often observed in farmers' fields, can result in the delay of root bulking of the cassava plant. This will result in a lower cassava yield if harvested at the usual harvest time. This can be compensated for by delaying the harvest date. The shading effect of the hedgerows, on the other hand, has little effect on the performance of shade-tolerant species such as cocoyam (*Colocasia* or *Xanthosoma* spp.) (Fig 5.7). In general the shading effect can be minimized by timely pruning of the hedgerows.

Fig 5.7 Alley farming of cocoyam (*Xanthosoma sagittifolium*) with *Leucaena leucocephala* at Ikenne in south-western Nigeria.

2 *Moisture competition* occurs below ground and is a problem in areas with a soil-moisture deficit during the cropping season, such as in the dry savannah or semi-arid zone. Under conditions of moisture stress, the hedgerow species also produce a low amount of biomass which has a limited effect if applied as prunings to the associated crops. This often limits the benefits of alley farming in the semi-arid tropics. Moisture competition varies with hedgerow species and inter-hedgerow spacing and is aggravated by a narrow alley width. Results of trials conducted in the semi-arid region have shown that moisture competition attributed to *L. leucocephala* hedgerows can extend to a distance of 5 m. The best way to minimize moisture competition is to increase the alley width (see Table 4.4, page 39).

3 *Nutrient competition* commonly occurs in nutrient-poor and acid oxisols and ultisols in the humid region. In these soils, crop and tree roots tend to concentrate in the relatively fertile surface soil, with fewer roots growing in the poorer lower soil horizons. The addition of lime, and especially phosphorus, can improve the performance of crops and woody species on these acid soils. However, roots of some well-adapted indigenous woody species do have deep root systems. On these soils, species such as *G. sepium* and *L. leucocephala* grow poorly and have shallow and poorly-developed root systems, while well-adapted species such as *D. barteri* grow well and have a deep root system. On these nutrient-poor and acid soils, root competition for nutrients between crops and trees can be very intense, resulting in poor growth of the alley crops, especially of plants growing near the hedgerows. The root competition in some instances can be reduced by tillage or by using wide alleys.

In traditional low-intensity cropping systems, farmers rectify these nutrient deficiencies by applying plant ash and household refuse. This is, however, inadequate with intensive cropping. Correction of nutrient deficiency, particularly that of phosphorus which is commonly deficient, and liming of acid soils are needed to improve crop as well as tree growth. The below-ground resource competition between hedgerows and crops is a less serious problem on the alfisols and associated soils, where soil moisture is not limiting during the cropping period. This is also the zone where alley farming has the highest potential for sustaining crop production with the use of the appropriate hedgerow species, as illustrated by the example shown in Fig 5.8. The long-term yield data showed that systems with *L. leucocephala* hedgerows can sustain the maize yield with basal dressings of phosphorus, as the soil phosphorus level is

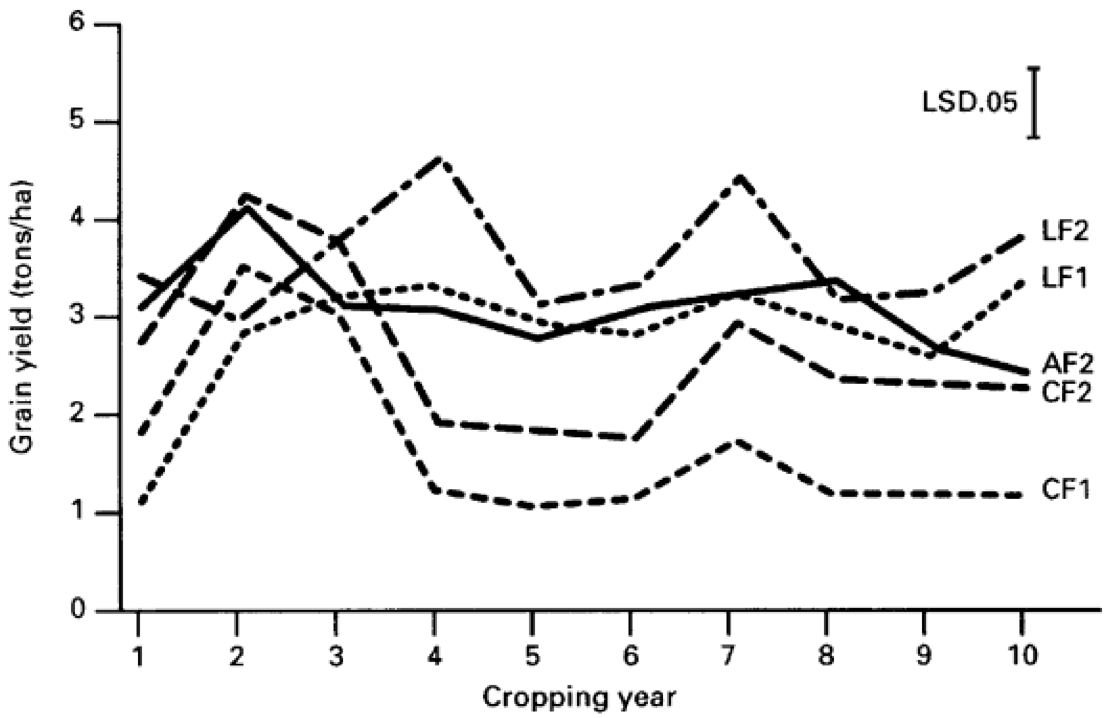


Fig 5.8 Long-term effect of alley farming with *Dactyladenia barteri* (A) and *Leucaena leucocephala* (L) compared to control (no hedgerow) (C) on grain yield of maize grown on a degraded alfisol in the humid zone of south-western Nigeria. (Fertilizer rate year 1, F_1 = 0, F_2 = 90-40-40; year 2–3, F_1 = 45-20-20, F_2 = 90-40-40; year 4–10, F_1 = 0-12-25, F_2 = 45-12-25 as N-P-K in kg/ha; LSD.05 only for year 10).

inadequate and the hedgerows cannot cycle an adequate amount of phosphorus to meet the crop requirement. However, with a low rate of nitrogen application (45 kg N/ha), a reasonably high maize yield can be sustained. In the system with *D. barteri* hedgerows, promising results were observed during the first few years, but yield declined with time. This is mainly due to the fact that *D. barteri* does not contribute nitrogen to the system. Higher nitrogen input is therefore required when using non-nitrogen-fixing species to sustain cereal crop yield.

The nutrient contribution from the hedgerows will be less if there is an offtake of prunings from the plots, for example, if part of the prunings are removed or used as browse in a cut and carry system (Fig 5.9). The results of an investigation at Muguga in the Kenyan highlands and at Lilongwe, Malawi, also confirmed the lower crop yield with the removal of the hedgerow prunings. Continuous removal of large amounts of prunings from the plots may result in nutrient depletion and a decline in soil productivity. This can be offset by only partial removal of browse during the off season and compensation of nutrient losses by the addition of fertilizer or by returning the animal manure produced.

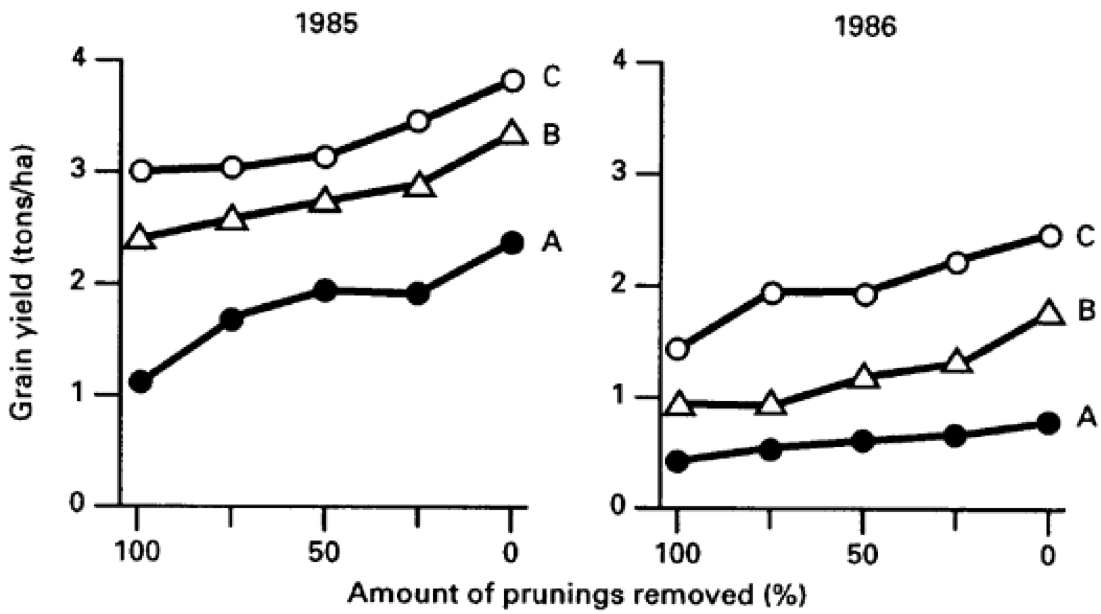


Fig 5.9 Grain yield of maize alley farmed with *Gliricidia sepium* on a sandy soil at Ibadan in south-western Nigeria affected by the removal of hedgerow prunings and nitrogen application. (N rate: 0 (A), 40 (B) and 80 (C) kg N/ha).

Properly-managed alley farming can provide the following benefits for crop production:

- High amount of plant biomass production and sustenance of high soil organic matter level.
- Inducement of increased activities of soil fauna.
- Maintenance of better soil physical conditions.
- Weed suppression.
- Soil conservation.
- Higher amount of nutrient cycling.
- Nitrogen with inclusion of nitrogen-fixing leguminous species.
- Sustenance of crop production using lower nitrogen input.

It should be noted, however, that the maintenance of soil and crop productivity is only feasible with continuous cropping if the reduction in nutrients is corrected. On acid soils liming and phosphorus application is recommended to increase biomass production. In areas where constraints in growth resources limit the production of the critical amount of biomass required to maintain soil productivity as observed in the dry areas, due to soil moisture limitations, the alley farming system is also less effective.

6 Alley farming with livestock

Alley farming has been viewed predominantly as a technology for crop farmers. However, a large proportion of smallholder farmers also keep livestock, which can also benefit from an alley farming system. Climate, especially rainfall, controls tree and crop production. As rainfall increases, agricultural potential and human carrying capacity of the land rises. Livestock production is the most important component in the agriculture sector in dry areas but crop production becomes increasingly important as rainfall increases. In pastoral societies, virtually all of the income generated from agriculture comes from livestock, whereas in the humid zone livestock may only contribute 5 per cent of agricultural income. However, agroclimatic conditions for the cultivation of animal feed are highest where crop production has the best biological and economic potential.

The function of alley farming, from a livestock viewpoint, is for the provision of animal feed. Foliage from leguminous trees is highly nutritious, being richer in protein than most other available forages, and can act as a high-quality addition to a traditional diet. A livestock focus for alley farming is likely to be more attractive to farmers where livestock contribute significantly to farm income, where high-quality feed is needed for their animals and where the potential for forage production is high. The first and last conditions are usually incompatible under present smallholder farming systems. The best compromise can be found on mixed crop-livestock farms in the sub-humid zone. Here rainfall of 1000–1500 mm promotes attractive growth from forages, and livestock can contribute 20 per cent and more towards farm income. The exceptional case, meeting all three conditions, is smallholder dairy production in the highlands close to urban markets, where alley farming allows intensification of production. In other situations, livestock productivity may increase from the adoption of alley farming, but *a priori* there is no reason to expect the technology to appeal specifically because of its benefits to livestock.

This chapter considers the needs of ruminant livestock for nutrients, and looks at how forages grown in an alley-farming system can contribute. The impact of these forages on production, together with the market value of the product, will determine the financial return to the farmer. We will consider the factors that determine whether the farmer should be advised to direct tree biomass output to livestock or to mulch for food crops, and the social factors that may outweigh our simple cash calculations. The concluding section lays out the conditions necessary before farmers should be encouraged to adopt alley farming for livestock.

Animal needs

Ruminant livestock in developing countries are kept for milk and meat production, and as a means of minimizing risk in an unfavourable climate. Livestock act as a savings account, to be sold for cash to purchase grain if the rains and crops fail or to meet other financial needs. For most small-scale farmers, the first priority is keeping animals alive, with the production of meat and milk in mixed farming systems being of secondary importance. Health and nutrition interact, so a well-fed animal will be more resistant to disease. Body-weight gains are made when feed is plentiful and nutrient intake allows a surplus over and above maintenance needs. Surplus nutrients are directed towards growth, fattening, foetal development, or milk production.

Stage 1: Feed selection and intake

Livestock have particular preferences for feed – cattle prefer grass, goats prefer browse – and a remarkable ability to select young and nutritious portions from the forage on offer. A number of factors influence palatability, especially for grazing animals. Many browse species contain more nutrients than does grass during the dry season, but they also contain tannins which have an unpleasant astringent taste which can limit intake. Stall-fed animals on smallholder farms are generally not offered enough feed for selection to be effective, and eat all that the farmer provides. Even when sufficient feed is offered, intake is depressed when the protein content of the diet falls below 6 per cent. In the dry season the overall protein content of tropical grasses may be as low as 2–3 per cent overall, but because of the selection of leaf rather than stem, the diet of grazing animals may still contain around 4–5 per cent crude protein. If a high-protein supplement is available (e.g. legume forage or oilseed cake), intake of the basic diet is stimulated, and better use is made of the ingested nutrients.

Intake can be predicted for grasses based on digestibility and/or chemical composition, but intake of tree legume forage cannot be accurately predicted in the same way. Leaf size and the content of polyphenolic compounds (see below) are additional factors to be considered.

Stage 2: Digestion

Digestion by ruminant animals is dependent initially on the action of rumen microbes. Much of the fibre and protein in feed is first broken down by the microbes into simpler compounds. The breakdown products of fibre and other carbohydrates in the rumen are partly used by the microbes, and the rest pass through the walls of the stomachs for use by the animal. Dietary protein degradation produces ammonia which is used by the microbes to synthesize protein for their growth and reproduction. Energy from fibre and carbohydrate breakdown is needed by microbes for efficient protein synthesis.

Crude protein levels in the foliage of tree legumes that are used in alley farming range from 12 to 30 per cent – higher than the 3 to 10 per cent found in tropical grasses, and their inclusion in rations can provide sufficient dietary protein to maintain a satisfactory level of rumen ammonia for microbial growth. However, tree legumes contain polyphenolic compounds (e.g. tannins) that reduce protein degradability in the rumen through the formation of complexes. The levels and types of polyphenolic compound vary greatly between tree species, but generally tree leaves with no tannin (*Albizia lebbeck*, *Sesbania* spp.) are easily degraded in the rumen, while tannin-containing species (*Calliandra calothyrus*, *Acacia* spp.) are of low degradability. If the protein-tannin complex can be broken in the intestinal tract post-rumen, protein can be digested and absorbed in the small intestine, but if the complex cannot be broken it is completely indigestible. Drying usually reduces tannin content and increases protein degradability. Rumen and small intestinal digestibilities for a range of tree legume forages are shown in Table 6.1.

With poor quality diets, the rate of breakdown of food in the rumen is depressed, passage through the gut is slow, and food intake is reduced. Additional dietary protein (e.g. from legumes) raises the protein : energy ratio, allowing improved synthesis of microbial protein, and faster microbial growth in the rumen, leading to a more efficient food breakdown, a faster rate of passage, and an increased food intake.

Table 6.1 Rumen degradability and post-ruminal digestibility of protein (g/kg DM)

Forage	Condition	Crude protein	Rumen degradable protein	Intestinal digestible protein	Indigestible protein
Erythrina verigata	Fresh	253	162	64	27
	Sun-dried	253	186	51	16
Gliricidia sepium	Fresh	261	179	66	16
	Sun-dried	261	182	49	30
Leucaena leucocephala	Fresh	246	96	90	60
	Sun-dried	246	117	84	45
Sesbania sesban	Dried	267	207	26	34
Calliandra calothyrsus	Dried	219	55	67	97

Stage 3: Absorption of nutrients from the gut, and utilization by the animal

Animals can only make use of dietary nutrients after digestion and absorption. Undegraded food and microbes are carried down the digestive tract from the rumen to the small intestine where a second breakdown of food and of microbes occurs, caused by enzymes secreted into the gut by the animal itself. This enzymic action releases amino acids which are absorbed through the gut wall into the blood stream. Finally, undigested residues are excreted in faeces.

It is only the absorbed nutrients that are of direct value to the animal. Animals use the absorbed compounds to assemble molecules for their own use. Chemical conversions occurring during metabolic reactions are not completely efficient and some wastage occurs (waste products are eventually excreted in urine). Maintenance reactions are the most efficient, followed by milk production, growth and finally fattening – the least efficient. Maintenance needs depend on body weight; production needs depend on the rate of growth, fattening or milk yield. Thus, when a small and a large animal have the same nutrient intake, the smaller animal would have more nutrients remaining for productive purposes. Stall-fed animals do not expend energy in searching for food as do grazing animals, and hence would be more productive on the same intake level as grazing animals.

Poor-quality roughage diets are the norm in smallholder farming, and overall digestibility is low. The inclusion of a legume supplement (or other protein sources) improves digestibility and can significantly raise the nutrient supply for production, over and above the maintenance requirements.

Forage production on alley farms

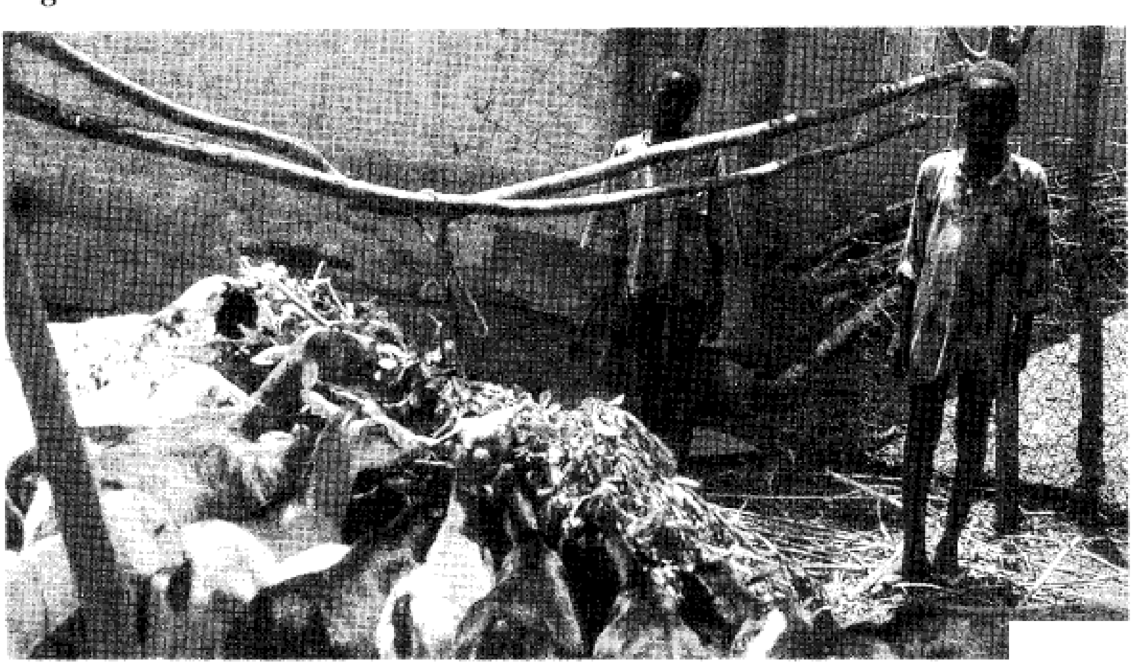
Three forms of forage production are considered here. First, tree/food crop combinations in an alley farm, where priority is given to the performance of the food crop; secondly, tree/grass combinations, where all the output goes for animal feed; and thirdly, tree-only plots, which again can be focused on forage production. Tree production will be greater where trees are allowed to establish fully before pruning.

Ideally, a period of 12 months unrestricted growth is recommended for strong root and trunk development. In areas where fallowing is common, trees can be planted in the last year of fallow, provided that weed competition can be minimized.

Tree-crop mixtures

A typical alley farm will produce food crops between the tree rows. Plant growth is influenced by competition between tree and crop for light, water and nutrients. The hedgerow trees must be managed to minimize shading of the companion crop. Prunings are used for mulch or green manure to improve soil fertility and crop yields. The more mulch or green manure is applied, the better the response of the crop. Hence, removal of mulch to feed to animals can be expected to reduce the benefits gained by the crop, as discussed in Chapter 5. Feed must be carried to livestock in this system, since grazing would damage crops in the ground (Fig 6.1).

Fig 6.1 Feeding goats with *Gliricidia sepium* prunings in south-western Nigeria.



Most of the studies in this area have focused on tree-maize combinations.

Between maize planting and harvest time, trees need to be pruned 2–3 times to prevent shading (Table 4.5, page 42). Since the ability of plants to respond to nutrients from mulch varies with age (Fig 5.4, page 55), the first application of mulch – at planting time – has a greater effect on plant growth than later prunings. A farmer with both crops and animals could therefore direct the third and possibly the second pruning to livestock feed without seriously reducing the benefits obtained by the crop. A further, less obvious benefit can be gained for livestock production, because the nitrogen content of maize stover is higher, and there is more leaf relative to stem when the crop has been mulched with leguminous material. This improves the quality of the crop residue as animal feed, and will have a small but beneficial effect on animal performance.

After the crop has been harvested it may be possible to graze crop residues and the tree legume prunings *in situ*. This would require that all crops had been harvested in the immediate area to minimize the risk of damage by wandering animals. Where intercropping is practised, grazing will only be possible after the final crop in the mixture has been collected. In parts of Indonesia animals are tethered in alleys and have access to feed from a restricted grazing area.

Stall-fed animals are, by definition, permanently confined, but free-roaming livestock are usually confined overnight, either for security or to prevent them wandering and damaging crops. Manure builds up in the kraal, and is a valuable resource to help maintain or improve soil fertility. The value of manure depends upon its nutrient content – and this is related to feed quality. High-quality feed results in high-quality manure. The addition of protein-rich leguminous forages to a diet improves digestibility for the animal, and also raises the nitrogen content of the manure. A typical adult cow in the tropics will deposit around three-quarters of a ton/year of dry manure in the kraal overnight, containing 9 kg nitrogen and 2 kg phosphorus. Many tropical soils are low in organic matter, and virtually all would benefit from additional nitrogen and phosphorus. In tropical Africa, the response to manure application varies from 50 kg of grain/ton of manure in semi-arid areas (where manure is most common) to 200–450 kg of grain/ton of manure in higher rainfall areas. In addition, the response of crops to inorganic fertilizer is enhanced when soil organic levels are raised through the addition of either mulch or manure.

Thus, using tree foliage to feed livestock does not prevent crops from benefiting as well, provided manure is returned to the soil. However, in parts of Africa relatively little use is made of manure because of high transport costs and labour requirements, or because manure is required for fuel. Manuring is more important where fields are close to the kraal (usually near the household) or where temporary kraals are established on crop land around the start of the rainy season, reducing or eliminating the need for transport. Grazing and tethering systems allow manuring *in situ* at no extra effort and need to be encouraged.

Tree-grass mixtures

Two main options for tree-grass combinations are trees with cultivated grasses or tree rows planted in natural indigenous grass pasture. The former will probably be used for cut-and-carry feeding, the latter for grazing. Smallholder systems have limited space and often need to intensify land productivity. As indigenous grasses are relatively unresponsive to intensification, cultivated grasses are a better option. Despite much research and extension effort, sustained adoption of cultivated grass systems has been very low among smallholder African farmers, with the exception of small-scale dairy producers in the highlands of East Africa where napier grass production has been widely adopted, because the financial returns from milk are sufficiently attractive to justify the extra effort of cultivating grass. Nutrient inputs are required to sustain grass production. One source of nutrients is biological fixation of nitrogen associated with legumes, and some farmers at the Kenyan coast and in western Kenya have successfully combined napier grass with *Leucaena* in an alley system (Fig 6.2).

Competition between trees and grass for light, water and nutrients influences the performance of grass when grown in alleys, just

Fig 6.2 Farmer's plot with intensive napier (*Pennisetum purpureum*) grass and *Leucaena leucocephala* hedgerows on the coastal lowland of Kenya.

as it does for food crops. The level of competition can be controlled by varying the spacing between trees – the most practical method for grazing systems – and by managing the amount of foliage on the tree by pruning or grazing. Foliage density, and hence the shading effect, can be fine tuned by pruning, but cannot be controlled or manipulated so easily in direct grazing systems, where tree survival is more variable.

Intensive systems

In intensive systems with cultivated grass, hedgerows need to be pruned to reduce shading, but pruning too frequently will adversely affect tree production. All biomass from the plot is destined for animal feed, so there is a high level of nutrient export. This will adversely affect productivity in the medium and long term unless nutrients are returned through fertilizer application or manure, even though deep tree roots will allow access to minerals that are out of reach of food crops or grass. Nitrogen fixation by leguminous trees is particularly helpful, and leaf drop from trees allows some recycling of nutrients even when all prunings are exported.

The grasses most widely used have been *Panicum maximum* and *Pennisetum purpureum*. Other species include *Brachiaria decumbens, Setaria sphacelata, Chloris gayana* and *Cenchrus ciliaris*. The choice of grass depends on environmental characteristics and the proposed mode of use. *Panicum* and *Pennisetum*, because of their upright growth habit, are more suitable for cut-and-carry systems, while the other grasses mentioned are preferred for grazing.

Grass plants in rows adjacent to the trees grow taller than those in the middle of an alley, in contrast to maize plants which show the opposite reaction. When trees are pruned every eight weeks, grass next to the trees is usually taller and greener than grass in the middle of the alley. This indicates differences in nutrient competition, possible because of contrasting rooting patterns and nutrient demand between grass and food crops. However, when the tree-pruning interval is extended to 20 weeks or more, grass next to the trees is less productive than grass in the middle of the alley, due to shading. Tree growth is more vigorous with older, well-established trees, especially if they have not been pruned for some time and have developed extensive rooting systems. If a more regular pruning system is not followed with older trees, a lack of light may shade out the companion grass.

Intercropping of napier grass (*Pennisetum purpureum* var. Bana) and *Leucaena* reduces dry matter yield/ha from grass, although yield/plant rises, reflecting the smaller number of grass plants/ha when some of the land is occupied by trees. *Leucaena* yield/tree, when grown in combination with grass, is higher than the yield on tree-only plots, showing that there is less competition between tree-grass than between tree-tree. Total dry matter yield/ha from tree-grass mixtures is higher than from grass-only or tree-only plots. As indicated earlier, protein content is at least as important as dry matter production because of the influence of dietary protein on animal performance. Crude protein production in *Leucaena*-napier alleys is over 2.5 times as great as in plots with only napier.

Grass-herbaceous legume mixtures have often been recommended for a high-quality diet in the tropics, but adoption by farmers is very limited. It is difficult to maintain the herbaceous legume content of the pasture under grazing or cut-and-carry regimes. Nevertheless, three-way mixtures of tree legume-grass-herbaceous legume (i.e. alley farming with grass and herbaceous legumes in the alleys) have been studied. The addition of *Clitorea ternatea*, for example to *Leucaena*-napier mixtures increased total dry matter, but decreased the *Leucaena* offtake. Crude protein production rises due to the contribution of the herbaceous legume. There may be benefits from the inclusion of a third component in the forage production system but its acceptability to farmers remains to be seen. For the time being it should be retained on the list of options offered by extension services to farmers.

The return of tree foliage as mulch for grass has been shown to be biologically beneficial. However, the economic benefits are lower than those from feeding tree foliage to livestock. In the unlikely event of any farmers having surplus tree foliage, it would be preferable to dry and store it for use later as feed, or to use it as a green manure for food crops rather than applying it to grass.

Fertilizer application will increase dry matter and crude protein yield from tree-grass mixtures, and the benefits from inorganic fertilizer have been demonstrated many times. Extension agents in Africa have enough difficulty persuading farmers to apply inorganic fertilizers to their food crops and it is difficult to see them having greater success with forages. In other parts of the world where inorganic fertilizer is cheaper and more readily available, its use on forage crops may prove acceptable to smallholders.

Manuring has a beneficial effect on both grass and tree production. Where the forage is used for cut-and-carry feeding, the plot should be established close to the animal shed, to minimize labour requirements for transporting manure back to the field.

Extensive grazing systems

Work on extensive grazing systems has occurred primarily in Australia and Latin America, with an estimated 20 000 ha of commercial *Leucaena* in central Queensland alone. *Leucaena* is very persistent once established and recovers well from heavy grazing. In areas of Queensland with 500–1000 mm of rainfall, *Leucaena* has been planted in widely-spaced rows (over 5 m apart). Successful establishment is a critical factor in the ability of the tree to contribute to animal intake, and weed control in the first year is vital. Animal access to *Leucaena* in extensive livestock production systems can be varied by modifying the inter-row distances, and hence the proportion of land under *Leucaena*. In an alternative system requiring more labour input, more suitable to dairy rather than beef production, a portion of the land can be planted solely to *Leucaena*, and animals allowed access for a limited period each day (see below). Tree height is usually kept within grazing reach by cattle, which have sufficient weight and strength to break older, taller stems. Trees in pasture can be grazed continually for extended periods, but a rest period of two to four months is needed during each year.

Tree-only plots

Fields used for alley farming, like other fields, benefit from fallowing. Animal feed from tree foliage can still be extracted during the fallow period. Tree management during this period can be different from during the cropping period because there is no need for frequent prunings to prevent shading of food crops. Within limits, annual pruning offtake rises as pruning interval increases. A study in southern Nigeria, with 1200 mm rainfall bimodally distributed, showed that two prunings per year, with the first in January (the middle of the dry season) and the second in October after growth throughout the rainy season, maximized foliage offtake from *Leucaena*. A single annual pruning from *Leucaena* gives a reasonable leaf yield, but *Gliricidia* loses leaves from mature branches in the dry season, and must be pruned twice a year. This demonstrates that the management practices needed to maximize tree foliage offtake vary between tree species.

Another tree-only arrangement – perhaps not strictly an alley farm, but worth considering – involves close planting to maximize the number of trees/ha. With a gap of 1–1.5 m between tree rows, food crop production is not possible. These plots may be attractive to farmers with limited land to supplement their other forage sources. Planting density (inter-row spaces of 0.5 m to 2.0 m, with 0.25 m intra-row spacing) and pruning intervals (6 to 12 weeks) have been studied with *Leucaena*. Initially, tree foliage yield was very high, but declined with time, particularly with the more frequent pruning regime. Lengthening the pruning interval produced more robust trees with thicker trunks and fewer deaths. Leaf production stabilized after three years at 15 tons of leaf DM/ha from long pruning intervals and high planting density. In practice, at least 1 m between rows is needed to allow farmers ease of access for pruning.

Conservation of forage

Tree-legume foliage grows twice as fast in the rainy season as in dry periods. Farmers may produce surplus forage in the wet season, but have insufficient at other times. Conservation is a means to alleviate the shortage. Small-scale farmers can leave the surplus material on the tree during the rainy season as a simple method for conserving feed, provided there are no companion food crops that would be affected by shading. An alternative, cheap method of conserving surplus material is by sun drying. Cut branches are left in the sun or partial shade for one or two days and the dry leaves easily fall off when shaken. The dried leaves can then be bagged and stored until required. Drying in partial shade is said to improve the digestibility of *Leucaena* by breaking down mimosine, but after drying in full sun, the resultant dark-brown leaf material has a lower nutritive value. In Tanzania, peri-urban smallholder dairy farmers buy dried *Leucaena* leaf meal as a dietary supplement for milking cows, providing a cash income to rural farmers where *Leucaena* grows as a naturalized plant on roadsides. Drying leads to a sharp drop in the digestibility of *Calliandra calothyrsus* forage and also depresses intake, but has a limited effect on most other tree-legume forages.

Forage utilization and animal performance

On average, each *Leucaena* tree in an alley farm will produce between 0.5–1.0 kg dry matter (DM)/year. Other tree species are less productive, and a larger number of trees are needed to ensure the same level of supplementation.

The most biologically efficient and financially rewarding use of forage from alley farms is for milk production. The addition of most protein sources to a lactating cows' diet in the tropics can be expected to increase milk production. Tree-legume forages contain around 20–25 per cent crude protein, so beneficial effects are not surprising. The quantitative impact depends on the milk production potential of the cow, the stage of lactation, the tree species used and the initial quality of the diet before the supplement was added. Dairy breeds will respond more than beef breeds, in early lactation than later, and when the quality of the basal ration is poor. In Kenya, for example, the average milk production from Friesian or Ayrshire dairy cattle crossed with *Bos indicus* cows is 5–6 kg/day, close to the maximum expected in the tropics from a grass-only ration (Fig 6.3). Overall, the addition of 1 kg/day of *Leucaena* leaf meal to a grass ration for stall-fed cows gives an extra 0.5–1.0 kg milk/day. When early lactation coincides with the dry season, more than double this response has been recorded, but in mid to late lactation a smaller response occurs, with a greater proportion of the additional nutrients being directed towards body tissue rather than milk. An improvement in body condition should lead to an improvement in conception rates, and shorter calving intervals, which will also benefit farmers since a female calf is a very saleable commodity. Concentrate supplements in addition to tree-legume forage further improve milk production. In Kenya, maize bran, which is readily available and relatively cheap, is a suitable supplement to *Leucaena*/grass mixtures. In the dry season, when grass quality is poor, cows in early lactation produced 6.0 kg milk/day when supplemented with 2 kg/day of *Leucaena* compared to only 3.7 kg from a napier grass diet, but 8.6 kg when offered supplements of 2 kg *Leucaena* plus 1 kg of maize bran.

Grazing dairy animals have also received *Leucaena* supplements, either by allowing access to a separate area of trees for a two to four hour period each day or by interplanting trees in the pasture. The average milk production increase in Latin American trials was 14 per cent, similar to the impact in stall-fed systems, although reports from Malaysia indicate better use of *Leucaena* forage by grazing animals than when the same forage is cut and carried to pen-fed animals. Grazing animals are able to select the most nutritious plant parts from a pasture, whereas stall-fed animals under smallholder conditions usually have insufficient material on offer for selection to make much difference. Grazing stock prefer young *Leucaena* shoots, the part of the plant where psyllid insects concentrate. There are reports that psyllid damage on grazed plots is less than on areas used for cut-and-carry feeding.

With beef cattle and small ruminants the impact of supplementary feeding with tree-legume foliage during lactation is shown by the performance of the offspring, rather than by milk offtake. Enhanced milk production will improve survivability of young stock in the critical first months after birth, increase offspring growth

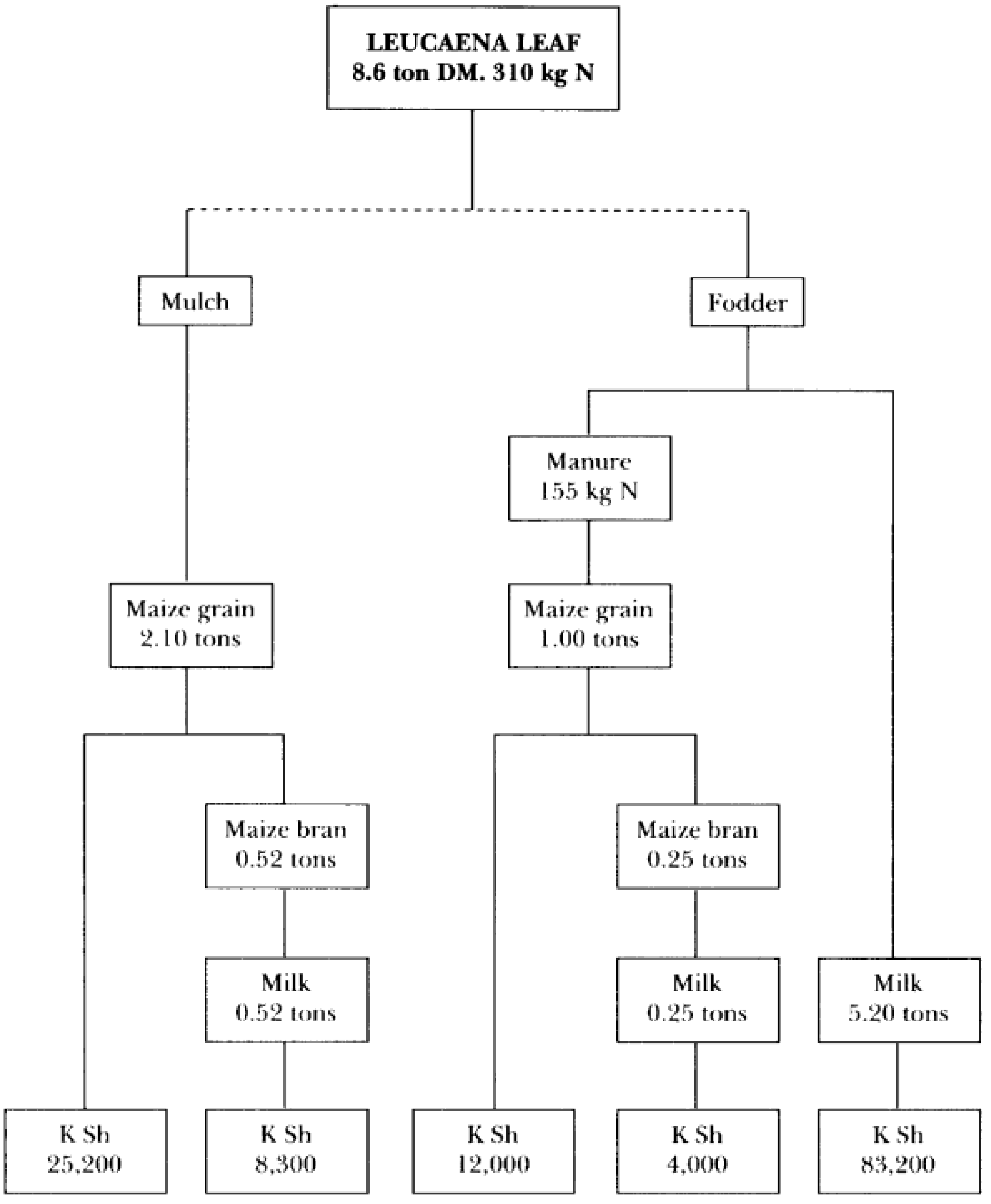


Fig 6.3 Effect of *Leucaena leucocephala* leaf as mulch for maize, or fodder for milk production, Kenya 1992.

rates, and reduce dam weight loss. Survival is a more immediately noticeable parameter for farmers than small improvements in body weight. Nigerian studies show that the survival rate of offspring rose steadily from 50 per cent to almost 100 per cent as the level of a mixed *Leucaena/Gliricidia* supplement increased from zero to 0.8 kg DM/day to sheep and goats on a basal grass diet. It is unlikely that any special properties in the tree-legume forage were responsible, other than the provision of protein, energy and a more digestible ration. An important point is the ability of farmers to produce the supplement themselves, rather than rely on purchased concentrates that come and go from the market and are very expensive.

Animal growth rates depend upon the age of the animal, and diet. In the tropics, growing and fattening animals are short of dietary protein for much of the year, a deficit that legume tree forages can reduce. Animals grow fastest around puberty, and that is the time when the best growth response to supplementary feeding can be obtained. The inclusion of *Leucaena* in pasture allows a higher stocking rate, and this, together with faster individual weight gains, greatly increases animal productivity per unit of land. Daily growth rates for cattle increase when animals are offered tree-legume supplements (Table 6.2). As with dairy animals, production gains are higher when the quality of the basal ration is low. In Indonesia, cattle were losing 20 g/day grazing poor quality natural pasture but gained 540 g/day with the inclusion of *Leucaena* in the ration (Fig 6.4). Similar results can be seen with sheep and goats (Table 6.3). In Ethiopia, sheep lost weight on poor quality hay but gained weight when *Leucaena* was added. The incremental improvement in animal performance decreased as more legume was included in the diet, so in general it would be more effective to provide all growing animals with a ration containing say 25 per cent legume, rather than divide the same amount of legume among

Table 6.2 Effects of tree-legume forage on the growth and fattening of cattle

Location	Basal forage	Browse	Browse intake % DMI	Growth rate g/day
Indonesia	Natural pasture		0	-20
		Leucaena	40	540
Latin America	*Brachiaria decumbens*		0	270
		Leucaena	4 h/day*	350
Southern Africa	*Pennisetum clandestinum*		0	70
		Leucaena	3 h/day*	340
Australia	*Brachiaria decumbens*		0	380
		S. sesban	20% by area†	610
Thailand	Rice straw		0	-113
		Gliricidia	33	10

* Time spent grazing the tree legume.

† Proportion of the land area planted to tree legume.

just part of the group. An exception would be where there is a market demand for specific types of animals (e.g. rams for Muslim festivals), which command a premium price.

Leucaena has featured most prominently in the above discussion of animal performance, but other tree legumes have also been used. Diversification of sources for feed is important, as the devastation caused by the *Leucaena* psyllid in Indonesia and the Philippines demonstrated. However, except on acid soils, other leguminous tree species tried so far produce less edible biomass than *Leucaena*, and have a lower impact on animal performance. *Gliricidia* is used by dairy farmers in Tanzania, Indonesia and the Philippines, and by small ruminant producers in West Africa and Central America. Animals find *Gliricidia* somewhat unpalatable when it is first introduced, but soon develop a taste for the forage. In some areas,

Fig 6.4 Supplementary feeding with *Leucaena leucocephala* prunings for cattle fattening in Flores, Indonesia.

Table 6.3 Effects of tree-legume forage on the growth and fattening of sheep and goats

Animal species	Location	Basal forage	Browse	Browse intake % DMI	Growth rate g/day
Sheep	Australia	Sorghum stover	—	0	–44
			Leucaena	15	85
	Ethiopia	*Eragrostis teff* hay	—	0	–9
			Leucaena	27	37
			Leucaena	45	53
	Nigeria	*Panicum maximum*	—	0	26
			Leucaena/ Gliricidia	30	44
Goats	Indonesia	*Pennisetum purpureum*	—	0	–1
			Leucaena	13	22
			Gliricidia	12	20
			S. grandiflora	12	20
	Nigeria	*Panicum maximum*	*Leucaena/ Gliricidia*	20	14
				60	20

Gliricidia is allowed to wilt before being offered to stall-fed animals, as this improves palatability by allowing volatile leaf substances to evaporate. *Calliandra calothyrsus*, on the other hand, is less palatable after wilting than when fresh. Other methods of improving palatability include the addition of molasses or salt, and confining new animals with ones already accustomed to the feed. Animals will gradually become accustomed to a feed such as *Gliricidia* over a period of a few weeks.

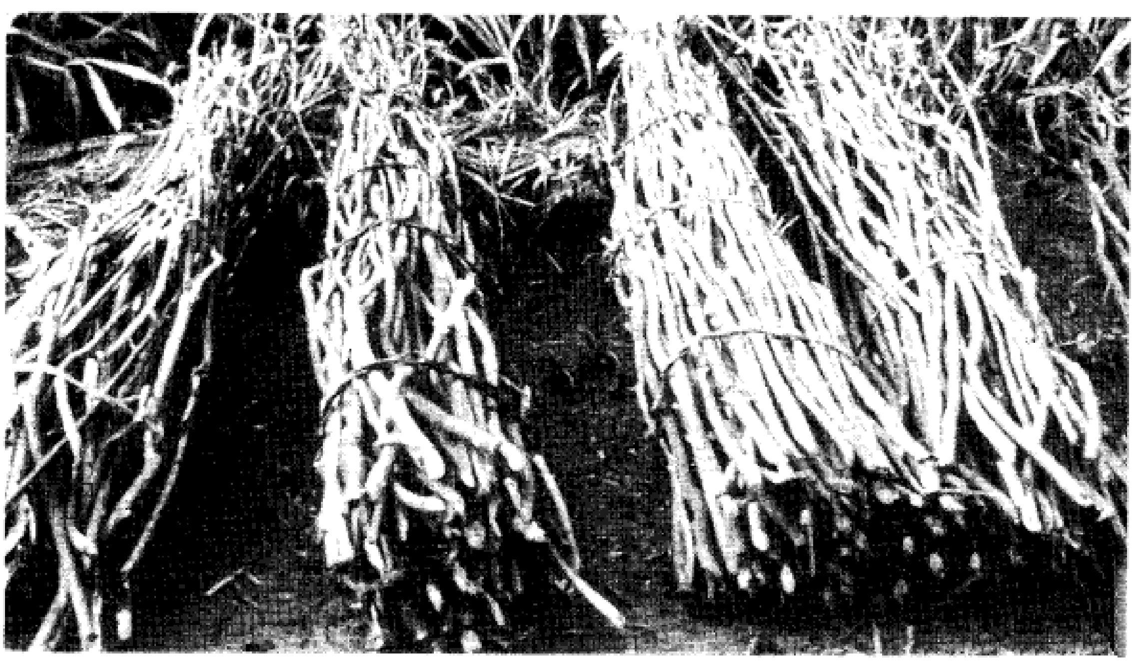
Farmers usually have limited supplies of the tree foliage, so the quantity offered daily to each animal is limited. In research trials, when a sole diet of *Leucaena* had been fed, a problem of toxicity from mimosine, a compound that is peculiar to *Leucaena*, has been encountered. There is no evidence of such problems occurring on smallholder farms, however. On commercial farms in Australia, where *Leucaena* is grazed and intake may be high at times, animals have been dosed by mouth with naturally occurring detoxifying bacteria that can live and reproduce in the rumen. These bacteria render mimosine and its metabolites harmless. Cross transmission of the bacteria from inoculated to uninoculated animals occurs naturally, so only a small proportion of animals in a group needed to be treated to ensure safety for all. There is evidence that inoculated animals, even in areas where there has been no indication of toxicity, show improved performance after treatment.

In summary, a row of *Leucaena* trees 90 m long, at 4 trees/m, will provide 12 months supplementary feed at a rate of 0.5–1.0 kg DM/day if all the tree foliage is used for forage. Through a combination of direct use and storage, this quantity could supplement a lactating dairy cow for six months, increasing milk production by around 250 kg. Alternatively, ten fattening sheep could receive supplements for 100 days producing an extra 40 kg of meat.

7 Auxiliary benefits

Trees and shrubs are important components of traditional farming systems. The woody species can provide much needed auxiliary materials for farm and domestic use, such as staking material, construction material, fuelwood and for making farm tools. In the humid zone of south-eastern Nigeria, traditional farmers retain or plant some woody species that are widely used for production of staking material, such as *D. barteri* (Fig 7.1) and *Nuclea latifolia*, while in south-western Nigeria farmers plant *G. sepium* for the same purpose. Because of the high rate of deforestation and over-harvesting of wood for domestic fuel use, in some yam growing areas such as in south-eastern and east-central Nigeria, there is already an acute shortage of staking material. This makes them more costly as they have to be imported from other areas. A shortage of fuelwood for domestic use is also an increasing problem in the subhumid zone of the tropics. The problem is very acute in most areas of the dry savannah and semi-arid zones of Africa and Asia. In these zones farmers, besides cutting the trees, also do a lot of pollarding of trees for use as firewood. In many instances, frequent pollarding of the trees results in die back.

Fig 7.1 Harvested stakes from *Dactyladenia barteri* hedgerows from a farmer's plot in south-eastern Nigeria.



Staking material

In alley farming trees and shrubs grown in hedgerows can provide, for example, the much needed alternative source of staking material. Staking is essential to support climbing sunlight-demanding crops such as white yam (*Dioscorea rotundata*), climbing bean species such as *Phaseolus* and *Vigna*, and for staking high value crops such as tomatoes, vanilla, black pepper, betel vine and passion fruits. An additional advantage of the presence of hedgerows in alley farms for yam production, is that farmers can do their land preparation and mounding, which is normally done during the dry season before the onset of rains, under the hedgerow shade, making seedbed preparation less strenuous. There are two main methods for staking, using either live or dead stakes.

Live stakes

Farmers in the Philippines and south-eastern Indonesia use live stakes of *Leucaena* for yam production. Yams in their initial stage of growth do better under partial shade, and the shade of the *Leucaena* plant promotes the early growth of the yam plant. When the yam plant reaches the stage of growth where assimilates are converted to tuber growth, the stem of the *Leucaena* plant is girdled at a low height (below 40 cm) from the ground. This process of removing the bark will kill the tree canopy. Once girdled, the tree top rapidly drops its leaves, allowing full sunlight on the yam vines, and the dead part of the stem provides a sturdy pole to support the yam. The stem beneath the girdle coppices, and the new sprouts are frequently cut and the prunings applied as a mulch. When the yam is ready for harvest, the dead part of the pole is cut and can be used as firewood, and the *Leucaena* plants are allowed to grow freely. However, the use of *Leucaena* live stakes are not recommended without stem girdling. Due to the rapid growth of *Leucaena* tops shading is a problem from ungirdled plants and can reduce the yam yield, as seen from Table 7.1.

Recent investigations in Côte d'Ivoire showed that *G. sepium* can serve as a live support system for water yam (*Dioscorea alata*). The *G. sepium* plant has suitable attributes for live staking because of its relatively weakly-developed root system that will not compete strongly with the crops, low leaf productivity, and an open architecture that allows sufficient space for a yam crop grown in association. Combined with the mulching effect from the *G. sepium* prunings, live support can more than double the yam tuber yield from 8.8 ton/ha in the control treatment against 20.7 ton/ha with staking.

Table 7.1 Effects of *Leucaena leucocephala* stakes on white yam yields (t/ha) in Benue State, Nigeria

Location	In-situ (ungirdled) live stakes			Cut-and-carry stakes		
	Live stake	Control	Yield increase decrease (%)	Cut stakes	Control	Yield increase (%)
Zakibiam	22.3	20.8	7.2	22.8	18.9	21
Isherev	9.2	24.3	-62	30.5	23	33
Abari	13.8	16.4	-16	19.4	10.5	85
Yandev	32.7	25	18	18.8	10.3	82
Amaladu	—	—	—	20	11	81
Nyikwagh	—	—	—	33.5	17.7	89
Mean	20	21	-5	23.3	15	55
LSD.05	22.9			7.3		

In the traditional alley cropping system with *D. barteri* hedgerows in south-eastern Nigeria, farmers use pollarded *D. barteri* hedgerows as live supports for yam production. By the end of the yam cropping period, the hedgerows are allowed to regrow into a fallow system.

Dead stakes

In most cases the stakes collected from hedgerows are used in a cut-and-carry system as dead stakes for climbing crops such as yam (Fig 7.2), tomatoes, vegetable cowpeas and string beans. Farmers in some areas give preference to staking material of certain shrub species such as *D. barteri*, which is known to be long lasting and can be used for two seasons. Observations in east-central Nigeria showed that the use of dead stakes more than doubled white yam yield (Table 7.1, above). With plantain and banana production, the stakes of the hedgerows can also be used for propping up the banana plants.

Firewood

In addition to supplying staking materials, the hedgerows can also serve as a source of firewood. *Leucaena* hedgerows have been widely used for this purpose, for example in Uganda. Allowing for short fallow periods, the hedgerows can produce substantial amounts of firewood. The stakes from hedgerow prunings serve as an import-

Fig 7.2 Staking of white yam (*Dioscorea rotundata*) with dead poles of *Leucaena leucocephala*.

ant supplementary source of domestic fuel in many rural areas in the tropics. This is already practised by farmers in the subhumid zones of South-east Asia and Africa, where shortage of fuelwood is increasing in importance with rapid urbanization. The amount of firewood production in alley farms varies with species, as illustrated in Chapter 4, and is influenced by pruning height and intensity (Fig 4.5, page 41) and inter-hedgerow spacing. Higher pruning height, lower pruning intensity and closer inter-hedgerow spacing increases the amount of wood production per unit area. An alley-farmed field with *Leucaena* planted at 4 m inter-hedgerow spacing and pruned to 25 cm height can produce about 4 tons of dry firewood/ha/year. By fallowing the alley farms, fuelwood harvested from the hedgerows can also reach commercial size and will gain market value. Results of a trial in south-western Nigeria with *L. leucocephala* (cultivar K 636) hedgerows planted at 4 m inter-hedgerow spacing and pruned to 25 cm height, fallowing for one, two and three years can produce respectively 15.2, 25.9 and 37.4 tons/ha of dry wood. *Leucaena* wood, because of its high density and calorific value, is known as a good source of firewood. This firewood source can be critical in buffer zone areas, to reduce both firewood gathering and the deforestation of protected buffer zone areas in the tropics. However, the substantial amount of firewood harvesting from alley farming can result in soil nutrient depletion without nutrient amendment.

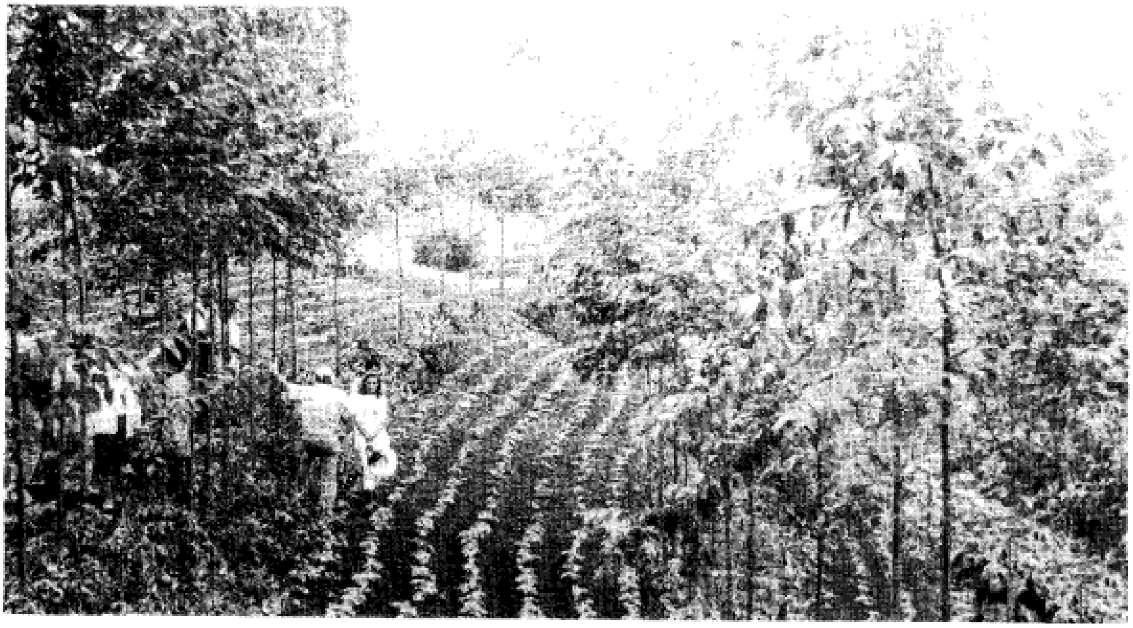
Timber

Timber shortage for construction and use as poles has encouraged farmers to grow fast-growing timber hedgerow species, such as *Acacia* *auriculiformis*, *Eucalyptus* species, *Gmelina arborea* and arboreal *Leucaena leucocephala*. In particular, farmers in areas and countries with a rapidly growing human population have a greater incentive to plant fast-growing species, as the economic rewards are increased. In Fig 7.3, farmers in central Mindanao, in the Philippines, planted *Eucalyptus* hedgerows in combination with vegetable production, to stabilize steep lands and for timber production. The *Eucalyptus* hedgerows benefited from the residual fertilizers applied to the vegetable crops. The *Eucalyptus* poles for domestic use or export can be harvested after four to five years. This is an attractive production system for local farmers in the area.

Other products

In south-eastern Nigeria farmers use *D. barteri* as a preferred source for charcoal production. In addition, farmers also collect edible mushrooms that grow on partially-burned *D. barteri* wood during the rainy season. Similarly *Leucaena* wood is a preferred source for making charcoal in South-east Asia. Wood from the arboreal *Leucaena* can also be used for furniture, pulp, clipboards and for parquet flooring. In South-east Asia people eat the young shoots, green pods and green seeds of *Leucaena* raw, or cooked or mixed with other ingredients or after fermentation. Roasted *Leucaena* seeds are also used as a substitute for coffee. Some farmers in Indonesia use *Sesbania grandiflora* flowers as a source of vegetables and some farmers in the southern Philippines are experimenting with hedgerows of fibre banana. The potential for planting of hedgerows with specific auxilliary products is vast and needs further exploration.

Fig 7.3 Over one-year-old *Eucalyptus deghepta* hedgerows alley farmed with *Phaseolus vulgaris* on sloping land with a greater than 30 per cent slope, at Lantapan, Mindanao, Philippines, for timber and vegetable production. (Courtesy T. Nissen, SANREM CRSP).



8 Economic aspects of alley farming

The economic viability of an intervention is one of the key factors that determines its adoption by farmers. In the case of alley farming, the economics of the system with and without inclusion of livestock production have been assessed through the use of linear programming models and also through partial budget analysis. Both methods were used to assess the incremental or additional costs and benefits arising from the alley-farming system as compared to the traditional shifting cultivation system. Table 8.1 illustrates the major types of incremental costs and benefits associated with alley farming. In order for alley farming to be economically viable, the incremental benefits arising from the system should be greater than the additional cost of operation over the traditional system.

Table 8.1 Potential benefits and costs in alley farming

Added costs	Added benefits
1 Hedgerow establishment (Planting/weeding)	1 Increased crop yields
2 Seedling establishment/cost	2 Increased livestock productivity
3 Seedling transport	3 Increased fuelwood availability
4 Pruning labour	

The hypothesis of economic profitability of alley farming can be simply expressed as follows: $B_{AF} - B_{TS} > C_{AF} - C_{TS}$
where:

B_{AF}	=	Total benefits from alley farming
B_{TS}	=	Total benefits from traditional farming system
C_{AF}	=	Total costs of alley farming
C_{TS}	=	Total costs of traditional farming system
$B_{AF} - B_{TS}$	=	Additional benefits from alley farming
$C_{AF} - B_{TS}$	=	Incremental cost as a result of alley farming.

Using a linear programming model, researchers in Nigeria in 1985 have indicated that *Leucaena*/maize alley farming was economically attractive. Although more labour was required to prune the trees, however, there is also a cost saving with the inclusion of *Leucaena* hedgerows for maize production. For example, less nitrogen fertilizer is required with the addition of *Leucaena* prunings and the cost of weeding is also lower due to partial weed suppression by the hedgerows. It was concluded in this study that under severe cash constraints, and where hired labour was available at relatively low cost, a *Leucaena*/maize alley-farming system was a most promising combination. This study was carried out in the forest and savannah transition zone in south-western Nigeria. A similar study carried out on a *Leucaena*/upland rice system in Sierra Leone in 1980 also gave similar results. Long-term observations conducted in the Benin Republic and in China have shown that the economic benefits from alley farming are more apparent in older than in newly-established alley-farmed fields.

Further economic analysis on alley farming carried out in Nigeria between 1980 and 1983 confirmed the higher labour costs in alley farming but revealed that the increased maize yield more than compensated for the additional labour costs, thus making the system economically attractive. In this study, however, the costs of pruning and mulching were overestimated, as they included time spent in stripping leaves off the pruned *Leucaena* branches. A study carried out in Nigeria in 1986–87 showed that actual labour use in alley farms in farmers' fields was much lower than usually estimated from on-station trials. Farmers usually do not strip foliage from branches; they simply spread branches on the soil to dry and the dry leaves are then shaken off onto the soil.

Further economic analysis on alley farming (referred to as 'hedgerow intercropping') has been done by the International Centre for Research in Agroforestry (ICRAF). Research on hedgerow intercropping in farmers' fields at Maseno, Kenya, produced variable responses from farmers with regard to the benefits derived from the system. In this research, 42 per cent, of the farmers felt the overall effect of the hedgerows on the maize was positive; 25 per cent, felt the effect was negative; and 33 per cent were undecided. In situations where the benefits of alley farming cannot be experienced at farm level, the issue of profitability does not arise, as in such cases the system is simply not feasible. Economic analysis on farmers' alley-farmed farms at Maseno, however, showed that a maize yield increase of about 18 per cent was required to cover the addi-

Table 8.2 Partial budget* showing the amount of added benefits required to cover the costs of adopting hedgerow intercropping relative to sole-cropped maize (Ksh/ha)[†]

Added costs		Added benefits		Net benefits	Discount factor (20%/yr)	Discounted value of net benefits
Year 1						
Seedlings	3472	Firewood	227			
Planting labour	805					
Pruning labour	68					
Subtotal	4345	Subtotal	227	–4118	0.83	–3419
Year 2						
Pruning labour	328	Added maize	1539			
		Firewood	380			
		Subtotal	1919	1591	0.69	1098
Year 3						
Pruning labour	328	Added maize	1539			
		Firewood	380			
		Subtotal	1919	1591	0.58	923
Year 4						
Pruning labour	328	Added maize	1539			
		Firewood	380			
		Subtotal	1919	1591	0.48	764
Year 5						
Pruning labour	328	Added maize	1539			
		Firewood	380			
		Subtotal	1919	1591	0.40	636

Trees planted	6944 per hectare	Labour cost	4 Ksh/ha
Survival rate	90%	Maize price	4.25 Ksh/kg
Seedling price	0.5 Ksh/plant	Firewood price	0.25 Ksh/kg
Planting rate	34.5 trees/hr	Firewood yield	907 kg/ha in Year 1, 760 kg/ha/year in Years 2–5
Planting labour	181 hr/ha		
Pruning labour	One pruning in Year 1, 4/yr in subsequent years or 41 hr/ha season, 82 hr/ha/year	Discount rate[‡]	20%/year

* A partial budget is a method of assessing the benefits and costs of a technology relative to not using the technology. Therefore, only costs and benefits that change between the control (sole-cropped maize) and the treatment (alley farming) are considered. The analysis shows that the extra maize yield required to cover the added costs is 362 kg/ha/year (includes two seasons), that is, an increase of about 18 per cent over average farmer yields of 2000 kg/ha/year.

[†] Ksh = Kenya shilling, valued at approximately 35 to USD 1 in 1992.

[‡] A discount rate is the interest rate used to determine the present worth of a future value.

tional costs of the system (Table 8.2). The analysis was highly sensitive to the cost of seedlings: if the cost increased from 0.5 to 0.75 Kenya shillings per seedling, the 'break-even' maize yield increase rose to 26 per cent. Farmer assessment also revealed two other critical constraints to the adoption of hedgerow intercropping, both related to labour. First, prunings must be done at the right time to minimize competition between the hedges and the crops. Timing is especially critical for the second cutting after the rains begin, when rainfall is heavy and farmers are busy weeding. The second pruning is additional work and women do not normally do it. On farms managed by a woman farmer alone, only one-third cut the hedges themselves, compared with two-thirds of the farms managed by men. This may limit adoption of the system among the many households in the area headed by women.

Recently a study was undertaken at the International Institute of Tropical Agriculture using a simulation model and a budgeting approach to evaluate the short and long-term impact of alley farming, no tillage and traditional bush fallow system on soil erosion and on agricultural productivity and profitability under different population scenarios in south-western Nigeria. Results of this study confirmed that alley farming was an economical technology when farming intensity increases due to an increase in population density.

For example, plantain production is an attractive enterprise for small-scale farmers in the humid and subhumid tropics. As discussed in Chapter 5, the plantain crop requires large amounts of organic mulch to produce a high yield and to maintain productivity over a number of years. However, producing a sufficient amount of mulch is labour intensive and costly, as it involves extra land for biomass production and the costs of gathering, transportation and application. Results of a study comparing different sources of mulch conducted on an ultisol in the humid zone of south-eastern Nigeria showed that alley farming can provide an alternative economic solution to the problem of mulch supply for plantain production. This study demonstrated that alley farming with *D. barteri* as an *in situ* source of mulch is more profitable than a cut-and-carry elephant grass *(P. purpureum)* mulch system. Although the elephant grass mulch treatment produced the highest plantain bunch yield and similar net revenues per hectare as *D. barteri* treatment, when the cost of extra land needed for mulch production was not included, it gave significantly lower returns to labour (Table 8.3). This is because labour used in pruning and weeding in the *in situ* system, is much lower than the labour required for gathering, transporting and spreading mulch in the elephant grass system. The cumulative net present value figures in Table 8.3 are equivalent to

Table 8.3 Total labour input for pruning, weeding and mulching with *Pennisetum purpureum* and four woody hedgerow species on cumulative plantain bunch yield and net present values at three-year period of cropping*

Mulch source	Total labour (Person-day)	Plantain bunch yield (t/ha)	Net present value/ha (US$/ha)	**Net present value (US$/ha)
Alley farmed				
D. barteri	272	31.5	1290	1290
A. cordifolia	429	24.4	542	542
S. siamea	395	25.1	654	654
G. arborea	535	23.0	334	334
Cut-and carry				
P. purpureum	1467	53.4	1120	–595
LSD (0.05)	35	6.2	477	395

* Adapted from B. A. Ruhigwa, M. P. Gichuru, D. S. C. Spencer and R. Swennen 1994, 'Economic analysis of cut-and-carry and alley cropping systems of mulch production for plantains in south-eastern Nigeria', *Agroforestry Systems*, 26:131–8.

** Considering the 0.7 ha extra land needed for *P. purpureum* mulch production.

an increase of about $4.74 per person-day over the average wage of $1.35 with the *Dactyladenia* system, compared with an increase of about $1.14 per person-day for the other alley-farming systems. For the elephant grass control system, they represent an increase of $0.76 when the production land is not valued, but decline by $0.41 per person-day when it is included. Further studies are needed to evaluate the cost saving by using natural bush regrowth as hedgerows instead of planted hedgerows.

For livestock production

A comparison of using *Leucaena* prunings for mulch with maize or feeding it to cross-bred dairy cattle was made at the Kenyan coast, using all the prunings either as mulch or feed, and manure from the animals returned to the food crop. Maize bran, a milling by-product was fed to cattle. The results shown in Fig 6.3 page 75, illustrate some of the factors to be considered when deciding on the allocation of forage for feed or mulch. Tree biomass, given the responses of crops and animals at the Kenyan coast, could be more profitably used for animal feed when the price of milk is greater or equal to 0.4 times the price of grain. In February 1993 milk was 1.3 times as expensive per kg than grain. Allowing for the use of the by-products (manure and bran), the return for using the *Leucaena* prunings as animal feed was 2.9 times higher than when used as mulch.

In contrast, a west African study compared using *Leucaena* prunings as mulch for maize or for feeding small ruminants. It showed that for crop farming, continuous alley farming was more profitable than alley farming incorporating fallow periods, and more profitable than traditional no-tree farming. The inclusion of small ruminants in a continuous alley-farming system, however, added only 13 per cent to the financial returns obtained from a cropping only system. The main factors determining whether it is financially more profitable to use prunings for mulch or feed are the relative prices received by farmers for grain and meat and the response of food crops and animals to the application of prunings. As a rough guide, development projects look for a 30 per cent improvement in returns to attract farmers to a new technology. The anticipated additional benefits may be insufficient for crop-oriented smallholder farmers in West Africa to warrant the extra complication of including small ruminants in alley farming operations. However, prices of rams rise strongly before Muslim festival and the New Year. Fattening operations targeted at meeting a particular market demand when prices are strong, is likely to be more remunerative than a general year-round growth/fattening operation.

As is the case with agroforestry in general, there is a great need for more information on the economics of alley farming, including more information on the factors that affect the profitability of the system. However, limited data available have thus far shown that alley farming can be profitable for production of crops such as maize and plantain or in combination with small ruminant production. Results of observations in the Benin Republic and southern China also showed that returns were higher on well-established than on newly-established alley-farmed fields.

9 Social acceptance and adoption

A new technology will only be of interest to farmers if it addresses and solves a constraint that the farmers themselves believe is important. A constraint can be defined as a problem that prevents an objective being met. Therefore, we need to look at farmers' objectives, and see whether alley farming is relevant in solving problems preventing those objectives being met. Identification of key constraints depends upon who is questioned. Farmers, extension staff and researchers usually all identify different problems as critical factors. Alley farming will not be appropriate for all given circumstances, and should only be considered as one of a menu of options. There was, however, a tendency in the early work on alley farming to see it as a solution for all degraded and low-fertility areas, and this led to the system being introduced even on highly-degraded, very low-fertility, highly-acid soils and into very dry zones, where the system failed.

Research and development

In Africa, most work with alley farming has been research oriented. Three international research centres in Africa – IITA, ILRI and ICRAF – have worked extensively on the system since the mid-1970s. National systems were encouraged and assisted to participate through networking – Agroforestry Research Networks for Africa (AFRENAs), and the Alley Farming Network for Tropical Africa (AFNETA). However, the majority of the work occurred on-station focusing on biological aspects of the technology.

Even the on-farm work had the primary objective, on balance, of generating research information activities in Africa, organized through extension services. Nevertheless, non-governmental organizations (NGOs) and private voluntary organizations (PVOs) working in agricultural development and environmental protection programmes, have introduced alley farming and other agroforestry techniques to farmers. Most of this work suffered from unfamiliarity with the technology and from inadequate technical backstopping and evaluation. Despite these shortcomings some local adoptions have taken place, for example in Adja Plateau of Benin Republic, Western Kenya, Central Uganda and the Gandajika area of south-central Congo (Dem. Rep.).

In the Asia-Pacific region most of the early work with alley farming has been undertaken by extension agencies with farmers, and adoption of the technology has been widespread. Relatively little research was available to backstop the technology. *Leucaena* was introduced to Indonesia several centuries ago, and initially used as a shade tree for plantation crops. The colonial masters in Indonesia compelled farmers to plant rows of *Leucaena* on hillsides to prevent erosion in the 1930s (see Chapter 3) when slash-and-burn farming methods on hillsides resulted in serious soil erosion problems. Hedgerow planting quickly reduced the soil loss. However, compulsion is not a method that generates long-term acceptance and the technology fell into disfavour until the mid-1970s, when *Leucaena* hedgerows were introduced by local extension services and the Catholic church. The technology was spontaneously adopted over a wide area, and by the early 1980s it covered an area of over 40,000 ha on the island of Flores. At about the same time the technology known as the Sloping Agricultural Land Technology (SALT) was also successfully promoted by the Baptist mission in the southern Philippines to control soil erosion.

Adoption by farmers

While few farmers have adopted alley farming in Africa, many thousands use the technology in the Asia-Pacific region. It is instructive to consider the problems which farmers are using alley farming to solve in the Asia-Pacific region, and to compare them to the problems that researchers are trying to solve in Africa. On steep slopes the removal of tree and bush cover for agriculture leads to high levels of soil erosion, low crop yields and land becoming unsuitable for cropping. With increasing population pressure, farmers have less opportunity to move to new land, especially on small islands, and they have realized that it is imperative to conserve soil cover to lengthen the cropping cycle. Adoption was demand driven.

Even in the same region reasons for adoption can vary greatly. For example, adoption on the island of Flores in south-eastern Indonesia as discussed earlier was for productive purposes. However, recent efforts to extend the technology to new areas on the neighbouring islands of Lombok and Sumbawa in the same region, where different site and socioeconomic conditions prevailed, have given mixed results. Some farmers adopted the technology not for productive reasons, but as a means to gain access to land, credit and for political favours.

In Africa, alley farming has been research driven. Soil erosion has not been a significant problem at most areas where research trials have been undertaken. Locations have been chosen because they were conveniently located in relation to research stations, or because crops and animal productivity were believed to be under pressure. Adoption by African farmers has been largely limited to those who received an incentive to participate in research trials and in only some cases where genuine soil fertility and soil erosion problems exist. This suggests that African farmers do not yet feel the same pressure to adopt 'sustainable' production techniques that were taken up by Asian-Pacific farmers.

Farmers' objectives

As indicated earlier, we must be sure that any technology offered to farmers addresses problems that relate to the farmers themselves and that the farmers feel to be important. Farmers' objectives can be divided into a number of categories:

- Subsistence, production to meet household food requirements.
- Generating income, production for the market.
- Security, production to spread risk in adverse conditions. Keeping livestock as a savings account falls into this category.

However, most farmers will have multiple objectives and we need to consider the relative priority given by farmers to their various objectives. As a general rule farmers will be most willing to use additional capital, land or labour when their objective is to generate income. A low-input technology, such as alley farming, can be viewed as a means of stabilizing production at a lower level of input than the usual extension recommendation, hence reducing cost. This approach is most likely to meet the objectives of households oriented toward subsistence production objectives or those that can afford to use some external inputs.

Under adverse environmental conditions, sustainability of production over time will be a factor that farmers may view as important, as can be seen on sloping land with soil erosion. Market-oriented farmers will seek to increase production levels and generate cash, allowing the use of higher levels of purchased inputs than do subsistence farmers. These farmers may be less willing to adopt a technology that requires a portion of their land to be planted with trees at the expense of planted crops, unless the trees themselves can also generate a significant amount of income.

Special characteristics of alley farming

System complexity

Although agroforestry is a traditional practice in many societies, alley farming *per se* is a new concept, and requires a number of innovations by practitioners. The timing of management activities is crucial to success. Farmers' understanding of why it is necessary to undertake tasks at a certain time would help ensure that an appropriate routine is followed, but this only comes with experience. While experience is being gained and mistakes made, farmers can become discouraged. Equally, extension advisers need to understand the technology so that they are able to advise and explain to farmers. Few have the necessary comprehension.

Labour requirements

Alley farming is demanding of labour at peak times, and hence the technology is most appropriate for areas with surplus labour. Where labour is in short supply, and hence expensive to hire, farmers may be unable to prune the hedgerows on time, so causing shade problems on companion crops. All the evidence to date suggests that labour shortage at key points during the production cycle is one of the major factors responsible for difficulties that farmers have in managing alley farms in Africa. It is also a reason often quoted by farmers for the low rate of adoption of the technology.

Supply of planting material

A factor which can work against the spread of agroforestry technology, including alley farming, is availability of planting material (seeds and seedlings) of the appropriate multipurpose trees. In experimental and trial situations, the seeds and seedlings have been produced and supplied by research organizations or NGOs. However, at the level of full-scale extension, it will need a systematic strategy and policy for providing the necessary planting material. This can be done by assisting farmers to establish their own nurseries, either on an individual or group basis.

Land tenure

Where land is plentiful, farmers can fallow land in order to regenerate fertility. As population expands and land becomes in short suppply the length of the fallow period decreases. To address soil fertility constraints through alley farming, a farmer must be sure that he/she will still have access to the land when the benefits materialize. A tree-based technology requires 'permanent' access to land. In western culture this can be achieved by land ownership. In other cultures many different forms of land tenure exist, some of which discourage the adoption of long-term systems because access to land cannot be guaranteed beyond the short term. Tenants on rented land may need permission from the landowner to plant trees. In some cultures this will not be forthcoming since tree ownership is divorced from landownership, and rights to the tree would remain with the planter, even if he/she no longer farms the land on which the tree stands.

Gender issue

In much of the developing world, women take primary responsibility for farm work, but this does not necessarily mean that they are able to take decisions on allocation of resources. Decisions on tree planting may rest with the husband, who may be working off-farm. In some communities women may be prevented from planting trees (linked to tree/land ownership traditions as indicated above). In addition, the physical effort required to prune hedgerows that have been left untended for over a year may require male labour.

Economics

Chapter 8 has covered the economic aspects of alley farming, but positive economic benefits alone will not guarantee the adoption of the technology. Farmers try to optimize the use of their resources of land, labour and capital in order to meet their economic and social objectives. Optimization is very different from maximization. More affluent farmers, who can afford to take a longer-term view, may be better able to forego current production in order to secure future production. Often, access to off-farm income is an important element in household finances, providing a level of security that allows additional farming risks, such as the adoption of a new technology. However, unless a technology provides a positive economic return, farmers are unlikely to adopt the new technology, whatever the environmental benefits in the long term.

Farmer involvement in research and development

In order to make real progress, research and development agencies have realized that farmers should be involved from the start. Farmers themselves are best placed to identify and prioritize their constraints. They can also participate in the identification of approaches to overcoming constraints, suited to their particular social and economic circumstances. A step-wise developmental on-farm research approach with a community focus can be used to introduce a new technology, for example, after determining that alley farming is appropriate for an area through a participatory research approach using Participatory Rural Appraisal (PRA) techniques. There are three main stages:

1 *Exploratory stage*. The goal is to establish a few (three to five) alley farms in the area to be used for demonstration and practical purposes. Considerable research/extension input will be provided at this stage. Farms will be used to demonstrate the concept, structure and management of the system to other farmers so that they obtain a better perception of the system.
2 *Intermediate stage*. A further 10–15 farmers are recruited to establish their own alley farm, with much less hands-on input from research/extension. The objective is to increase farmer understanding and involvement in field activities, and to allow research/extension to assess farmer interest and to identify unforseen problems in the management of the system. Some of these elements of the developmental on-farm research has been implemented successfully in the Benin Republic.
3 *Pilot-project stage*. The technology is introduced and assessed at community level. Extension input, in terms of advice is maximized, and there is no researcher involvement in actual field operations. Farmers are fully responsible for establishment and management, and are free to modify the system as they feel appropriate. PRA techniques are used to monitor and evaluate the system. It is essential that social and economic suitability of the system be assessed, as well as biological factors. If successful, the technology can be offered more widely by extension services, using recommendations of domains identified from evaluation of the pilot scheme. Direct farmer-to-farmer dissemination of information will allow another route to spreading a successful technology.

10 Conclusions

Alley farming is a system with a potential for addressing soil fertility, soil conservation, and the fodder production needs of small-scale farms. It can also be managed to produce gains in wood production and for weed control when fallows are incorporated into the system.

Alley farming is not suitable for all agroecological zones and has the following potential and limitations for various ecozones:

- It is a proven technique for stabilizing farming on sloping land and is adopted on such lands in East Africa, South-east Asia and the Caribbean islands.
- For crop production it has the best potential on high base status soils where suitable nitrogen-fixing hedgerow tree and shrub species are already available and where soil moisture is not limiting (≥ 1200 mm annual rainfall). The technique can be used for sustaining crop production with lower external chemical inputs.
- Research evidence has shown that under moisture-stress conditions, the system reduces crop and hedgerow biomass yields, thus it is not usually recommended as an option for semi-arid areas with narrow inter-hedgerow spacing. The low hedgerow biomass production is also inadequate for maintaining soil productivity. However, the concept of using wider alleys and the planting of hedgerows with economic trees and shrubs in such areas needs to be further explored. Hedgerows can serve as windbreaks and for erosion control in the dry zones and in addition planting of trees/shrubs in hedgerows can better facilitate future mechanized farming in the drier zones than random planting of woody species.
- The technique has limitations on highly-acid and low-base status soils in the humid zone due to: 1) the limited number of suitable hedgerow species, and 2) on these nutrient poor soils, nutrient competition between crops and hedgerows can be

severe and the addition of sufficient amounts of external chemical inputs are needed. Further research is needed to select suitable woody species for these soils.

In mixed crop/livestock systems, the impact on cropping is usually more important to farmers. Alley farming can be recommended for the provision of livestock feed in subhumid zones with non-acid soil where land is a greater constraint than labour. Tree foliage can be most profitably used for animal feed where the livestock product has a higher market value than the mulch. Smallholder dairy farmers are the most likely to benefit, and may wish to consider tree/grass mixtures as an alternative to tree/food crop combinations. Tree-only plots may be worthwhile to smallholder dairy farmers where space is particularly limiting.

Smallholder meat producers will only see a large financial benefit from the use of tree foliage as fodder if there is a premium price available in the market for their meat – this may be possible by targeting production at rams for festival periods. A lower return is likely from other livestock production systems in the smallholder sector, but can be maximized by feeding females in early lactation to increase survival rates for offspring.

Large-scale livestock producers in semi-arid and subhumid areas with extensive rangelands may wish to consider the incorporation of widely-spaced rows of leguminous trees in unimproved pasture. With increasing numbers of trees/ha, however, they may need to inoculate some animals with detoxifying bacteria. For dairy producers planting an area of leguminous trees that can be grazed for a period each day after milking may be economical.

Adoptability by farmers is, however, influenced by agroecological and socioeconomic considerations. The system is more likely to be adoptable in situations where:

- Land is in short supply and fallowing of farm land is not an option because of land scarcity.
- Soil erosion is a problem (especially in sloping land areas).
- External inputs are expensive and limited in availability.
- High-quality fodder for livestock (especially dairy cows) is in demand.
- Labour is not excessively limiting.
- Land and tree tenure regulations do not inhibit tree planting and ownership.

To better delineate potential areas where alley farming can be expected to succeed, more use could be made of Geographical Information Systems (GIS) based on the biophysical and socioeconomic factors of the region. They allow different data sets to be overlaid and are therefore used for the task of defining adoption domains.

Research and development collaboration is required for assessing the adoptability and promoting the concept in target areas. The developmental on-farm research process offers a framework within which this can be done. Research and development institutions need to work together to explore possibilities within this framework for assessment of adoptability and promotion of the technology in target, high-potential areas. Farmers should be given the opportunity to experience and experiment with the system, and adapt it to fit their own specific circumstances. Such pilot projects, when successful, will then be the loci from which a full-scale extension programme on alley farming could be launched. The support of research institutions, development agencies, and donor institutions towards such research and development activities is essential.

The economic feasibility of alley farming depends on the agronomic advantage of the system relative to the traditional system of farming in the locality where the system is being tested. Even in areas of agronomic suitability, the profitability of the system should still not be taken for granted, as it is influenced by socioeconomic and policy considerations operating in the area. The profitability of the system is influenced greatly by the agroecological zone in which it is established. Profitability can also be enhanced if livestock and/or certain trees with marketable produce (e.g. pulses, poles, timber, etc.) are integrated into the system, as shown by examples from Kenya and the southern Philippines.

Further reading

In preparing this publication, we made particular use of the following publications:

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Glossary

Definitions in this glossary relate particularly to the contents of this book.

Acid soil Refers to soil with surface soil pH less than 7.0.

Adaptable Refinement or modification of technology to suit a local site and local socioeconomic conditions.

Adoptable Methods which are easily incorporated into the existing farming practices of the intended clientele.

Agroforestry Collective name of land-use systems in which woody species are grown on the same land-management unit as agricultural crops and/or pasture and livestock.

Allelopathy Direct or indirect harmful or beneficial effects of one plant on another through the production of compounds that escape in the environment.

Alley farming The practice of growing annual crops or pasture in the spaces between rows of trees or hedgerows. This is sometimes called hedgerow intercropping or alley cropping.

Biological nitrogen The metabolic assimilation of atmospheric nitrogen through the fixation aid of microorganisms and especially rhizobia that live in symbiosis in roots of some leguminous plants.

Biomass The weight of material produced by a living organism. The term is usually applied to plant material.

Browse Consists of buds, shoots, leaves, flowers or woody regrowth which can be eaten by livestock.

Buffering capacity In biological systems this refers to the ability of a system to cope with changes and return to a steady state.

Cation exchange capacity Is a measure of the ability of the soil to hold exchangeable bases (K^+, Ca^{++}, Mg^{++}, Na^+) plus total acidity (H^+, Al^{+++}). When measured at the natural soil pH it is called effective cation exchange capacity (ECEC).

Compost Organic residues or a mixture of organic residues and soil, with or without the addition of fertilizers, manure or lime, that are allowed to undergo the process of incubation or decomposition.

Contour Line joining all places at the same height above sea level.

Coppicing The technique of cutting trees and shrubs, to stimulate the growth of shoots and regrowths of trees.

Cut-and-carry Practice in which fodder or plant products are harvested and carried to a different location to be used or consumed.

Cuttings A piece of a branch, stem or root cut from a living plant with the objective of developing roots and growing to a new plant, and which is genetically identical to the original parent.

Deforestation The process of cutting and removing natural forest vegetation.

Digestible The ease with which browse may be consumed and absorbed by livestock.

Direct seeding Sowing seeds directly where they are to develop into mature plants.

Dormancy Arrested development of a plant owing to structural or chemical properties of the seed that prevent germination when environmental conditions are not favourable.

Fallow Land resting from cropping, which may be grazed or left unused; often colonized by natural vegetation.

Fodder Parts of a plant which are eaten by domestic animals.

Foliage The mass of leaves of trees or shrubs.

Forage Herbaceous plants or plant parts consumed by animals.

Girdle This is a circular cut of at least 0.5 cm around the stem/trunk of a tree where the bark is removed

Green manure Green, leafy material incorporated in the soil to improve soil fertility.

Hedgerow Closely-planted line of perennial plants often forming a boundary or fence.

Herbaceous A plant that is not woody and does not persist above ground beyond one season.

High altitude Refers to land area located at 1200 m or more above sea level.

High-base status Soils that have base saturation of over 35 per cent of ECEC measured in the subsoil.

Humid zone Areas with annual precipitation of over 1300 mm and a growing period of 270 days or more.

Indeterminate Refers to the ability of plants to flower continuously.

Indigenous Native to a specified area.

Inoculation Addition of effective rhizobia to legume seed or plant for the purpose of promoting biological nitrogen fixation.

Intercropping Growing more than one plant species together at the same time on the same piece of land.

Inter-hedgerow Between hedgerows.

Intra-hedgerow Within the same hedgerow.

Kraal Enclosure for confining livestock.

Land degradation Process in which the quality and productivity of the land is declining.

Land tenure The occupation of land for a defined period of time.

Land-use system The way in which the land is used by an individual or particular group of people within a specified area.

Leaching Downward movement of soluble chemicals in the soil with water.

Live mulch Mulch made up by living plants.

Low altitude Refers to land area located at less than 800 m above sea level.

Low-base status Soils that have a base saturation of 35 per cent or less of ECEC measured in the subsoil.

Microclimate The temperature, sunlight, humidity and other climatic conditions in a small localized area, for example in one field, stand of trees or crops or in the vicinity of a given plant.

Mid-altitude Refers to land area located between 800–1200 m above sea level.

Minimum tillage Method of soil tillage with minimal disturbance of soil surface.

Mono-cropping Planting of only one plant species on a piece of land.

Mulch Mainly organic material that is spread on the soil surface to cover and protect the soil.

Multipurpose trees (MPT) Trees and shrubs that have more than one product or function.

No-till (zero tillage) A procedure whereby a crop is planted directly in the soil without tilling the soil.

Palatable Acceptable as feed by livestock.

Pastoral A method of farming dependent on the maintenance of livestock for survival.

Perennial A plant that grows for more than one year, in contrast to an annual, which grows for only one season or year before dying.

Pollarding Cutting back the crown of a tree in a more or less systematic fashion with the objective of harvesting wood, shoots and browsing materials. This stimulates regrowth beyond the reach of animals or reduces the shade cast by the tree crown.

Provenance The place in which any stand of trees is growing. The stand may be indigenous or non-indigenous.

Pruning The process of cutting back the new growth of plants, including roots, but more particularly the sides of trees or hedgerows.

Ration A 24-hour allowance of feed or mixture of feedstuffs making up an animal's diet.

Rhizobia Species of bacteria that live in symbiotic relationship with legume plants, mainly within nodules of the plant roots, that can fix atmospheric nitrogen for use by the host plants.

Root turnover Amount of roots that scenesced (aged and died) per unit area and time in the soil.

Rotation In agriculture, changing of crops grown on a particular piece of land from season to season. In forestry, the length of time between the establishment and harvesting of a plantation or tree.

Ruminant livestock Animals with a ruminant digestive system.

Runoff The portion of precipitation or irrigation in an area which does not infiltrate into the soil and is discharged from the area.

Semi-arid zone Areas with annual precipitation of 900 mm or less and a length of growing season of 120–150 days.

Shrub A woody plant that remains less than 10 m tall and produces shoots or stems from its base.

Slash-and-burn Traditional farming practice that involves hand clearing of land followed by burning of natural vegetation, in preparation for planting a crop.

Soil bulk density The mass of dry soil per unit bulk volume.

Soil conservation Protection of the soil against physical loss by erosion or against chemical deterioration.

Soil erosion The wearing away of the land surface mainly by rain, irrigation water or wind.

Soil fertility The ability of a soil to supply nutrients in adequate amounts and balance for the growth of specified plants or crops.

Soil management The sum total of all tillage and planting operations, cropping practices, input use, and other treatments conducted on or applied to a soil for the production of plants.

Soil productivity The capacity of a soil to produce a certain yield of crops or other plants with a specified management system.

Spatial arrangement Planting arrangement of plants according to space.

Subhumid zone Areas with annual rainfall precipitaion of 900–1300 mm and a length of growing period of between 150–270 days.

Sustainable production A production system that can produce a stable yield of desired crop(s) over a long period of time with minimal soil degradation.

Temporal arrangement Planting arrangement of plants according to a planting time.

Tenure The right to property, granted by custom and/or law, which may include land, trees and other plants, animals and water.

Terrace Flat areas of land on any slope, made naturally or by human effort.

Trees A woody plant with one main trunk or more and a more-or-less distinct and elevated crown.

Woody Plants that consist partly of wood; not herbaceous.

Index

(Page numbers in **bold** refer to illustrations)

The Tropical Agriculturalist

The Tropical Agriculturalist is a series of practical field guides and textbooks for:

- producers, farmers and farm managers
- agricultural extension officers
- agricultural diploma, degree and vocational students
- teachers and lecturers
- senior secondary students, as reference books
- adult education, rural and community development programmes

This book has been written to help readers understand the principles of alley farming and its potential as a sustainable farming technique. Alley farming is an important farming and land-use system which has evolved with time in the humid and subhumid tropics, and has adapted to local ecological and socioeconomic conditions. The book covers the development of alley farming, provides practical guidelines for establishing and managing it, including soil management, and the benefits to crop and livestock production and other by-products. It also tackles the problems of social acceptance and adoption.

Alley Farming has been written in a concise and practical format. It is illustrated with diagrams and photographs and has a list of books for further reading.

It is hoped this book will help to make alley farming more widely used, as its widespread adoption could reduce the threat to the world's remaining tropical forests and transform the prospects for sustainable agriculture in the fragile lowland tropics.

The Tropical Agriculturalist series is published in association with the Technical Centre for Agricultural and Rural Co-operation (CTA) established under the ACP-EU Convention of Lomé.

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